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Superpave Mix Designs for Low Volume Roads

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8. ABSTRACT

Most research current to the time of these projects was focused on use of Superpave mix designs on higher volume roads. Low volume roads have different requirements in terms of mix design, aggregate types, aggregate sources and project budgets. The purpose of this research was to determine if the Superpave mix design strategy for low volume roads was practical and economical.

Eight projects were selected in five counties. The projects were completed in the summer of 1998. Performance evaluation of the resulting pavements is being carried out annually.

There was no significant increase in costs related to the use of Superpave. Nor were there any significant construction issues. There were some differences noted in placement and compaction in the field, but these were not serious.

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43

TABLE OF CONTENTS

Introduction 1

Objective 1

Project Locations and Descriptions 1

General Superpave Considerations 2

Construction 2

Testing 18

Project Costs 18

Acknowledgement 19

References 19

Appendices

Appendix A - Project Location Maps 20
Appendix B - Superpave Overview 27
Appendix C - Mix Designs 31
Appendix D - Photographs 40

DISCLAIMER

The contents of this report reflect the views of the author(s) and do not necessarily reflect the official views of the Iowa Department of Transportation. This report does not constitute any standard, specification or regulation.

INTRODUCTION

This research was initiated to fill in a gap in the work that was being done to develop and implement the Superpave mix design method for Asphalt Cement Concrete (ACC) paving. Superpave is a mix design system that expands on the Marshall mix design method using performance specified materials and a gyratory compaction regimen. A lot of attention had been paid to the use of Superpave for high volume roads and almost none to its use on low volume roads.

Paving on low volume roads has many characteristics that are quite different from their high volume counterparts. The differences fall in three principle areas: Mix design performance requirements, aggregate requirements and availability, and project budget levels. The mix design requirements are performance based and can be less restrictive for low volume roads than for higher volume roads. Aggregate requirements (mostly for shape and angularity) are less restrictive as well. However, most Superpave mix designs under higher traffic loads require a fraction of manufactured sands (crushed aggregate) in proportion to natural sands. This could lead to increased costs if the crushed aggregate requirements hold for lower traffic levels. Finally, the budgets for projects on low volume roads are much smaller than higher volume roads because they are usually part of a county or municipal road system.

OBJECTIVE

The objective of this research was to determine what issues affect the use of Superpave on low volume roads. The issues to be evaluated include economics, resources and constructability.

PROJECT LOCATIONS AND DESCRIPTIONS

The research section in the Office of Materials selected eight projects in five counties for this research. These projects were selected based on the response to a statewide survey of interest in the research. The intent initially was to have a wide selection of locations around the state. However, the available projects were somewhat less diverse than that intent. A list of the project locations and brief descriptions of each is provided below. Maps detailing the project locations may be found in Appendix A.

County	Location	Project Description
Scott	Y30 from Jct IA 927 to Jct IA 130	Overlay over Crack-and-Seat PCC
Mahaska	G29 from Jct US 63 to Jct T65	Overlay over cold-in-place recycled ACC
Cerro Gordo	S70 from Jct US 18 to Jct B47	Overlay over cold-in-place recycled ACC
Cerro Gordo	B60 from Jct IA 107 to WCL Rockwell	Overlay over cold-in-place recycled ACC
Dubuque	IA 966 from ECL Centralia to Jct US 20	Overlay over rubblized PCC
Cass	N16 from NCL Atlantic to Jct I-80	Overlay over composite pavement
Cass	M56 from Jct IA 48 to SCL Lewis	Paving and widening over old ACC
Louisa	X17 from Jct G62 to SCL Columbus City	Overlay over cold-in-place recycled ACC

GENERAL SUPERPAVE CONSIDERATIONS

All of the projects in this research were considered to be low volume applications of Superpave. As a result, the specification for 300,000 Equivalent Single Axel Loads (ESALs) or less was used in all of the mix design requirements. A brief discussion of Superpave mix design requirements is provided in Appendix B. At the time that these projects were being let for bids, values for aggregate gradation and mix compaction characteristics were set more stringently than they are currently. The consensus of national experts in 1997 was that mix design criteria for Superpave were based on high traffic loadings that may not have been appropriate for all mixes (1). However, to gain experience with Superpave, the original, more stringent requirements were enforced for these projects.

CONSTRUCTION

The following descriptions are highlights of the construction and mix design aspects of each project. Each description is shown in a standard format for clarity (although not all of the data was available for every project). These descriptions will include the following items:

- A project description with the existing pavement dimensions and conditions
- General design considerations for the pavement
- Initial mix design details[1]
- Mix design changes and challenges
- Construction issues
- Performance to-date

Scott County Road Y30

Project Description

This first project length was approximately 11 km. The original road was constructed with 152 mm thick PCC. It was 30 years old and badly deteriorated. Prior to overlay placement, the pavement was cracked and seated. Previously installed subdrains were left in place and the road width remained at a nominal 6.7 m with 2 m granular shoulders.

Design Considerations

This was the first project of the research series and was approached with the least amount of background and experience. The asphalt cement concrete overlay was paved in three lifts with a total thickness of 127 mm. Average annual daily traffic (AADT) on Y30 in 1994 was 690 vehicles per day (vpd) with 20 percent trucks. A portion of the route overpassed I-80 and provided access to a truck stop at the exit, so a small portion of the route experienced higher truck traffic than the rest.

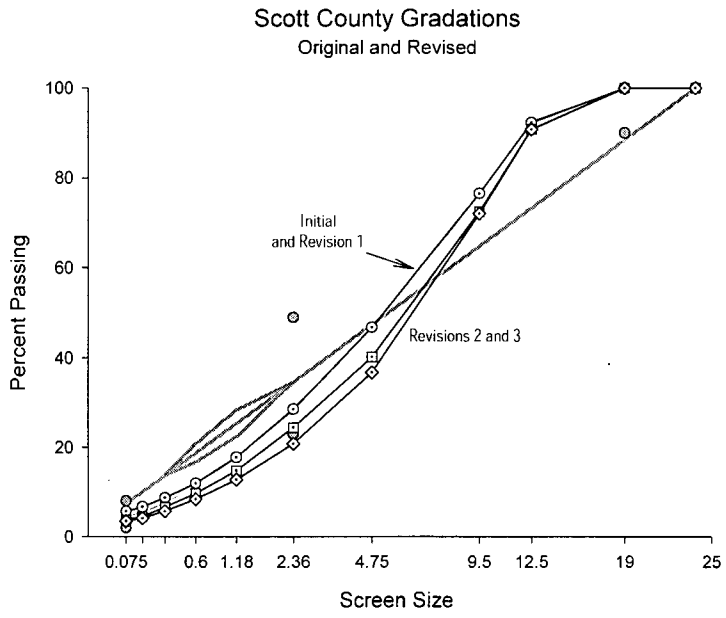
[1] Mix design details are provided in Appendix C.

Mix Design Details

Before the county engineer decided to use a Superpave mix design on this project, he had specified a 3/4-inch, 50-blow Marshall design using PG 58-22 asphalt. Under Superpave criteria the mix was changed to a 19 mm design with PG 58-28 asphalt (all projects covered by this report used a PG 58-28 asphalt). During the project the county and contractor made several mix design changes. These changes were made in an effort to control lab-measured air voids (hereafter called lab voids). Because of delays in finalizing the initial Superpave mix design, the contractor used the original Marshall mix design for the first day of work - approximately 3 km of the lowest lift on the south end of the project. The remainder of this project used mixes prepared using Superpave criteria.

Gradation: Figure 1 shows the power curves[2] of the mix gradations. An important observation of this graph is the strong "S" shape of the curves, meaning that they are almost as far from the maximum density curve as they can be while staying within the control points. Gradations with this characteristic would be expected to have more room for AC, higher Voids Mineral Aggregate (VMA), and film thickness than other mixes. Early in the development of the Superpave mix design process, this characteristic shaped curve was the goal. Since that time, the shape of the desired curve has changed as will be discussed with later projects in this series. This strong "S" type of distribution has been linked to difficult compaction of the mix in the field.

Figure 1



[2] For an explanation of the gradation terms and graphs see appendix B.

Mix Design Changes and Challenges

During the paving in Scott County, several revisions were made to the mix design. The gradation changes are also shown in Figure 1. The first revision consisted of removing the 1 percent mineral filler and reducing the AC content from 5 percent to 4.9 percent. This change, which did not affect the overall gradation significantly, was made in an effort to increase the lab voids to the target of 4 percent. Subsequently, two other changes were made in efforts to increase the VMA - these changes resulted in a coarser mix (note the stronger "S" shape of the later plots in Figure 1). The amount of AC in the mix was adjusted during these changes as well.

Figure 2

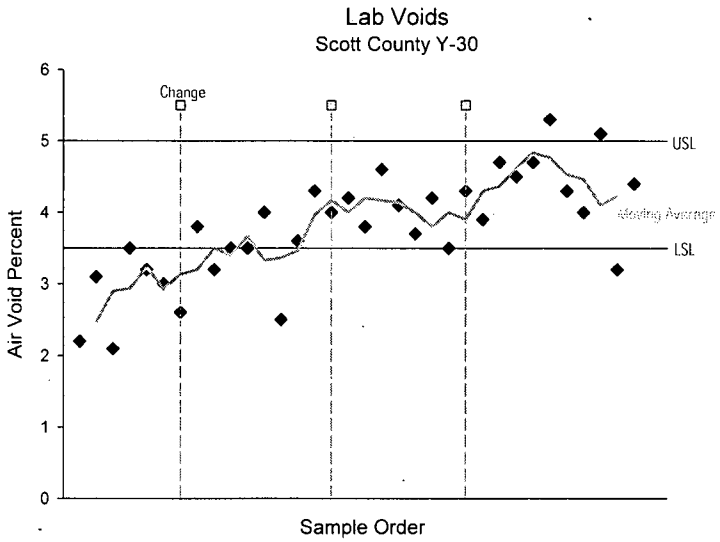
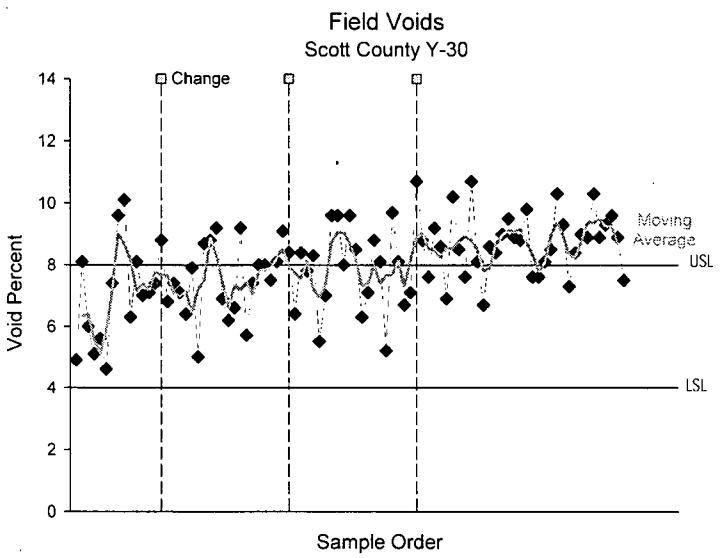


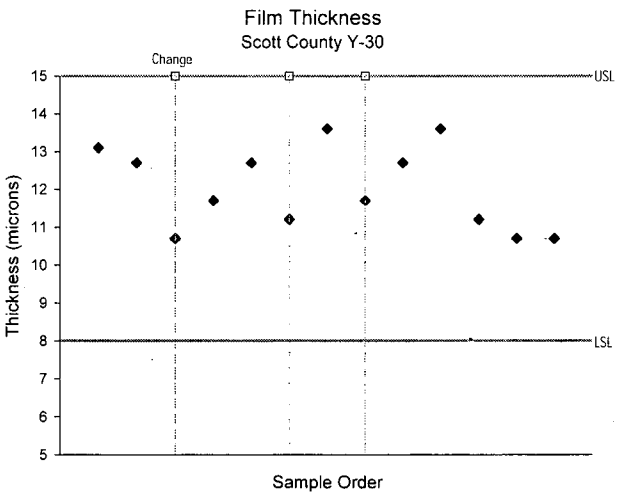
Figure 2 shows the percentage of lab voids recorded during this project. The upper and lower specification limits (USL and LSL respectively) are shown. Generally it is the value of the moving average, which determines the timing of a mix design change. The data clearly show the efforts to increase the lab voids - with air void percent generally increasing after each change in the gradation.

Figure 3



The term Field Voids refers to the void content measured in samples cored from the road after paving. Figure 3 shows the data from this project. While the lab voids began too low and progressed into the specified zone with adjustments to the mix; the field voids began within specified limits and progressed above the upper limit. This upward trend in field voids may be an indication of the increasing difficulty of compacting an increasingly coarse mix. Field voids above the upper specification limit are of significant concern - they can indicate problems with high permeability and early aging of the ACC. Field voids should probably be included in Construction Issues, because they are mostly a result of the level of compaction in the field. They are discussed here to provide an easier comparison with the lab voids data.

Figure 4



The last of the data to be considered is film thickness. This calculated value is the thickness of the film of asphalt on each particle in the mix, measured in microns. If the film thickness is too low, the pavement will be at risk for stripping, raveling and cracking; too high and there will be stability problems. Figure 4 shows the data for film thickness on this project.

In the short segment of road around the truck stop, the county engineer chose a completely different mix design with natural sand and an added hardening agent to the ACC - a natural asphalt product called gilsonite. The gilsonite will probably have a positive effect on the load carrying capability of the pavement but will probably also result in higher levels of thermal cracking.

Construction Issues

The majority of placement issues with this project had to do with stiffness and workability. This was because the contractor used 100 percent manufactured sand in the fine portion of the gradation. Compaction was difficult and required that the breakdown roller proceed immediately behind the paver. Handwork was difficult because of stiffness - the problem was alleviated somewhat by increasing the temperature of the mix. On the positive side, there was no sign of tenderness or shoving in the mix. ACC placement over sealed cracks in the underlying cracked and seated pavement exhibited asphalt rich strips known as "tar strips" in the first day's paving with the original Marshall mix. These strips required blading prior to placing the next lift of ACC. This problem did not occur with the Superpave mix.

Note: Natural versus Manufactured Sands.

Good performance from ACC pavement requires a balance of mix characteristics. The fine part of a Superpave gradation is made up of natural and manufactured (crushed) sands. Natural sands have rounded grains that provide a lubricating effect in the ACC during compaction. Manufactured sands are angular and provide part of the structure for the pavement. Too much natural sand and the mix may be tender; too much manufactured sand and the mixture can be stiff and very difficult to compact.

Performance

Iowa DOT personnel have performed detailed crack surveys on this project each summer since placement. No cracks have appeared yet in the pavement. Structural evaluation, smoothness testing, rut depth measurement and friction testing are being performed annually. The results of these tests have not yet been evaluated.

Mahaska County Road G-29

Project Description

This project in northern Mahaska County, extended from the junction of county road G-29 and US-63 eastward through the unincorporated town of Lacey to the junction with county road T-65. Total project length was approximately 7 km. The original pavement consisted of 152 mm asphalt treated base overlaid with a 50 mm ACC overlay. This existing pavement was recycled using cold-in-place recycling to a depth of approximately 100 mm then overlaid with nominally 75mm of ACC in two lifts. Several areas had localized problems with poor subgrades and pavement distress. These problems were addressed with full depth patching and strengthening courses. Subdrains were also installed as part of the project.

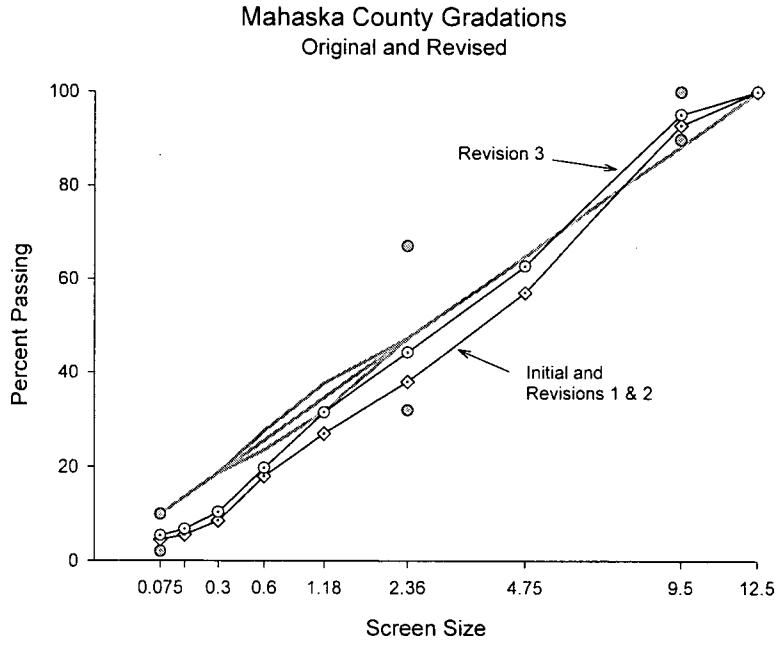
Design Considerations

This road had an AADT of 210 - 310 vpd in 1994 with an unknown percentage of trucks. The number of trucks was expected to increase significantly with the building of hog confinement facilities near the east end of the project.

Mix Design Details

This project specified a 9.5 mm mix. Figure 5 shows a graph of the gradation power curve for this mix. Notice that this curve has a less pronounced "S" shape and is and closer to the maximum density line than the Scott County curve (Figure 1).

Figure 5



Mix Design Changes and Challenges

Three revisions were made to the mix design during the project, each was made to try to improve the lab voids. The first revision consisted of changing the target asphalt content from 6.91 to 6.70 percent. A minor aggregate exchange was made for revision 2, exchanging a portion of the 3/8-inch chips for manufactured sand. Neither of these changes affected the gradation significantly. The final change was made at the beginning of the last day of paving to address low lab voids. This was a major gradation change, which is evident in the power curves shown in Figure 5. The effect of this change was to move the gradation very close to the maximum density line. Although this was a major change, production and construction quality control problems made the change largely ineffective.

Graphs of the void data are shown in Figures 6 and 7. Note the wide variation in the lab voids above and below the specified range and the very high values for field void measurements in the latter half of the project. The lab void problems are generally from material or production quality control problems. The field void variations are most likely the result of placement issues that will be discussed next. Eventual testing of cores from various parts of this project in troubled areas should provide some additional information about the causes of the void results.

Figure 6

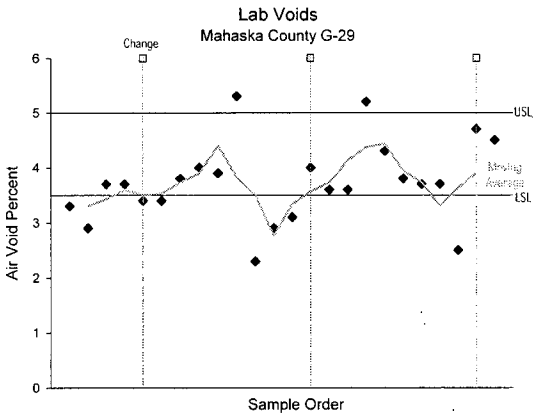


Figure 7

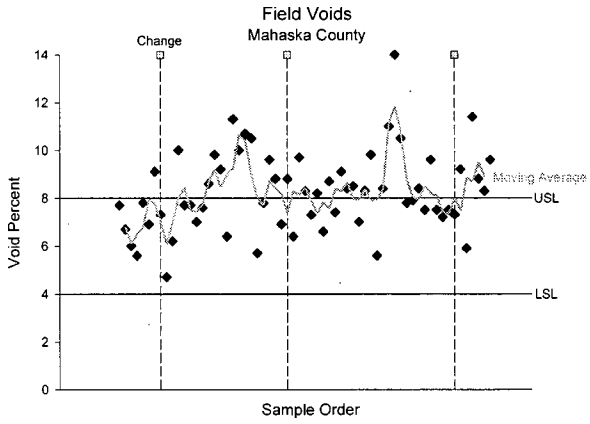
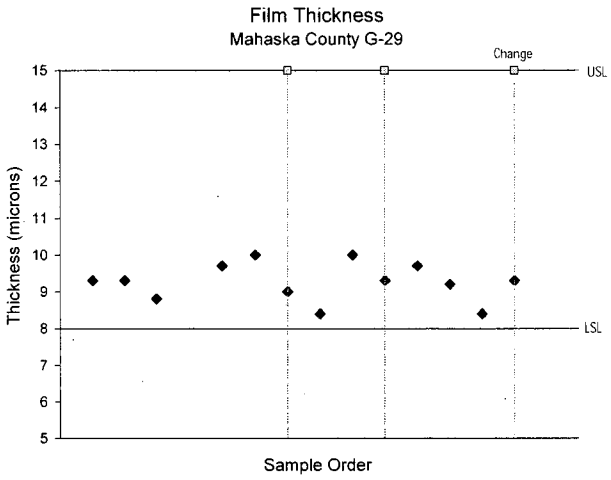


Figure 8



Film thicknesses (Figure 8) were within the specified limits although the values remained near the lower limit. This is consistent with a small mix size. For comparisons, refer to the film thicknesses of the Scott County project (Figure 4) - a large and coarse mix, and those of the Dubuque County project (Figure 16) - a large and fine mix. For a discussion of mix sizes see Appendix B.

Construction Issues

This project was beset by quality control and construction difficulties - none of which had any connection with the use of the Superpave design system. The following are a few examples:

Subgrade weakness caused considerable difficulty to all aspects of this paving project. Some areas were identified in the planning phase, some during cold-in-place recycling, and some only during paving. In the first two cases, the full-depth patching list was updated and patching and strengthening courses placed as appropriate. At least one section on the east end of the project, exhibited severe movement and rutting of the new pavement under truck traffic immediately after paving. This rutting appeared to be a combination of weak subgrade and insufficient density. Parts of this section were removed and replaced by the contractor at some time after the completion of the project.

Cold-in-place recycling did not adequately provide crown and cross section correction to the road bed. These corrections were left to the paving operation. This resulted in lifts in some locations that exceeded 100 mm in thickness. Some of the high field void values are likely due to poor compaction in these thick lift areas. Coring of the pavement in various locations is pending - the results should provide a correlation between lift thickness and field voids for this project.

There were no reports of problems with placement compared to a conventional mix. However, this project will provide a good test of ACC pavement under unusual conditions. Photographs of some of the conditions are provided in Appendix D.

Performance

Crack surveys have been performed annually since construction. As of the summer of 2000, no cracks were evident. Other performance data are pending.

Cerro Gordo County Roads B-60 and S-70

Project Description

There were two roads involved in the research for this county. The project on B-60 started at the junction with IA-107 and proceeded east to the east corporate limits of Rockwell passing over I-35 near the west end. The project on S-70 extended from the junction with county road B-47 north to the overpass with the new US-18. Existing roads in both cases consisted of 150 mm ACC, with a nominal width of 6.7 m and variable width shoulders.

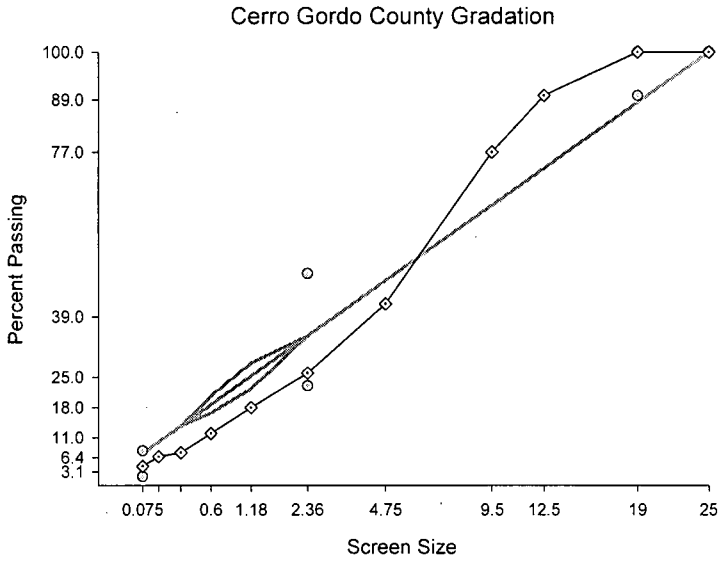
Design Considerations

The AADT was measured in 1993; on B-60 it was 380-910 vpd, and on S-70 it was 270-430 vpd. Percent truck values were not available. Parts of both roads are or will be connected with major highways; so it is likely that the roads will experience heavy loads and higher traffic levels at various times. Both projects included cold-in-place recycling of older ACC Pavement. Paving for this project consisted of two lifts, each 38 mm thick. The final road remained at nominally 6.7 m wide but now with fixed 1.2 m granular shoulders.

Mix Design Details

Because the two projects were paved at the same time with the same materials, the data were evaluated as if from one project. These projects used a 19 mm mix. Figure 9 shows a graph of the gradation power curve for the mix.

Figure 9



Mix Design Changes and Challenges

There was only one mix design change on these projects and it took place after the first day of paving. The intention was to lower the lab void values. After this change, the lab voids remained within specified limits and with little variation. Field voids were distributed around the upper limit. See Figures 10 and 11. Film thicknesses were within limits throughout both projects.

Figure 10

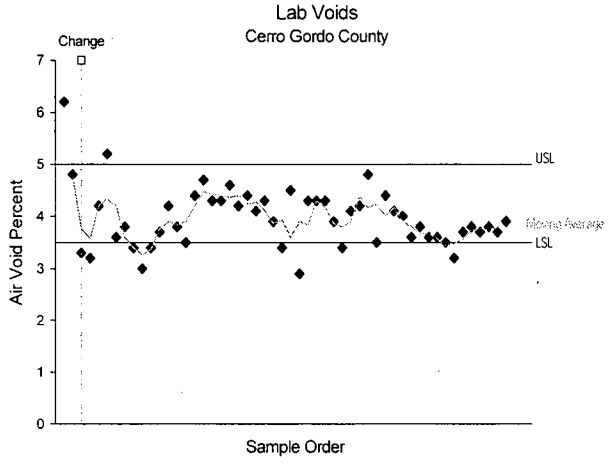
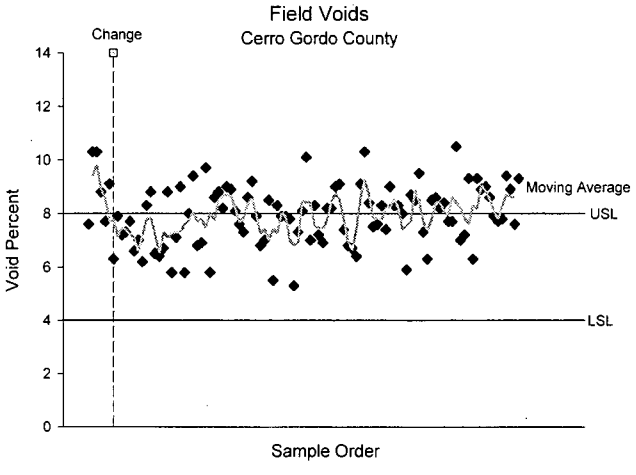


Figure 11



Construction Issues

The contractor and inspectors did not report anything unusual about the placement and compaction on these projects.

Performance

Crack surveys have been performed annually since construction. As of the summer of 2000, no cracks were evident. Other performance data are pending.

Dubuque County Road IA 966 (old US 20)

Project Description

This project is part of a larger reconstruction effort on IA 966 from Farley, through Epworth and Centralia, to the junction with new US 20 in Dubuque County. The original pavement consisted of 254 mm PCC, 5.5 m wide with a 60 mm ACC overlay. This pavement was rubblized and covered with 76 mm of "chokestone" (an aggregate mixture with a high percentage of fines). Paving took place in two phases - a base lift was placed one year and the surface was placed the second year. Many areas had very poor subgrades. In these locations, the county engineer directed complete excavation and replacement of the poor soil with higher quality fill. Subdrains were also installed as part of the project.

This project provides a good comparison of the Superpave and Marshall mix design processes. From Farley to Epworth, both lifts of pavement used Marshall mixes. From Epworth to Centralia, the base lift was Marshall and the surface lift was Superpave. Finally from Centralia to the junction with US 20, both lifts used Superpave mix designs.

Design Considerations

This road had an AADT of 1,280 vpd with 10 percent trucks and localized heavy truck traffic in several areas. Rubblization of a PCC road is estimated by the industry to leave a base with approximately 1.5 times the structure that would be provided by an ordinary aggregate base of the same thickness. The widening had to be placed without the rubblized PCC as a base. This was accomplished using virgin aggregate for the base material.

Mix Design Details

In contrast with the other projects, this mix design used a very fine gradation (for a description of gradation terms see Appendix B). Note in Figures 12 and 13 that the gradation power curve is almost entirely above the maximum density line and above the restricted zone. The paving consisted of a 19 mm mix for the base lift and a 12.5 mm mix for the surface lift.

Figure 12

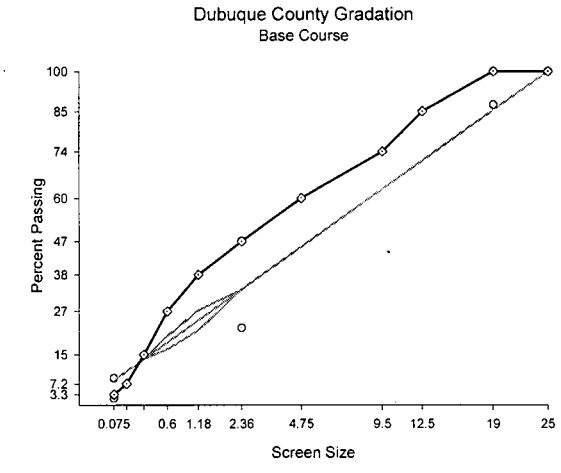
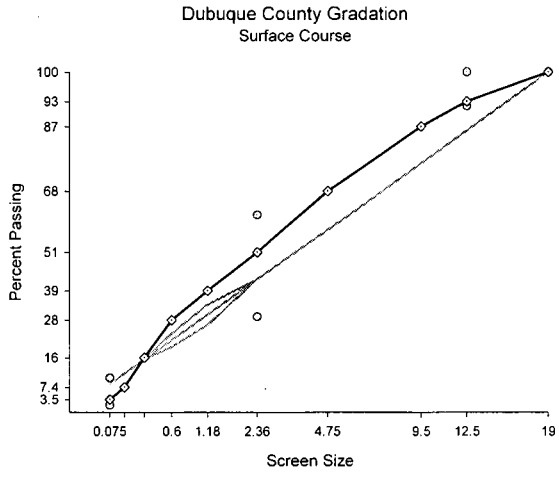


Figure 13



Mix Design Changes and Challenges

Other than the change in gradation between lifts, there were no significant changes made to the mix design. It was almost identical to the conventional Marshall mix designs on previous projects. As with some of the other projects, lab voids were generally within specified limits and field voids ran high (see Figures 14 and 15). Note in the figures that the two lifts are separated by a vertical line and that they were placed in different years with different aggregate gradations.

Figure 14

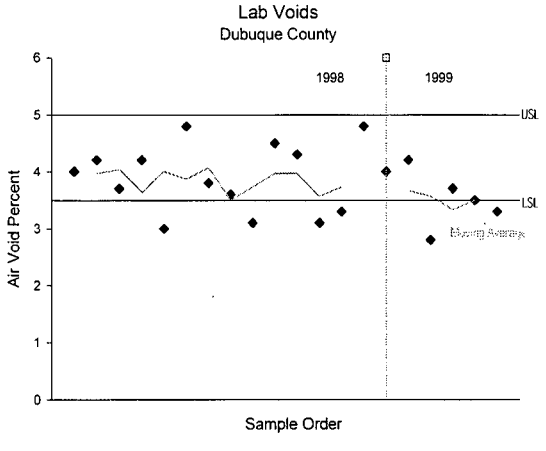
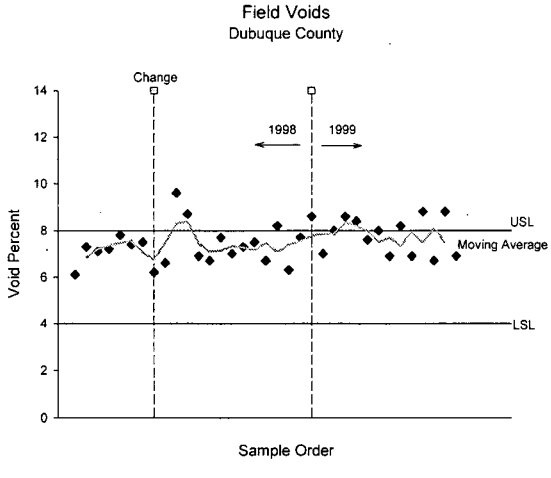
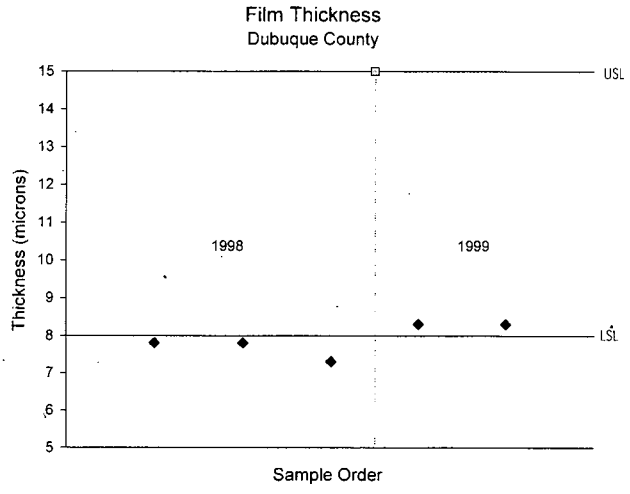


Figure 15



Film thickness for this project is shown in Figure 16. These values are quite low, which is consistent with a very fine mix.

Figure 16



Construction Issues

There were no issues involving the mix design mentioned by the contractor or county on this project. However, there were several placement issues having to do with the road width, poor subgrade and drainage.

Performance

Crack surveys have been performed annually since construction. As of the summer of 2000, no cracks were evident. Other performance data are pending.

Cass County Road N16

Project Description

This project extended from just north of Atlantic north approximately 9.7 km. The original pavement was 152 mm PCC with a 76 mm ACC overlay. It was to be overlaid with a 50 mm single lift of ACC. Some grading and full depth work was to be done in localized areas. Also sub-drains were installed where applicable.

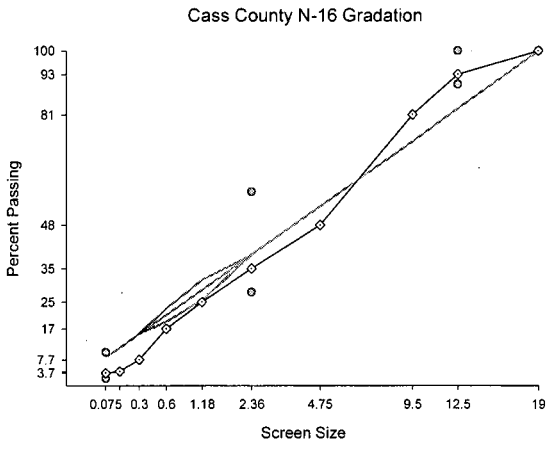
Design Considerations

This road had an AADT of 1930 vpd with 20 percent trucks. Truck traffic was heavy due to the close access to I-80 (at the north end of the project) and the proximity of several truck intensive businesses.

Mix Design Details

The mix design for this project was challenging. Initially, there was considerable concern on the part of the county about using locally available aggregate. They indicated that if aggregate had to be shipped from another location to meet the Superpave requirements, the county would not be able to afford the project. Luckily, the locally available aggregate met all of the requirements for Superpave.

Figure 17



The gradation power curve for this mix (figure 17) has a well defined upward curving portion called a "sand hump" near the restricted zone. This sand hump, at times, has been indicative of a tender mix. However, there was no evidence of tenderness in this project.

An additional problem encountered had to do with gradation size in relation to lift thickness. The rule-of-thumb for lift thickness has been three times the nominal maximum aggregate size. For a 12.5 mm mix this results in a 37.5 mm lift thickness. As paving commenced, there was a significant amount of shoving over previously sealed cracks in the underlying pavement. Iowa DOT personnel recommended that the paving be performed in two lifts with tight blading after the first lift to remove bumps. However, each lift would have to be at least 37.5 mm thick with a resulting overlay thickness of 75 mm. The Additional 25 mm, when extended over the 9.5 km project length, represented considerable added cost. In the end, the county chose to place a nominal 19 mm thick scratch coat prior to the 50 mm overlay. This alleviated the problem at a somewhat lower cost.

Mix Design Changes and Challenges

The lab voids were low throughout this project (see Figure 18). The AC percent was decreased by 0.1 in each of the three changes, attempting to increase the lab voids. Field voids (Figure 19) remained consistently within specified limits after the first few samples and film thicknesses were unremarkable.

Figure 18

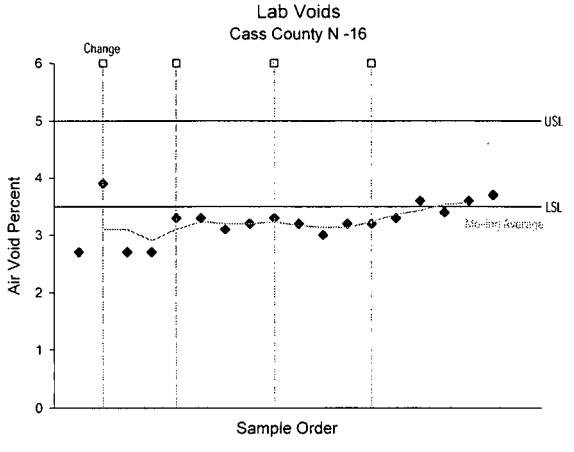
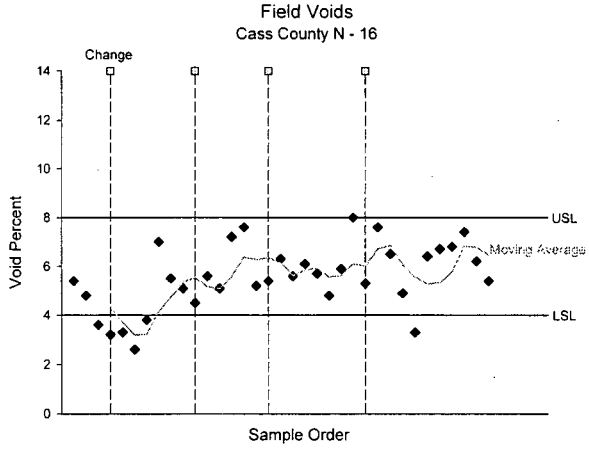


Figure 19



Construction Issues

Other than the previously mentioned problems with shoving over sealed joints, there were no placement issues reported.

Performance

Crack surveys have been performed annually since construction. Within a few weeks after placement cracks began reflecting through this overlay. After two years, there were cracks throughout the project. This is reasonable with such a thin overlay of a cracked composite pavement. The cracking does not appear to be related to the use of Superpave.

Cass County Road M56

Project Description

This project started at the junction with IA 48 and extended 7.6 km east and north to the southern corporate limits of the town of Lewis in west-central Cass County. The existing road was a thin asphalt overlay over granulated sub-base, with a nominal width of 6.7 m and variable width shoulders.

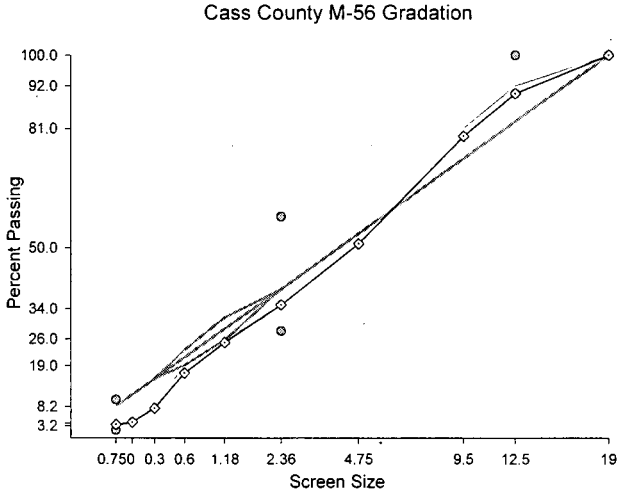
Design Considerations

The AADT for this project was 470 vpd, with an unknown, but small, percentage of trucks. The base was widened to 8.2 m and the final pavement to 7.9 m. Current paving consisted of 100 mm of ACC placed in two 50 mm lifts. Some areas had severe deterioration due to drainage problems and construction truck traffic. These were excavated to 150 mm below grade and backfilled with stone. Also a section in the center of the project near Cold Springs County Park had been part of a grading project. This approximately 1 km section was excavated and filled the previous year with stone and geotextile fabric.

Mix Design Details

This project specified a 12.5 mm mix - Figure 20 shows a graph of the gradation power curve for this mix. As with the previous project on N16, this graph exhibits a "sand hump" near the restricted zone. This gradation is the closest to the maximum density line of all the projects evaluated.

Figure 20



Mix Design Changes and Challenges

Three revisions were made to the mix design during the project, two were aggregate interchanges and one was an adjustment of AC content (see Figures 21 and 22). The reasoning behind the changes is unknown - a good possibility is that the first two were made to increase the lab voids.

Figure 21

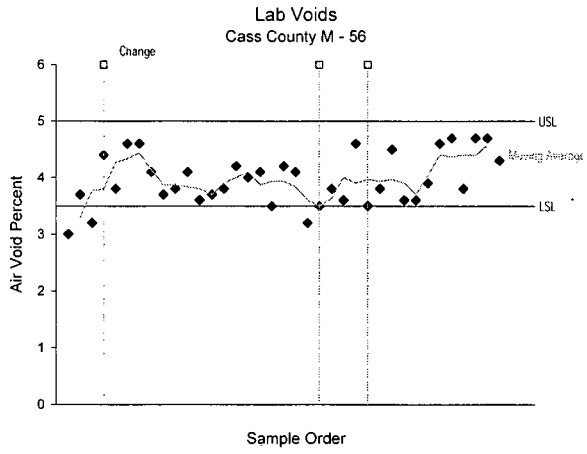
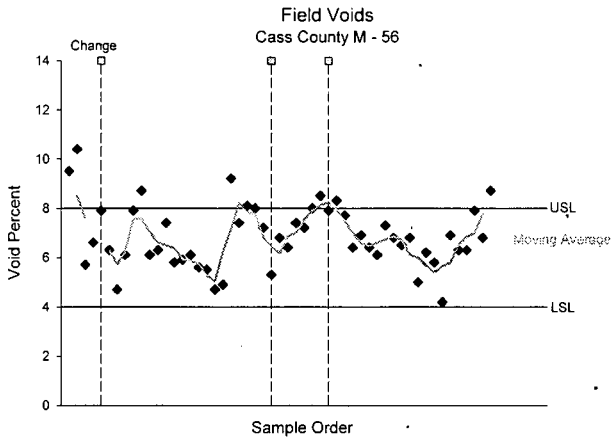
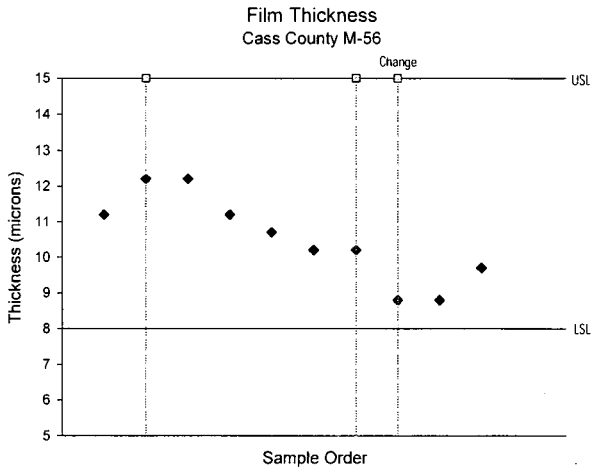


Figure 22



The film thickness varied considerably during this project, but remained within specifications (see figure 23).

Figure 23



Construction Issues

Construction of this roadway was hampered by subgrade difficulties. These were exacerbated by exceptionally heavy rain and flooding shortly before paving was due to begin. Areas that had marginal structure before were completely destroyed by a combination of subgrade, water and construction truck traffic (see photographs in Appendix D). The county engineer decided to excavate all of the distressed areas down to approximately 150 mm below grade and replace with 50 mm minus stone.

Before the new pavement was laid, a 19 mm scratch coat was placed. The contractor noticed cracking in the scratch coat along the widening joint in several places. A fabric was considered initially to strengthen this area but was deemed unnecessary.

Performance

Crack surveys have been performed annually since construction. As of summer 2000, no cracks were evident. Other performance data are pending.

Louisa County Road X-17

Project Description

This project on X-17 began at the junction with Louisa County road G62 and extended northerly to just inside the corporate limits of Columbus City in central Louisa County. The existing road consisted of 150 mm ACC, with a nominal width of 6.7 m and variable width granular shoulders.

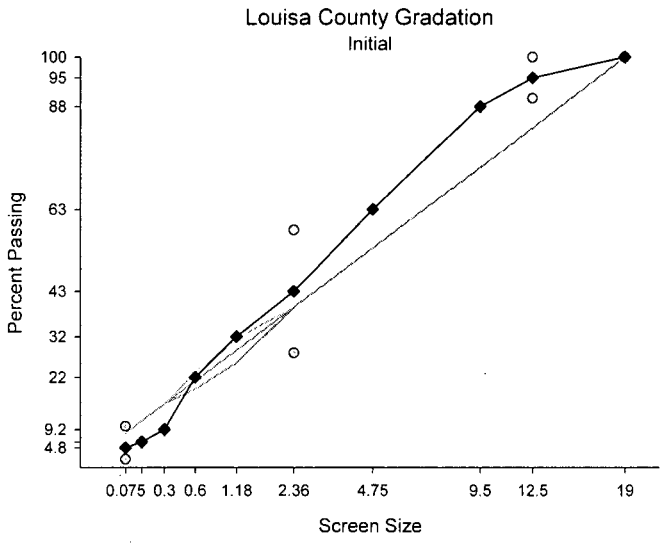
Design Considerations

The AADT measured in 1994 was 220-740 vpd with an unknown percentage of trucks. This project included cold-in-place recycling of the older ACC pavement. Current paving consisted of 76 mm ACC placed in two lifts of 38 mm each. The final road remained at 6.7 m with fixed 1.5 m granular shoulders. For the last approximately 1 km, there was no recycling and the ACC was overlaid directly on the old pavement (with a thick scratch coat).

Mix Design Details

This project specified a 12.5 mm mix. Figure 24 shows the gradation power curve. Note that this gradation passes through the restricted zone. Another big difference between this project and the other seven projects in this research was the absorptive nature of the aggregate. Typically aggregates from this area have required the use of as much as 7.5 percent AC to reach the minimum film thicknesses and effective asphalt contents needed in the final mix. Because of the absorptive aggregate, this project was chosen for an additional research activity that examined the effect of an acrylic sealant. The sealant was intended to block some of the pores in the aggregate and reduce the amount of AC absorbed. As a result, some sections of pavement had a slightly modified mix design using less AC.

Figure 24



Mix Design Changes and Challenges

There were several changes in the mix design, all of them were adjustments in the AC target amount. Part of the problem leading up to the changes had to do with the placement of the ACC plant. The mix design process assumes a significant time between mix production and placement - say 20 minutes. On this project, the plant was located within 5 minutes or less of the paving process. That did not allow time for the asphalt to soak into the aggregate before cooling and thickening. As a result, until the AC percentage was lowered, there were puddles of AC in places on the pavement, and void levels were extremely low (Figure 25). More adjustments were required soon thereafter to improve lab void levels. By the last half of the project, void levels were within specified limits. Field voids (Figure 26) started out low and migrated to the upper specification limit.

Figure 25

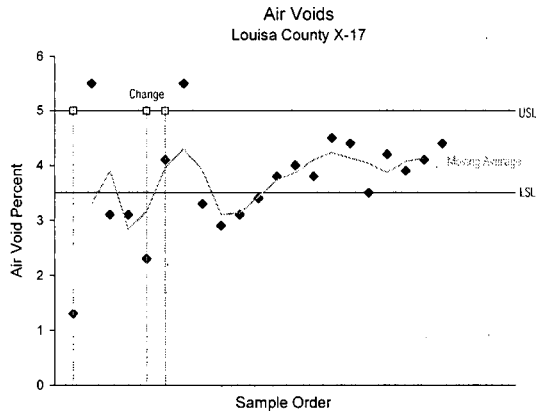
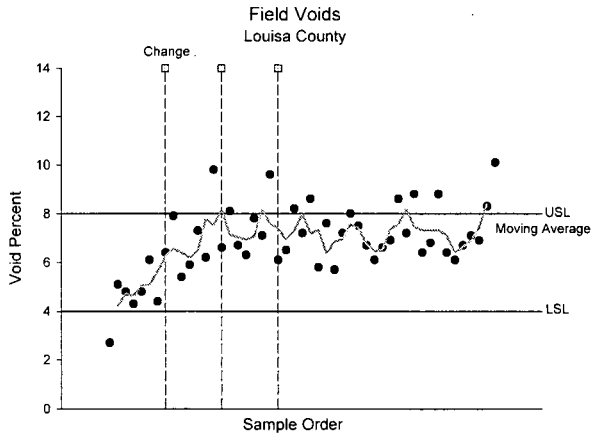
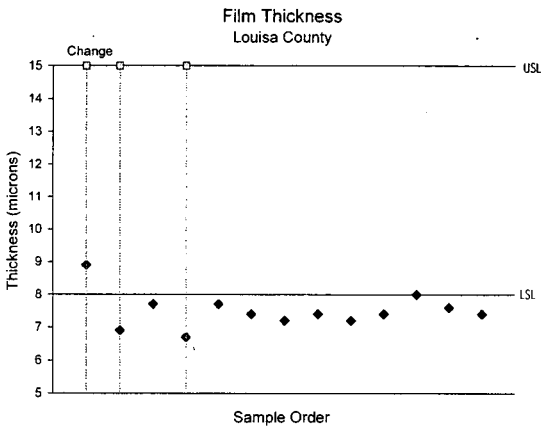


Figure 26



Film thicknesses were below specification throughout (Figure 27), despite the high asphalt content. The cause for this is unclear.

Figure 27



Construction Issues

Other than the problems described in the last paragraph, the contractor and inspectors did not report anything unusual about the placement and compaction on these projects.

Performance

Crack surveys have been performed annually since construction. As of summer of 2000 there were no cracks in the portion of the project that was placed over cold-in-place recycling. The last kilometer of the project on the north side was a thin overlay over existing ACC - this section has significant reflective cracking.

TESTING

Much of the testing on these projects is ongoing or pending. Each year the pavements will undergo structural testing using either Roadrater or Falling Weight Deflectometer equipment. In cases such as the Mahaska County project, coring will be done to determine actual pavement thicknesses and verify final densities. Other annual tests will be for smoothness and friction values. Finally, there may be some testing of permeability values for the various pavements. All of the results for these tests will be evaluated and summarized in the final report.

PROJECT COSTS

It became clear early on that it would not be possible to obtain an objective measure of project costs in comparison to the costs of paving with conventional mixes. The only risk of increase in costs appeared to be from changes in aggregate requirements. In a practical sense, this did not become an issue because the aggregates already in use met the Superpave requirements for this level of traffic.

ACKNOWLEDGEMENT

Research project TR-414 was sponsored by the Iowa Highway Research Board and the Iowa Department of Transportation. Partial funding for this project was provided by the Secondary Road Research Fund.

The author would like to extend thanks to the Iowa Highway Research Board and all of the counties and contractors who helped make this research project possible; to Mike Heitzman, John Hinrichsen, Dan Redmond, Dan Seward and the rest of the ACC section in the Materials department of the Iowa DOT for testing and mix designs and providing considerable technical advice.

REFERENCES

1. Specification for Superpave Hot Mix Asphalt, AASHTO Provisional Standard MP2-96, American Association of State Highway and Transportation Officials, 1996.
2. McGennis, R.B., Anderson, R.M., Kennedy, T.W., Solaimanian, M., *Background of Superpave Asphalt Mixture Design and Analysis.* Report No. FHWA-SA-95-003. Federal Highway Administration, U.S. Department of Transportation, 1995.

Appendix A
PROJECT LOCATION MAPS

HIGHWAY AND TRANSPORTATION MAP

MAHASKA COUNTY

IOWA

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Iowa Department of Transportation

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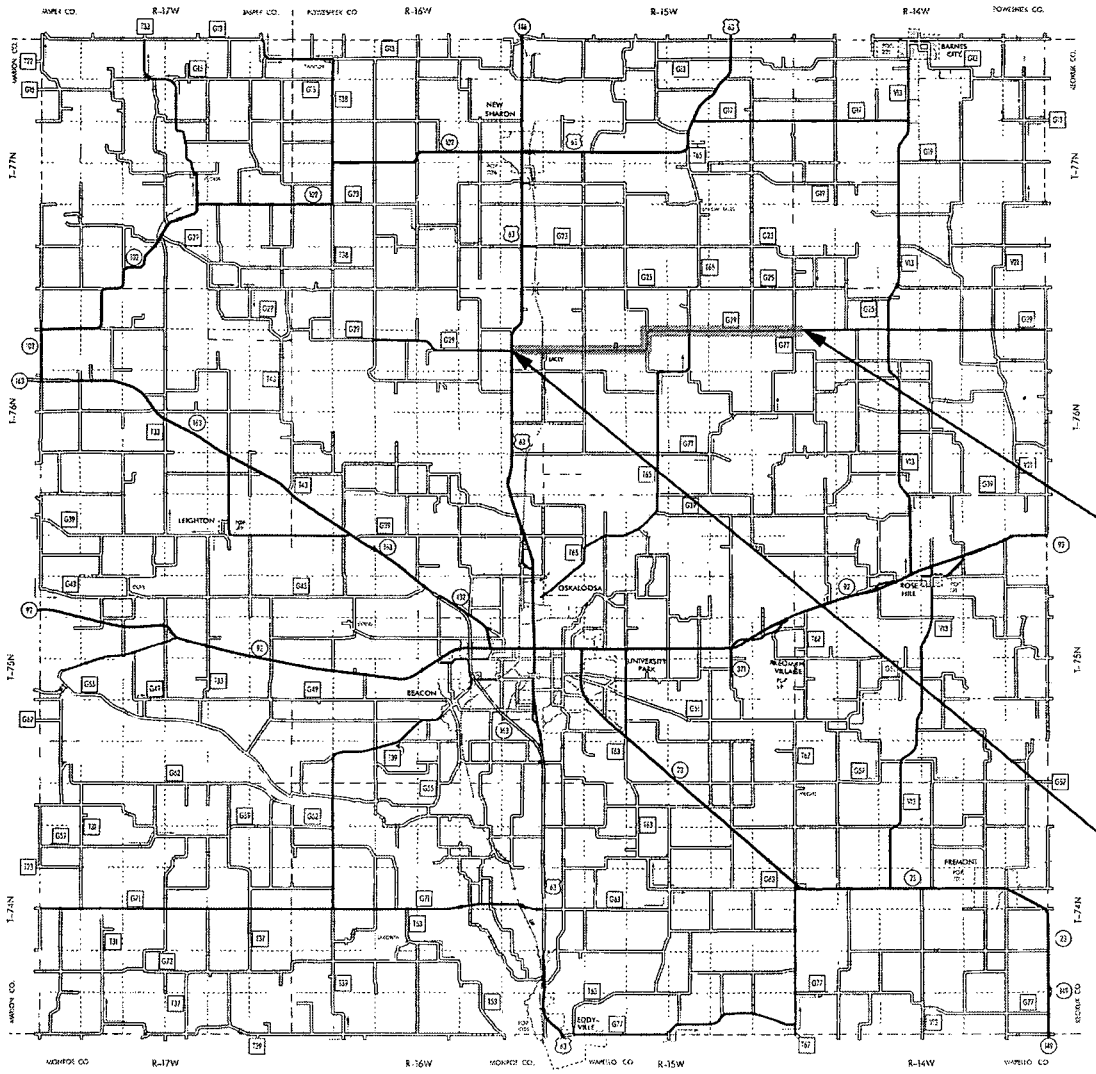
In Cooperation With

United States Department of Transportation

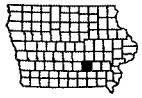
JANUARY 1, 1999

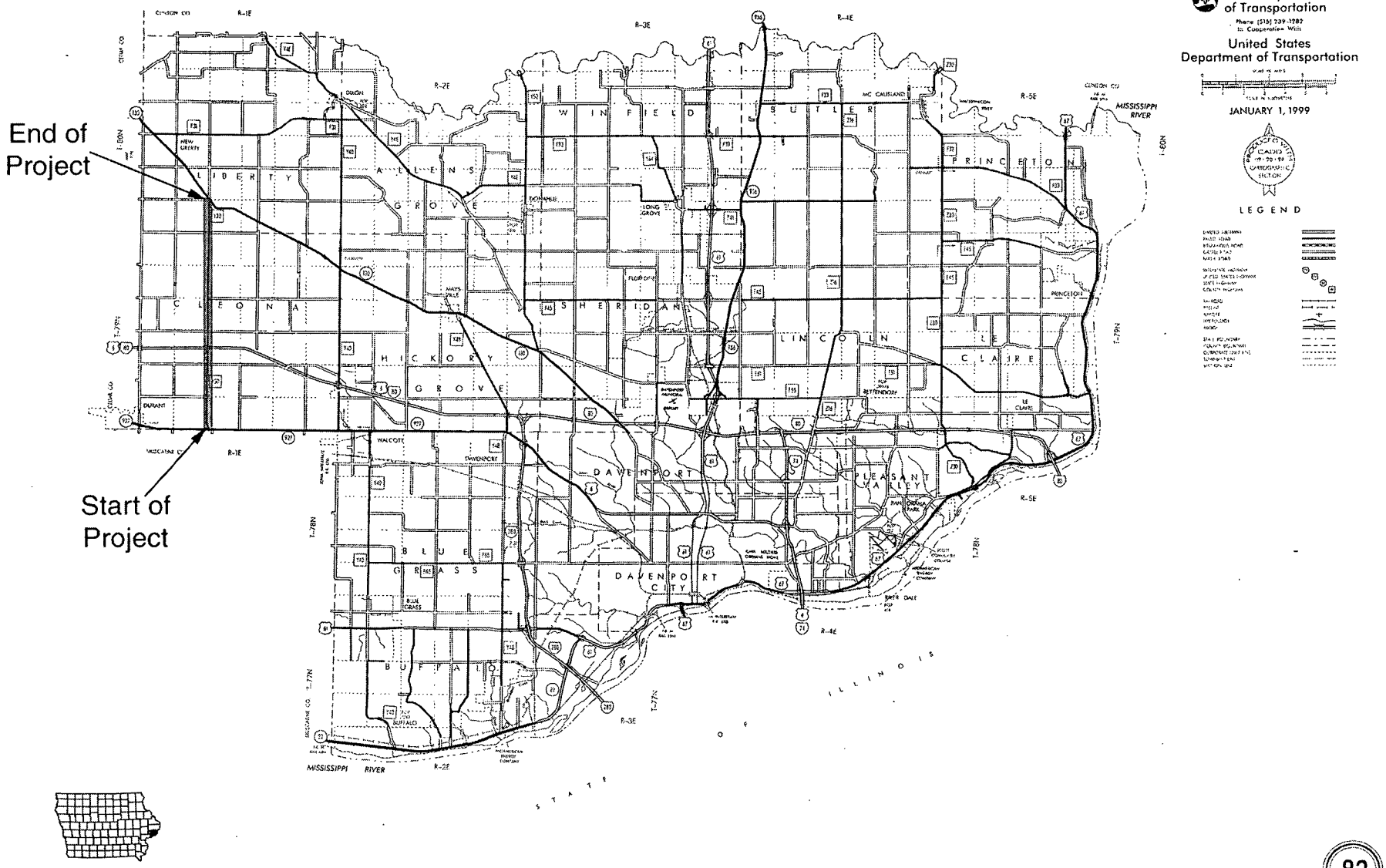


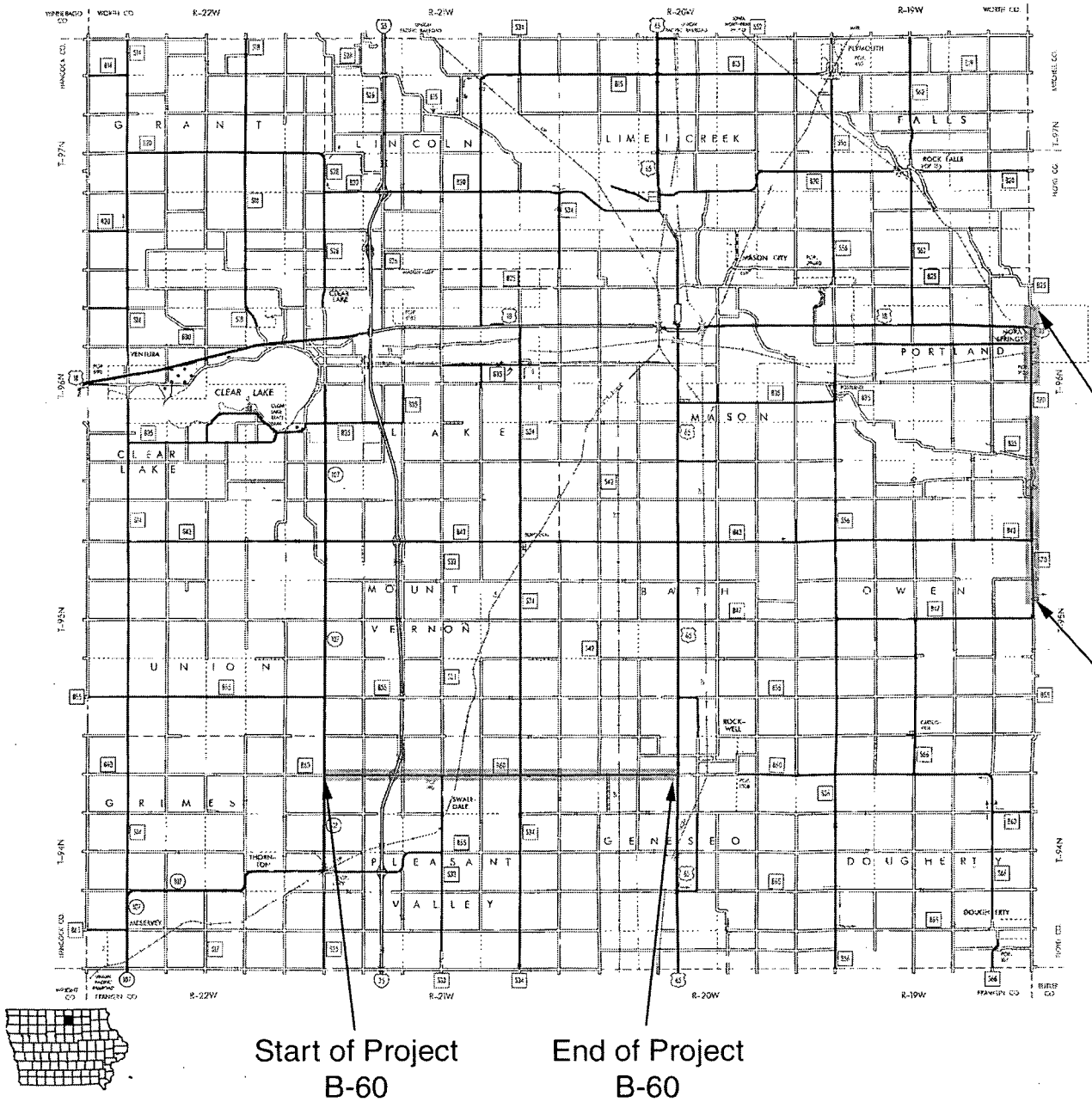
End of Project

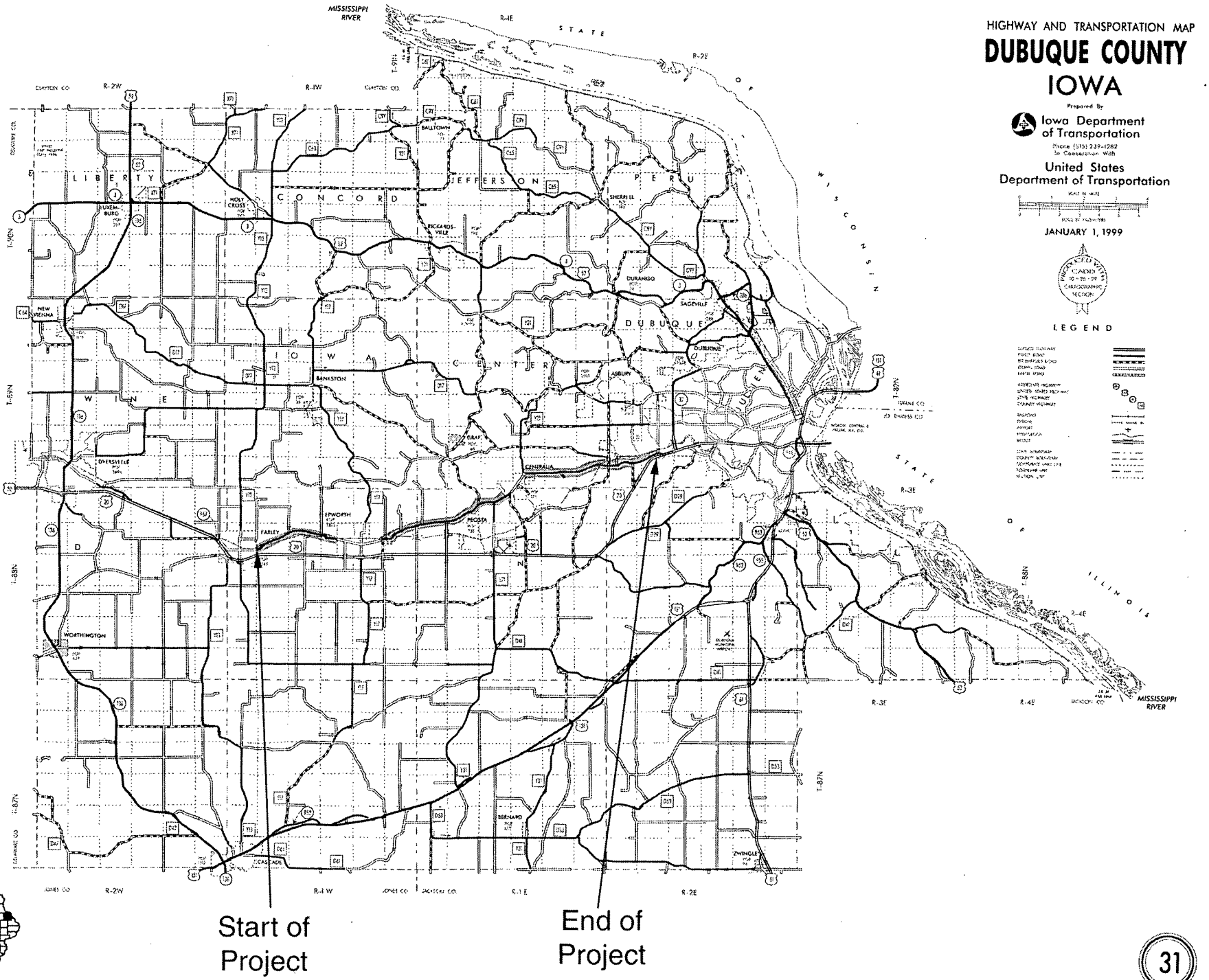
Start of Project

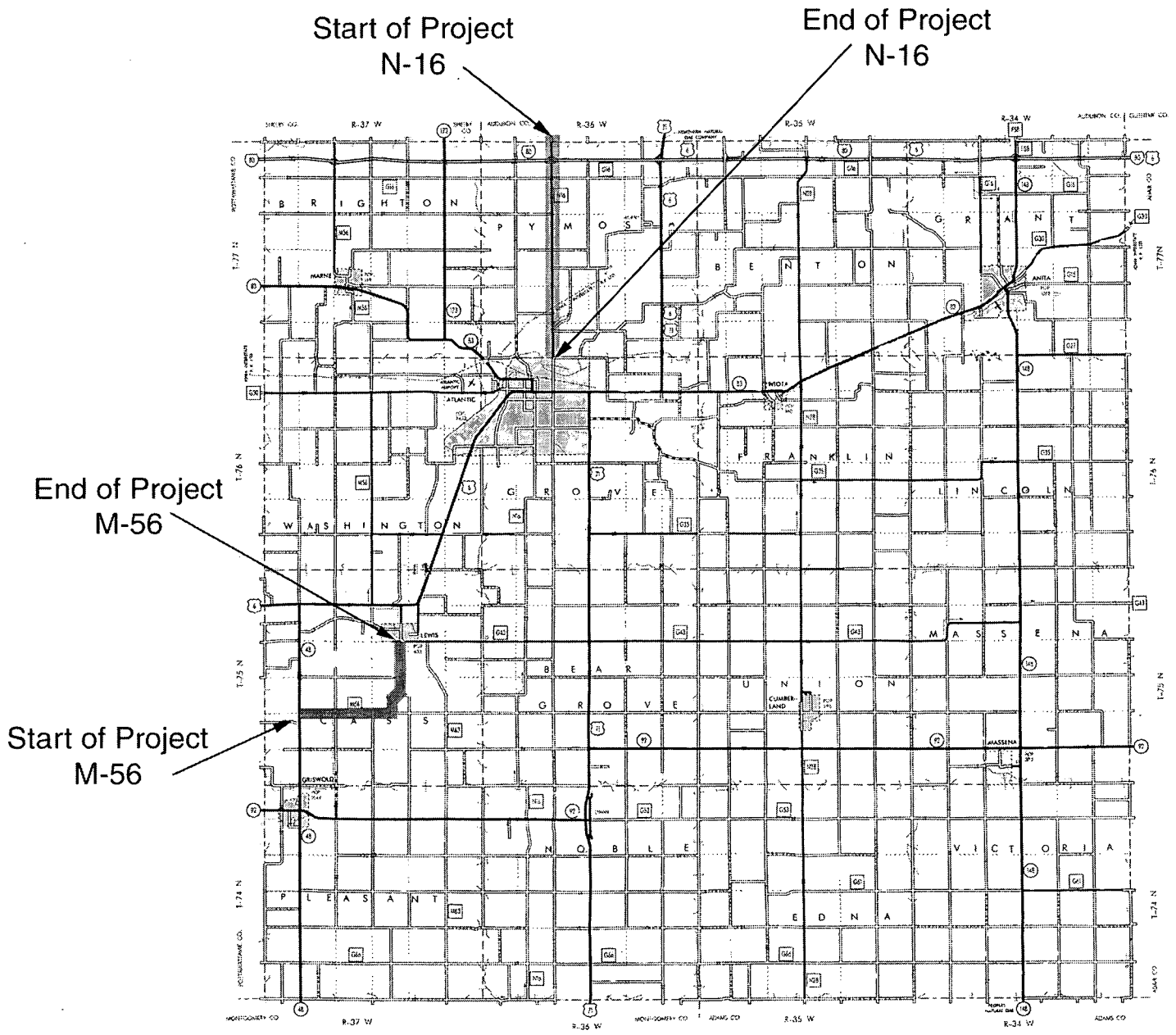
LEGEND




End of Project
Start of Project
HIGHWAY AND TRANSPORTATION MAP
SCOTT COUNTY
IOWA
Prepared By
Iowa Department of Transportation
In Cooperation With
United States Department of Transportation
JANUARY 1, 1999
LEGEND
WINFIELD
BUTLER
PRINCETON
ALLENS GROVE
LIBERTY
CLEONA
HICKORY GROVE
SHERIDAN
LINCOLN
LE CLAIRE
DAVENPORT
PLEASANT VALLEY
BLUE GRASS
DAVENPORT CITY
BUFFALO
MISSISSIPPI RIVER
STATE OF ILLINOIS


HIGHWAY AND TRANSPORTATION MAP
CERRO GORDO COUNTY
IOWA
Prepared By
Iowa Department of Transportation
In Cooperation With
United States Department of Transportation
JANUARY 1, 1999
LEGEND
End of Project S-70
Start of Project S-70
Start of Project B-60
End of Project B-60
GRANT
LINCOLN
LIME CREEK
FALLS
PORTLAND
MASON
LAKE
CLEAR LAKE
MOUNT VERNON
BATH
OWEN
UNION
GRIMES
GENESEO
PLEASANT VALLEY
DOUGHERTY
CLEAR LAKE
MASON CITY
ROCK FALLS
PLYMOUTH
VENTURA
SWALEDALE
ROCKWELL
DOUGH CITY
T-97N
T-96N
T-95N
T-94N
R-22W
R-21W
R-20W
R-19W


HIGHWAY AND TRANSPORTATION MAP
DUBUQUE COUNTY
IOWA
Prepared By
Iowa Department of Transportation
In Cooperation With
United States Department of Transportation
JANUARY 1, 1999
LEGEND
MISSISSIPPI RIVER
Start of Project
End of Project



HIGHWAY AND TRANSPORTATION MAP

CASS COUNTY
IOWA

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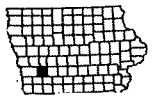
JANUARY 1, 1999

LEGEND



HIGHWAY AND TRANSPORTATION MAP

LOUISA COUNTY

IOWA

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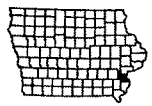
JANUARY 1, 1999

LEGEND

End of Project

Start of Project



Appendix B
SUPERPAVE OVERVIEW

SUPERPAVE MIX DESIGN SYSTEM OVERVIEW

The Superpave mix design process has four major attributes:
- Use of a performance graded AC,
- Careful gradation control with control points instead of gradation bands
- Aggregate consensus and source properties, and
- Gyratory compaction.

Note that this is just an overview - there are many good references available, which provide detailed descriptions and explanations. Also note that many of these requirements are in flux and have changed since this research was started.

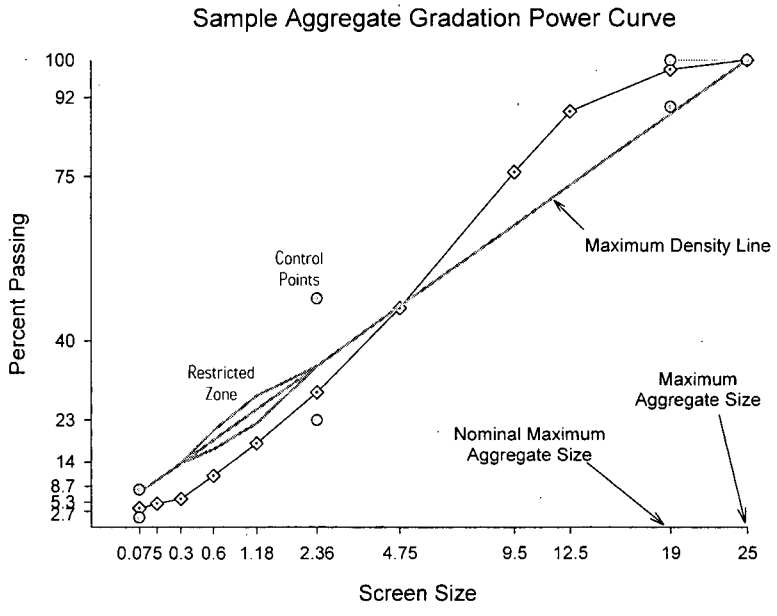
Performance Graded AC

The use of performance graded AC provides the pavement with a binder that is strong at high temperatures to resist rutting and yet soft enough at cold temperatures to resist thermal cracking. A performance graded asphalt such as 58-28 is designed to maintain these properties at +58°C and -28°C. There are numerous charts published by the Superpave centers and asphalt producers that show what parts of the state should be using which binders. However, for the most part, Iowa has chosen 58-28 for use essentially statewide.

Gradation

One of the core principles underlying Superpave mix designs is the idea of the aggregate providing a structure or skeleton that bears most of the load in a pavement and the AC holding the aggregates together. In order for the aggregate to provide this structure, the mix of aggregate sizes and the aggregate shapes have to be such that there is a lot of point to point contact between pieces. There has to also be enough smaller particles to fill in any large gaps in the matrix but not so many that there is no room for AC.

For the discussion of gradation in a Superpave mix design context, it is often helpful to look at the gradation plotted on a 0.45 power curve such as the one at right. This is simply a plot of the percent of the mix passing through each of a series of sieves. The plot has four major components: a maximum density line, a restricted zone, control points and the gradation data.



The horizontal axis represents the screen mesh size measured in millimeters, but scaled to the 0.45 power. That is, the 12.5 mm label is placed at a position value of $12.5^{(0.45)} = 3.12$ and so on. The vertical axis represents the percentage of the mix that passes through each screen. This means that the vertical difference between any two points represents the percentage of material that is larger than the mesh of the lower screen and smaller than that of the upper screen. The nominal maximum aggregate size is the sieve one size larger than the first sieve to retain more than ten percent of the combined aggregate. The maximum aggregate size is one sieve larger than the nominal maximum. General reference to the mix will refer to the nominal maximum size. So the mix above would be described as "a 19 mm mix".

The maximum density line represents an approximation of the maximum density a specified mix could attain - essentially the most aggregate that could be packed into a unit volume. If the mix was truly at this maximum density, there would be almost no room for asphalt. This line provides a qualitative reference to which we can compare the shape of the actual gradation. The closer to this line the gradation gets, the less room there will be for asphalt and air voids in a well compacted mix.

The control points and restricted zone are defined by Superpave requirements. Generally speaking Superpave mix design gradations are expected to pass between the control points and around (below or occasionally above) the restricted zone.

The philosophy behind the restricted zone has to do with an historical school of thought that gradations passing through this area will result in ACC mixes that are prone to be tender. There is some controversy about this contention. Another school of thought maintains that avoiding compaction during certain temperatures (tender zones) is more important than avoiding mixes with gradations that pass through the restricted zone.

When the projects used in TR-414 were let, Superpave mix designs for low volume roads were expected to avoid the restricted zone. After the projects in this research had been completed, the specifications for Superpave in Iowa were changed to remove the restricted zone from mixes for low volume roads. Because of that initial requirement, the zones have been left in the graphs for this research.

A distinction is made between the definitions of a fine mix and a small size mix in the context of the Superpave mix design method. In this context a "fine" mix is one whose gradation line lies above the maximum density line across most of the gradation graph. A good example of a fine mix was shown in the report with the Dubuque County project. The "size" of the mix is defined by the nominal maximum aggregate size. So the graph above would be designated as a "19 mm" mix or "a mix with a 19 mm nominal maximum aggregate size". Thus it is possible to have a "large" mix that is also "fine" and a "small" mix that is "coarse".

Aggregate Consensus and Source Properties

These are the requirements for the aggregate particles themselves. The reader should note that the contractors for these projects met all of the requirements with locally available aggregates.

Consensus Properties	Source Properties
coarse aggregate angularity	toughness
fine aggregate angularity	soundness
flat, elongated particles	deleterious materials
clay content	

Gyratory Compaction

This is probably the most important aspect of the Superpave mix design process. Most of the other listed requirements are not much different from the conventional Marshall method. Using a gyratory compactor offers several benefits compared to the Marshall hammer method: (1) The samples are larger so there are fewer edge effects especially with the larger aggregate mixes, (2) Compaction is achieved with a kneading motion instead of a hammering motion - this more closely models the actual compaction that the ACC would experience in the field, (3) A gyratory compactor provides continuous data output so that compaction and void data can be determined for every step in the process.

Appendix C
MIX DESIGNS

Cass County
Highway M-56

Form 956

Iowa Department of Transportation
Project Development Division - Office of Materials
ACC Superpave Mix Design

County :	Cass	Project :	STP-S-15(24)--5E-15	Lab No. :	SWI8-26
Size :	12.5	Contracter :	Henningsen Const	Contract No. :	
Mix Type:	Type B	Design Life ESAL's :	100.000	Date Reported :	08/21/98
Intended Use :	Surface	Proj. Location :	Lewis		

Agg. Sources :	5/8 Cl Stone	A01004	Schildberg Jefferson	@ 20.0%
	1/2 Stone Jeff	A01004	Schildberg Jefferson	@ 31.0%
	1/2 Washed St	A01002	Schildberg Menlo	@ 22.0%
	Sand	A05506	Hallett Exira	@ 27.0%

Job Mix Formula - Combined Gradation (Sieve Size mm)

25	19	12.5	9.5	4.75	2.36	1.18	600µ	300µ	150µ	75µ
					Upper Tolerance					
100	100	100	90		39.1	25.6	19.1	15.5		10
100	100	90	79	51	35	25	17	7.7	4.1	3.5
100	100	90			28					2
					Lower Tolerance					

Asphalt Source and Grade: Koch PG 58-28

	Gyratory Data				Interpolated	
% Asphalt	4.50	5.00	5.50	6.00	5.55	
Corrected Density @ N-Design	2.281	2.289	2.318	2.319	2.318	Avg. Design High Air Temp. C
Max. Sp.Gr. (Gmm)	2.457	2.436	2.416	2.404	2.415	<39
% Gmm @ N- Initial	85.61	86.40	87.25	88.09	87.34	
% Gmm @ N-Max	93.87	95.14	97.04	97.69	97.11	mm from Surface
% Air Voids	7.16	6.03	4.06	3.54	4.00	0
% VMA	15.83	15.98	15.36	15.77	15.40	
% VFA	54.77	62.27	73.57	77.55	74.00	Number of Gyrations
Film Thickness	9.86	11.28	12.66	13.72	12.77	N-Initial
Filler Bit. Ratio	0.91	0.80	0.71	0.65	0.70	7
Gsb	2.588	2.588	2.588	2.588	2.588	N-Design
Gse	2.630	2.626	2.623	2.629	2.627	68
Pbe	3.90	4.46	5.00	5.42	5.05	N-Max
Pba	0.63	0.57	0.53	0.62	0.59	104
% New AC	100.00	100.00	100.00	100.00	100.00	
AC Sp.Gr. @ 25c	1.026	1.026	1.026	1.026	1.026	Gsb for Angularity
% Water Abs	1.60	1.60	1.60	1.60	1.60	Method A
S.A. m^2 / Kg.	3.95	3.95	3.95	3.95	3.95	2.624
% +4.75mm Friction Agg.	0.0	0.0	0.0	0.0	0.0	
Angularity-method A						Slope of Compaction
% Flat & Elongated						Curve
Coarse Agg. Angularity	*97/97	*97/97	*97/97	*97/97	*97/97	12.00
Sand Equivalent	76	76	76	76	76	

Minimum % AC for this aggregate combination is 4.94%
Disposition : An asphalt content of 5.55% is recommended to start this project.
Data shown in 5.55% column is interpolated from test data.

Comments . SWI8-26 For Mix Design #4BD8-35

Copies to : Henningsen Const DOT Lab Henningsen
SWI

Signed : Scott Schoeneman
For Gary Schoeneman

Cass County
Highway N-16

Form 956

Iowa Department of Transportation
Project Development Division - Office of Materials
ACC Superpave Mix Design

County :	Cass	Project :	FM-15(27)--55-75	Lab No. :	4BD8-19
Size :	12.5	Contracter :	Henningsen Const	Contract No. :	
Mix Type:	Type A	Design Life ESAL's :	100,000	Date Reported :	05/05/98
Intended Use :	Surface	Proj. Location :	North of Atlantic on Olive St		

Agg. Sources :	5/8 CL St	A01002	Schildberg Const Menlo	@ 16.0%
	1/2 Wased St	A01002	Schildberg Const Menlo	@ 29.0%
	1/2X1/4 Stone	A01002	Schildberg Const Menlo	@ 30.0%
	Conc Sand	A05506	Hallett Materials Exira	@ 25.0%

Job Mix Formula - Combined Gradation (Sieve Size mm)

25	19	12.5	9.5	4.75	2.36	1.18	600µ	300µ	150µ	75µ
					Upper Tolerance					
100	100	100	90		39.1	25.6	19.1	15.5		10
100	100	93	81	48	35	25	17	7.7	4.2	3.7
100	100	90			28					2
					Lower Tolerance					

Asphalt Source and Grade: Koch PG 58-28

	Gyratory Data				Interpolated	
% Asphalt	4.70	5.20	5.70	6.20	5.74	
Corrected Density @ N-Design	2.308	2.329	2.334	2.346	2.335	Avg. Design High Air Temp. C
Max. Sp.Gr. (Gmm)	2.464	2.450	2.434	2.413	2.432	<39
% Gmm @ N- Initial	84.85	87.08	87.66	88.05	87.69	
% Gmm @ N-Max	94.93	96.27	97.29	98.72	97.41	mm from Surface
% Air Voids	6.33	4.94	4.11	2.78	4.00	0
% VMA	16.05	15.73	15.99	16.01	15.99	
% VFA	60.56	68.60	74.30	82.64	74.98	Number of Gyrations
Film Thickness	10.88	11.97	13.17	14.57	13.28	N-Initial
Filler Bit. Ratio	0.85	0.77	0.70	0.63	0.69	7
Gsb	2.620	2.620	2.620	2.620	2.620	N-Design
Gse	2.647	2.652	2.654	2.650	2.651	68
Pbe	4.32	4.75	5.23	5.78	5.27	N-Max
Pba	0.40	0.47	0.50	0.44	0.45	104
% New AC	100.00	100.00	100.00	100.00	100.00	
AC Sp.Gr. @ 25c	1.026	1.026	1.026	1.026	1.026	Gsb for Angularity
% Water Abs	1.16	1.16	1.16	1.16	1.16	Method A
S.A. m^2 / Kg.	3.97	3.97	3.97	3.97	3.97	2.628
% +4.75mm Friction Agg.	0.0	0.0	0.0	0.0	0.0	
Angularity-method A						Slope of Compaction
% Flat & Elongated						Curve
Coarse Agg. Angularity	*97/97	*97/97	*97/97	*97/97	*97/97	12.08
Sand Equivalent	79	79	79	79	79	

Minimum % AC for this aggregate combination is 4.77%
Disposition : An asphalt content of 5.74% is recommended to start this project.
Data shown in 5.74% column is interpolated from test data.

Comments : For Mix Design 4BD8-19
SWI8-10

Copies to : Henningsen Const Henningsen Const DOT Lab
SWI

Signed Gary Schwenneker

Dubuque County
Highway IA-966

Form 956

Iowa Department of Transportation
Project Development Division - Office of Materials
ACC Superpave Mix Design

County :	DUBUQUE	Project :	STP-S-31(20)--5E-31	Lab No. :	ABD8-6005
Size :	19mm	Contracter :	River City Paving	Contract No. :	31-0031-020
Mix Type:	A	Design Life ESAL's :	280,512	Date Reported :	05-26-98
Intended Use :	Binder	Proj. Location :	On Dubuque county road, Centralia to Radford Road		

Agg. Sources :	19mm Cr. Lmst.	A31010	River City Stone; Brown Qr.; Beds 3-9A	@ 25.0%
	19mm Clean St.	A31010	River City Stone; Brown Qr.; Beds 3-9A	@ 25.0%
	Manf. Sand	A31010	River City Stone; Brown Qr.; Beds 3-9A	@ 25.0%
	Nat. Sand	A31502	Aggregate Materials; Nine Mile Island	@ 25.0%

Job Mix Formula - Combined Gradation (Sieve Size mm)

25	19	12.5	9.5	4.75	2.36	1.18	600µ	300µ	150µ	75µ
					Upper Tolerance					
100	100	90			49					8
100	100	85	74	60	47	38	27	15	7.2	3.3
100	90				34.6	28.3	20.7	13.7		2
					Lower Tolerance					

Asphalt Source and Grade: KOCH @ DUBUQUPG 58-28

	Gyratory Data				Interpolated	
% Asphalt	5.16	5.66	6.16	6.66	5.28	
Corrected Density @ N-Design	2.391	2.403	2.413	2.428	2.394	Avg. Design High Air Temp. C
Max. Sp.Gr. (Gmm)	2.499	2.478	2.477	2.457	2.494	<39
% Gmm @ N- Initial	90.10	91.13	91.18	92.86	90.35	
% Gmm @ N-Max	96.64	97.90	98.34	99.37	96.95	mm from Surface
% Air Voids	4.32	3.03	2.58	1.18	4.00	50
% VMA	14.07	14.10	14.20	14.12	14.08	
% VFA	69.30	78.51	81.83	91.64	71.59	Number of Gyrations
Film Thickness	7.91	8.94	9.32	10.33	8.16	N-Initial
Filler Bit. Ratio	0.79	0.70	0.67	0.61	0.77	7
Gsb	2.639	2.639	2.639	2.639	2.639	N-Design
Gse	2.710	2.707	2.730	2.728	2.719	68
Pbe	4.19	4.74	4.94	5.47	4.33	N-Max
Pba	1.02	0.98	1.30	1.27	1.14	104
% New AC	100.00	100.00	100.00	100.00	100.00	
AC Sp.Gr. @ 25c	1.028	1.028	1.028	1.028	1.028	Gsb for Angularity
% Water Abs	1.88	1.88	1.88	1.88	1.88	Method A
S.A. m^2 / Kg.	5.30	5.30	5.30	5.30	5.30	2.656
% +4.75mm Friction Agg.	0.0	0.0	0.0	0.0	0.0	
Angularity-method A						Slope of Compaction
% Flat & Elongated						Curve
Coarse Agg. Angularity	0	0	0	0	0	17.77
Sand Equivalent						

Minimum % AC for this aggregate combination is 4.94%
Disposition : An asphalt content of 5.28% is recommended to start this project.
Data shown in 5.28% column is interpolated from test data.

Comments : _____

Copies to : River City Paving AMES E.C.I.T.C. CONTRACTOR JOBGEN
LOHRER PRODUCER'S LAB LIKE

Signed : _____

Mahaska County
Highway G-29

Form 956

Iowa Department of Transportation
Project Development Division - Office of Materials
ACC Superpave Mix Design

County :	MAHASKA	Project :	FM-62(29)--55-62	Lab No. :	ABD8-5016
Size :	9.5	Contracter :	MANATTS	Contract No. :	
Mix Type:	A	Design Life ESAL's	200	Date Reported :	05/22/98
Intended Use :	SURFACE	Proj. Location :	FM-62(29)--55-62		

Agg. Sources :	1/2 DUST	02	LR498002	A79002 MALCOM ST. BEDS 10-13	@ 40.0%
	3/8 CHIP	03	LR498003	A79002 MALCOM ST. BEDS 10-13	@ 20.0%
	M. SAND	06	LR498006	A50002 MARTIN MARIETTA BEDS	@ 20.0%
	SAND	05	LR498005	A86502 MANATTS TAMA SAND	@ 20.0%

Job Mix Formula - Combined Gradation (Sieve Size mm)

25	19	12.5	9.5	4.75	2.36	1.18	600µ	300µ	150µ	75µ
					Upper Tolerance					
100	100	100	100		47.2	31.6	23.5	18.7		10
100	100	100	93	57	38	27	18	8.6	5.5	4.5
100	100	100	90		32					2
					Lower Tolerance					

Asphalt Source and Grade: BITUMINOUS - TAPG 58-28

	Gyratory Data				Interpolated	
% Asphalt	6.60	7.10	7.60	8.10	6.91	
Corrected Density @ N-Design	2.321	2.332	2.348	2.347	2.328	Avg. Design High Air Temp. C
Max. Sp.Gr. (Gmm)	2.433	2.420	2.390	2.378	2.425	<39
% Gmm @ N- Initial	87.74	88.22	89.91	89.81	88.04	
% Gmm @ N-Max	96.75	97.81	99.60	99.96	97.41	mm from Surface
% Air Voids	4.60	3.64	1.76	1.30	4.00	0
% VMA	15.39	15.44	15.32	15.81	15.42	
% VFA	70.11	76.42	88.51	91.78	74.05	Number of Gyrations
Film Thickness	10.38	11.32	12.92	13.83	10.97	N-Initial
Filler Bit. Ratio	0.94	0.86	0.75	0.70	0.89	7
Gsb	2.562	2.562	2.562	2.562	2.562	N-Design
Gse	2.694	2.700	2.683	2.690	2.692	68
Pbe	4.77	5.20	5.93	6.35	5.03	N-Max
Pba	1.96	2.05	1.81	1.91	1.93	104
% New AC	100.00	100.00	100.00	100.00	100.00	
AC Sp.Gr. @ 25c	1.027	1.027	1.027	1.027	1.027	Gsb for Angularity
% Water Abs	2.59	2.59	2.59	2.59	2.59	Method A
S.A. m^2 / Kg.	4.59	4.59	4.59	4.59	4.59	2.647
% +4.75mm Friction Agg.	0.0	0.0	0.0	0.0	0.0	
Angularity-method A						Slope of Compaction
% Flat & Elongated						Curve
Coarse Agg. Angularity	0	0	0	0	0	12.53
Sand Equivalent						

Minimum % AC for this aggregate combination is 6.63%
Disposition : An asphalt content of 6.91% is recommended to start this project.
Data shown in 6.91% column is interpolated from test data.

Comments : central lab., bit.eng., j.webb, d.lubbe, m.trueblood, manatts, norris, christensen gettings, ruddy

Copies to : MANATTS

Signed : SIGNATURES ON FILE SG

Scott County
Highway Y-30

Iowa Department of Transportation
Project Development Division
Office of Materials
ACC Superpave Mix Design

County :	Scott	Project :	FM-82(20)--55-82	Lab No. :	ABD7-24
Size :	19 mm	Contracter :	McCarthy Imp.	Contract No. :	
Mix Type:	A	Design Life ESAL's :	< 300000	Date Reported :	05/29/97
Intended Use :	Binder / Surface	Proj. Loacation :			

Agg. Sources :	3/4" ACC Chips	A82008	Linwood Mining & Minerals Beds 20-25	@ 29.0%
	1/2" ACC Chips	A82008	Linwood Mining & Minerals Beds 20-25	@ 42.0%
	Man. Sand	A82008	Linwood Mining & Minerals Beds 20-25	@ 28.0%
	Mineral Filler	A82008	Linwood Mining & Minerals Beds 20-25	@ 1.0%

Job Mix Formula - Combined Gradation (Sieve Size mm)

26.5	19	13.2	9.5	4.75	2.36	1.18	600µ	300µ	150µ	75µ
Upper Tolerance										
100	100	92			34.6	22.3	16.7	13.7		8
100	100	92	75	40	23	14	8.7	5.3	3.4	2.7
100	90				23					2
Lower Tolerance										

Asphalt Source and Grade:	Koch Davenport PG 58-28			
	Gyratory Data			Interpolated
% Asphalt	3.88	4.88	5.88	5.41
Corrected Density @ N-Design	2.338	2.339	2.387	2.364
Max. Sp.Gr. (Gmm)	2.513	2.477	2.451	2.463
% Gmm @ N- Initial	83.10	84.62	86.49	85.62
% Gmm @ N-Max	94.75	96.29	99.22	97.85
% Air Voids	6.96	5.57	2.61	4.00
% VMA	13.37	14.23	13.39	13.78
% VFA	47.94	60.86	80.51	71.29
Film Thickness	9.87	13.36	16.27	14.90
Filler Bit. Ratio	0.96	0.71	0.58	0.64
Gsb	2.594	2.594	2.594	2.594
Gse	2.668	2.669	2.682	2.673
Pbc	2.82	3.82	4.65	4.26
Pba	1.10	1.12	1.30	1.17
% New AC	100.00	100.00	100.00	100.00
AC Sp.Gr. @ 25c	1.030	1.030	1.030	1.030
% Water Abs	1.54	1.54	1.54	1.54
S.A. m^2 / Kg.	2.86	2.86	2.86	2.86
% Friction Agg.	0.0	0.0	0.0	0.0
Angularity-mthd A				
Flat & Elongated	0.0	0.0	0.0	0.0
Coarse Agg. Angul.	100.0	100.0	100.0	100.0
Sand Equivalent				

Minimum % AC for this aggregate combination is 5.02%
Disposition : An asphalt content of 5.41% is recommended to start this project.
Data shown in 5.41% column is interpolated from test data.

COMMENTS : Marshall density at 50 blows is 2.369 at the intended AC content.

COPIES TO : McCarthy Imp. John Himrichsen Cent. Lab. Roger Boulet
Larry Mattush Scott County Eng.

SIGNED : _____

Cerro Gordo County
Highways S-70 and B-60

Form 956

Iowa Department of Transportation
Project Development Division - Office of Materials
ACC Superpave Mix Design

County :	CERRO GORDO	Project :	FM-17(28&29)-55--17	Lab No. :	ABD8-2015
Size :	19MM	Contracter :	FRED CARLSON C(	Contract No. :	17-0017-029
Mix Type:	B1	Design Life ESAL's :	100,000	Date Reported :	
Intended Use :	BASE	Proj. Location :	PORTLAND AREA, AND B-60		

Agg. Sources :	13.2MM GRVL	A17506	NELSON-FORBES PIT, BECKER, PORT	@ 25.0%
	19MM MINUS	A17008	MM, PORTLAND	@ 20.0%
	19MM CLEAN	A17008	MM, PORTLAND	@ 30.0%
	9.5 CHIPS	A17008	MM, PORTLAND	@ 25.0%

Job Mix Formula - Combined Gradation (Sieve Size mm)

25	19	12.5	9.5	4.75	2.36	1.18	600µ	300µ	150µ	75µ
Upper Tolerance										
100	100	90			34.6	22.3	16.7	13.7		8
100	100	89	77	39	25	18	11	6.4	4.2	3.1
100	90				23					2
Lower Tolerance										

Asphalt Source and Grade: KOCK, DUBUQUE PG-58-28

	Gyratory Data				Interpolated	
% Asphalt	3.89	4.39	4.89	5.39	5.02	
Corrected Density @ N-Design	2.385	2.438	2.435	2.450	2.439	Avg. Design High Air Temp. C
Max. Sp.Gr. (Gmm)	2.582	2.563	2.546	2.525	2.541	<39
% Gmm @ N- Initial	83.16	85.44	85.81	86.78	86.06	
% Gmm @ N-Max	93.80	96.55	97.25	98.61	97.60	mm from Surface
% Air Voids	7.63	4.88	4.36	2.97	4.00	0
% VMA	15.13	13.70	14.26	14.18	14.24	
% VFA	49.57	64.38	69.42	79.06	71.92	Number of Gyrations
Film Thickness	9.81	11.26	12.67	14.27	13.08	N-Initial
Filler Bit. Ratio	0.95	0.83	0.74	0.66	0.72	7
Gsb	2.701	2.701	2.701	2.701	2.701	N-Design
Gse	2.750	2.752	2.755	2.753	2.753	68
Pbe	3.24	3.72	4.18	4.71	4.32	N-Max
Pba	0.68	0.71	0.75	0.72	0.71	104
% New AC	100.00	100.00	100.00	100.00	100.00	
AC Sp.Gr. @ 25c	1.028	1.028	1.028	1.028	1.028	Gsb for Angularity
% Water Abs	0.89	0.89	0.89	0.89	0.89	Method A
S.A. m^2 / Kg.	3.30	3.30	3.30	3.30	3.30	2.649
% +4.75mm Friction Agg.	0.0	0.0	0.0	0.0	0.0	
Angularity-method A	44	44	44	44	44	Slope of Compaction
% Flat & Elongated						Curve
Coarse Agg. Angularity	0	0	0	0	0	10.16
Sand Equivalent	77	77	77	77	77	

Minimum % AC for this aggregate combination is 4.44%
Disposition : An asphalt content of 5.02% is recommended to start this project.
Data shown in 5.02% column is interpolated from test data.

Comments : QMA VERIFIED MIX DESIGN.
FINAL ACCEPTANCE OF MIX BASED ON TEST RESULTS OF PLANT PRODUCED MIXTURE

Copies to : FRED CARLSON CO, CENTRAL LAB, FILE, TC LAB, CERRO GORDO COUNTY, PAULSON, AC. TECH. ASSURANCE, MARTIN/MARIETTA BECKER,

Signed : Keith E. Corris P.E.

Louisa County
Highway X-17

Form 956

Iowa Department of Transportation
Project Development Division - Office of Materials
ACC Superpave Mix Design

County :	Louisa	Project :	FM-58(17)--55-58	Lab No. :	ABD8-30
Size :	12.5mm	Contracter :	Norris Asphalt	Contract No. :	
Mix Type:	B	Design Life ESAL's :	290,000	Date Reported :	08/18/98
Intended Use :	Surface	Proj. Location :	Louisa Co. X-17 N&E to IA 70		

Agg. Sources :	1/2"	A58002	R.P. Col. Jct. W. Beds 16-19 5CJ8-001	@ 30.0%
	3/8 Chip	A58002	R.P. Col. Jct. W. Beds 16-19 5CJ8-003	@ 20.0%
	Man Sand	A58002	R.P. Col. Jct. W. Beds 16-19 5CJ8-002	@ 30.0%
	Nat Sand	A58504	R.Prod. Fredonia 5FR8-001	@ 20.0%

Job Mix Formula - Combined Gradation (Sieve Size mm)

25	19	12.5	9.5	4.75	2.36	1.18	600µ	300µ	150µ	75µ
					Upper Tolerance					
100	100	100			58					10
100	100	95	88	63	43	32	22	9.2	6.2	4.8
100	100	90			39.1	31.6	23.1	15.5		2
					Lower Tolerance					

Asphalt Source and Grade: Amoco Davenport PG58-28

	Gyratory Data				Interpolated	
% Asphalt	6.60	7.10	7.60		6.66	
Corrected Density @ N-Design	2.314	2.339	2.326		2.317	Avg. Design High Air Temp. C
Max. Sp.Gr. (Gmm)	2.415	2.403	2.390		2.414	<39
% Gmm @ N- Initial	88.82	90.52	89.93		89.03	
% Gmm @ N-Max	96.87	98.38	98.43		97.05	mm from Surface
% Air Voids	4.18	2.66	2.68		4.00	0
% VMA	15.18	14.72	15.65		15.12	
% VFA	72.46	81.93	82.88		73.60	Number of Gyrations
Film Thickness	9.63	10.44	11.29		9.72	N-Initial
Filler Bit. Ratio	0.98	0.90	0.84		0.97	7
Gsb	2.548	2.548	2.548		2.548	N-Design
Gse	2.669	2.676	2.682		2.676	68
Pbe	4.89	5.31	5.74		4.94	N-Max
Pba	1.83	1.93	2.02		1.93	104
% New AC	100.00	100.00	100.00		100.00	
AC Sp.Gr. @ 25c	1.029	1.029	1.029		1.029	Gsb for Angularity
% Water Abs	3.42	3.42	3.42		3.42	Method A
S.A. m^2 / Kg.	5.08	5.08	5.08		5.08	2.638
% +4.75mm Friction Agg.	0.0	0.0	0.0		0.0	
Angularity-method A	N/A	N/A	N/A		N/A	Slope of Compaction
% Flat & Elongated	N/A	N/A	N/A		N/A	Curve
Coarse Agg. Angularity	100/100	100/100	100/100		100/100	14.60
Sand Equivalent	85	85	85		85	

Minimum % AC for this aggregate combination is 6.21%
Disposition : An asphalt content of 6.66% is recommended to start this project.
Data shown in 6.66% column is interpolated from test data.

Comments : 1.0 lbs latex to 1 ton of aggregate

Copies to : Norris Asphalt John Hinrichsen Cent. Lab. Louisa Co. Eng.
Jim Webb

Signed : Kim Lowe

Louisa County
Highway X-17

Form 956

Iowa Department of Transportation
Project Development Division - Office of Materials
ACC Superpave Mix Design

County :	Louisa	Project :	FM-58(17)--55-58	Lab No. :	ABD8-29
Size :	12.5mm	Contracter :	Norris Asphalt	Contract No. :	
Mix Type:	B	Design Life ESAL's :	290,000	Date Reported :	
Intended Use :	Surface	Proj. Location :	Louisa Co. X-17 N&E to IA 70		

Agg. Sources :	1/2"	A58002	R.P. Col. Jct. W. Beds 16-19 5CJ8-001	@ 30.0%
	3/8 Chip	A58002	R.P. Col. Jct. W. Beds 16-19 5CJ8-003	@ 20.0%
	Man Sand	A58002	R.P. Col. Jct. W. Beds 16-19 5CJ8-002	@ 30.0%
	Nat Sand	A58504	R.Prod. Fredonia 5FR8-001	@ 20.0%

Job Mix Formula - Combined Gradation (Sieve Size mm)

25	19	12.5	9.5	4.75	2.36	1.18	600µ	300µ	150µ	75µ
					Upper Tolerance					
100	100	100			58					10
100	100	95	88	63	43	32	22	9.2	6.2	4.8
100	100	90			39.1	31.6	23.1	15.5		2
					Lower Tolerance					

Asphalt Source and Grade: Amoco Davenport PG58-28

	Gyratory Data			Interpolated	
% Asphalt	7.60			7.21	
Corrected Density @ N-Design	2.310			2.298	Avg. Design High Air Temp. C
Max. Sp.Gr. (Gmm)	2.382			2.393	<39
% Gmm @ N- Initial	89.50			88.52	
% Gmm @ N-Max	98.13			97.15	mm from Surface
% Air Voids	3.02			4.00	0
% VMA	16.23			16.33	
% VFA	81.39			75.35	Number of Gyrations
Film Thickness	11.58			10.79	N-Initial
Filler Bit. Ratio	0.82			0.88	7
Gsb	2.548			2.548	N-Design
Gse	2.671			2.671	68
Pbe	5.88			5.48	N-Max
Pba	1.86			1.86	104
% New AC	100.00			100.00	
AC Sp.Gr. @ 25c	1.029			1.029	Gsb for Angularity
% Water Abs	3.42			3.42	Method A
S.A. m^2 / Kg.	5.08			5.08	2.638
% +4.75mm Friction Agg.	0.0			0.0	
Angularity-method A					Slope of Compaction
% Flat & Elongated					Curve
Coarse Agg. Angularity	0			0	13.58
Sand Equivalent					

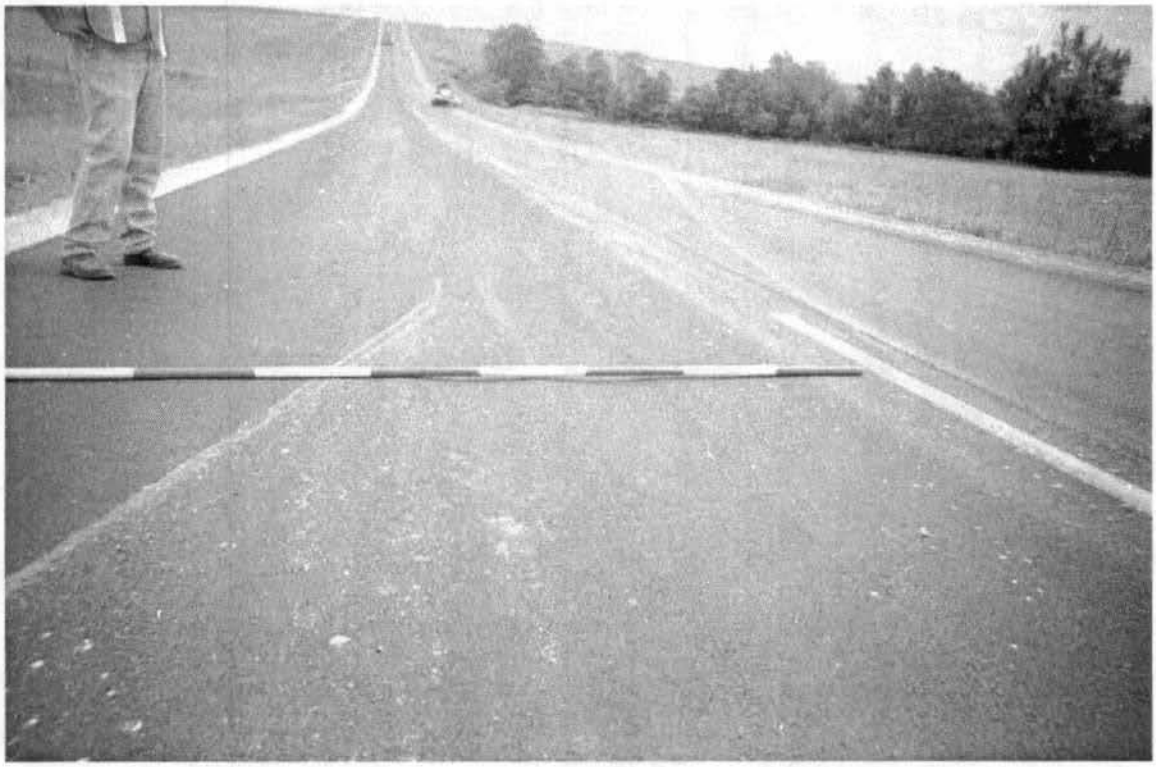
Minimum % AC for this aggregate combination is 6.15%
Disposition : An asphalt content of 7.21% is recommended to start this project.
Data shown in 7.21% column is interpolated from test data.

Comments : Verification of mix NAP8-022

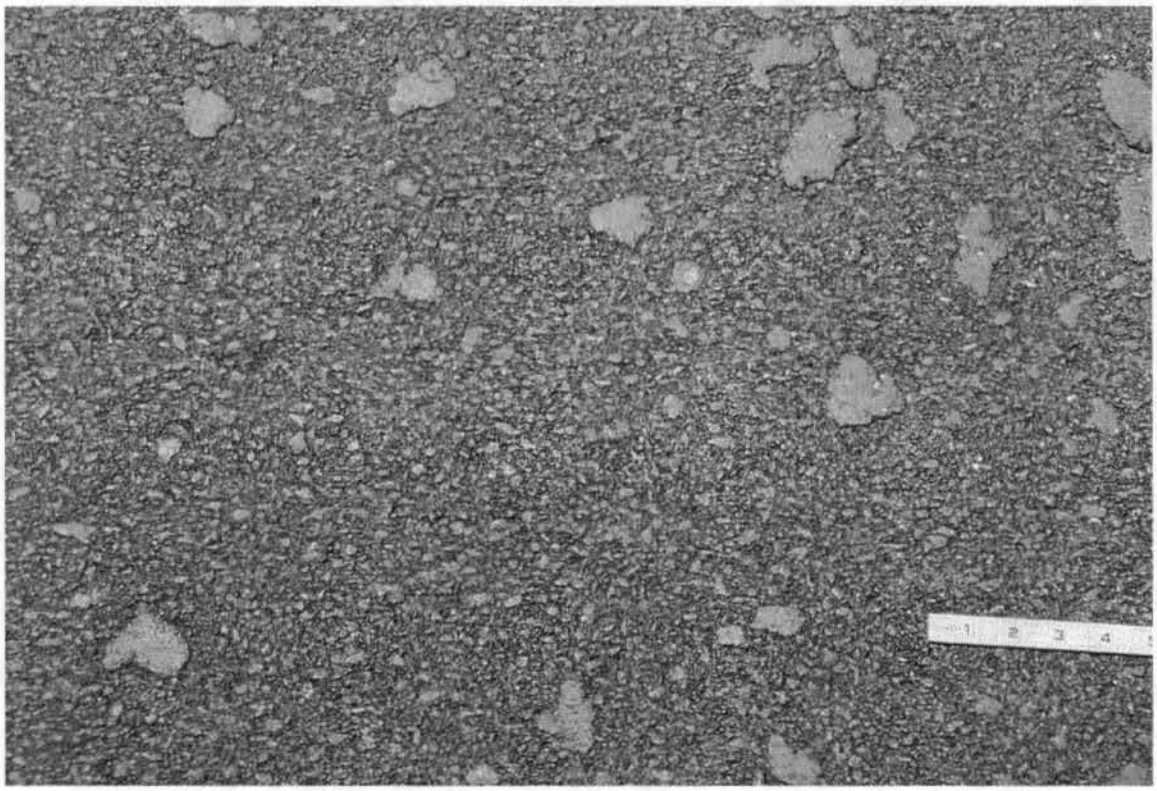
Copies to : Norris Asphalt John Hinrichsen Cent. Lab. SEITC
Jim Webb

Signed : _____

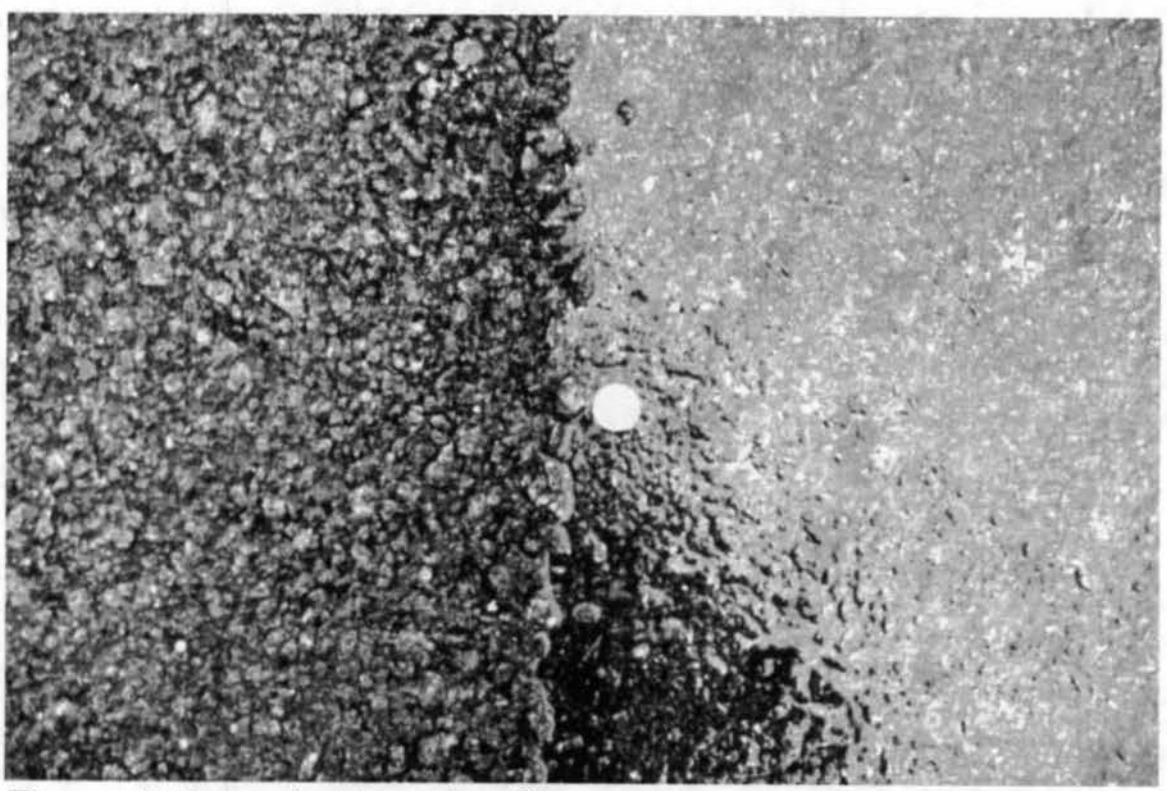
Appendix D
PHOTOGRAPHS



Rutting in the newly-placed first lift.



"Patties" of AC on pavement surface due to inadequate roller tire temperature.



These photographs show the difference in texture before (smooth) and after (coarse) a mix design change on this project. Note that the pavement is wet from rain and that the circle in the bottom photograph is approximately 25mm.

Cass County Highway M-56

These photographs show the distress that existed prior to paving. The weakened-subgrade areas were excavated and replaced.