Superpave Mix Designs for Low-Volume Roads

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Iowa Highway Research Board
Project TR-414

Edward J. Engle, P.E.
Secondary Road Research Coordinator
515-239-1382
Office of Materials
Highway Division
Iowa Department of Transportation
Ames, Iowa 50010

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5. AUTHOR(S)

Edward Engle, P.E.
Secondary Road Research Coordinator

6. PERFORMING ORGANIZATION ADDRESS

Iowa Department of Transportation
Materials Department
800 Lincoln Way
Ames, Iowa 50010

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Scott County Engineer
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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 was 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.

9. KEY WORDS

Asphalt Cement Concrete (ACC)
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INTRODUCTION

This research was initiated to fill in a gap in the work that was being done to develop and implement the Superpave[1] 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 related specifications for materials and a gyratory compaction regimen. Up to the time of this research, 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: (1) Mix design performance requirements, (2) aggregate requirements and availability, and (3) project budget levels.

(1) The mix design requirements are performance related and can be less restrictive for low volume roads than for higher volume roads.
(2) Aggregate requirements (mostly for shape and angularity) are less restrictive as well. However, most Superpave mix designs under higher traffic loads require a certain 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.
(3) 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 included 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 in Table 1. Maps detailing the project locations may be found in Appendix A.

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[1] Although Superpave was the common name for this mix design process at the start of this research project, current convention is to call it Gyratory Mix Design. This was done to move away from the impression that Superpave is a product and toward its status as a mix design process.

Table 1

County	Location	Project Description
Scott	Y30 from junction IA 927 to junction IA 130	Overlay over crack-and-seat PCC
Mahaska	G29 from junction US 63 to junction T65	Overlay over cold-in-place recycled ACC
Cerro Gordo	S70 from junction US 18 to junction B47	Overlay over cold-in-place recycled ACC
Cerro Gordo	B60 from junction IA 107 to WCL Rockwell	Overlay over cold-in-place recycled ACC
Dubuque	IA 966 from ECL Centralia to junction US 20	Overlay over rubblized PCC
Cass	N16 from NCL Atlantic to junction I-80	Overlay over composite pavement
Cass	M56 from junction IA 48 to SCL Lewis	Paving and widening over old ACC
Louisa	X17 from junction 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 based on the reported traffic levels and truck percentages. As a result, the contemporary (1997) specification for 300,000 Equivalent Single Axel Loads (ESALs) or less was used in all of the mix design requirements[2]. In the years following the letting of these projects, the specified values for aggregate gradation and mix compaction were eased (especially for low-volume roads).

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 (Reference 1). However, to gain experience with Superpave, the original, more stringent requirements were enforced for these projects.

INDIVIDUAL PROJECT DETAILS

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). They include the following items:

A project description with the existing pavement dimensions and conditions
General design considerations for the pavement
Initial mix design details[3]
Mix design changes and challenges
Construction issues
Performance to-date

A short note on units is warranted. Superpave mix design work is currently performed in SI (metric) units. However, the projects and associated plans were done with English units. Also, some of the testing results are in English units and some in SI. It was not feasible in this report to convert everything to one set of units or the other, or provide dual units, while maintaining clarity in the writing. Although there is a mix of units, the majority of distance and thickness units are in the English system. Where stations are used, they are the English, 100-foot stations.

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[2] For an explanation, see the brief discussion of Superpave mix design requirements that is provided in Appendix B.

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

Scott County Road Y30

Project Description

This first project length was approximately 7 miles. The original road was constructed with 6-inch 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 22-feet with 6-foot 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 ACC overlay was placed in three lifts with a total (nominal) thickness of five inches. Average annual daily traffic (AADT) on Y30 in 1994 was 690 vehicles per day (vpd) with 20 percent trucks. A small portion of the route passed over I-80 and provided access to a truck stop at the exit. So this portion of the route was expected to experience higher truck traffic than the rest (the truck stop was shut down and removed soon after paving took place).

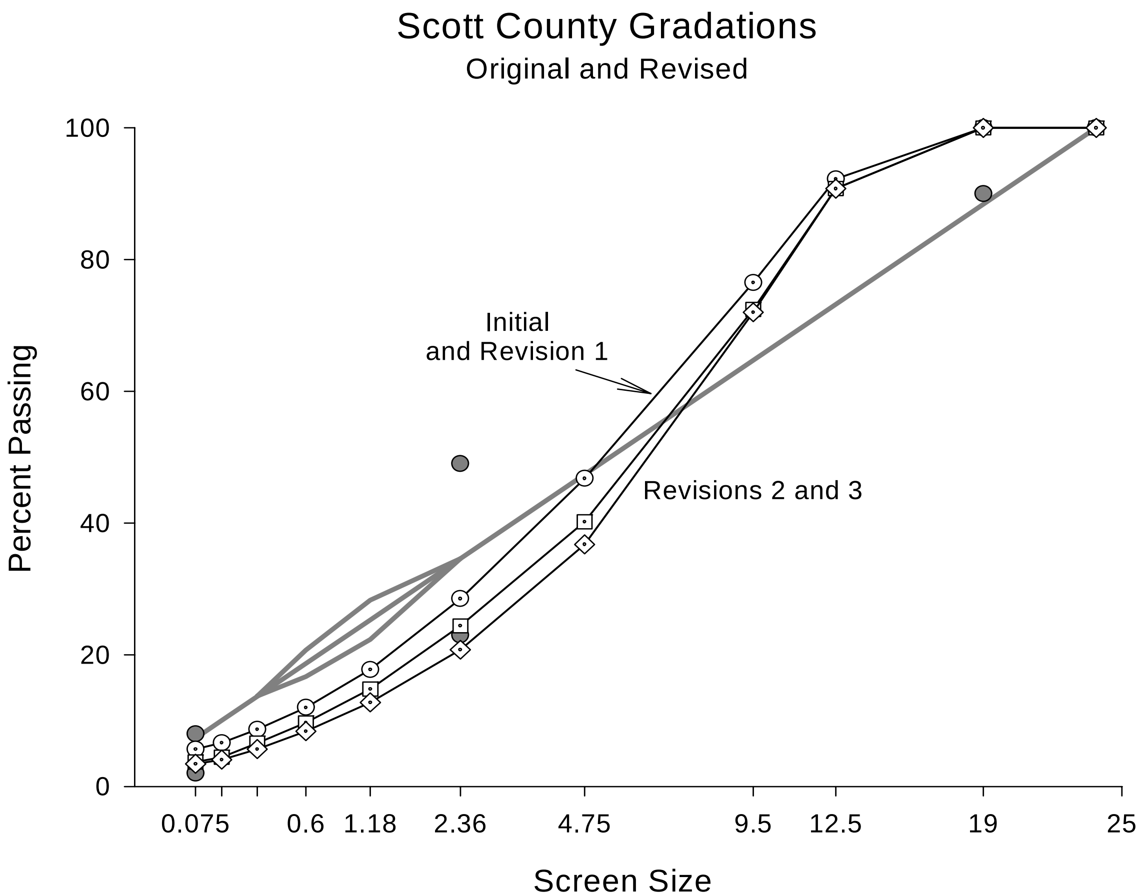
Mix Design Details

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 2 miles of the lowest lift on the south end of the project.

Gradation: Figure 1 shows the power curves[4] 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 binder, higher Voids in the Mineral Aggregate (VMA), and greater 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.

[4] For an explanation of the gradation terms and graphs, see Appendix B.

Figure 1

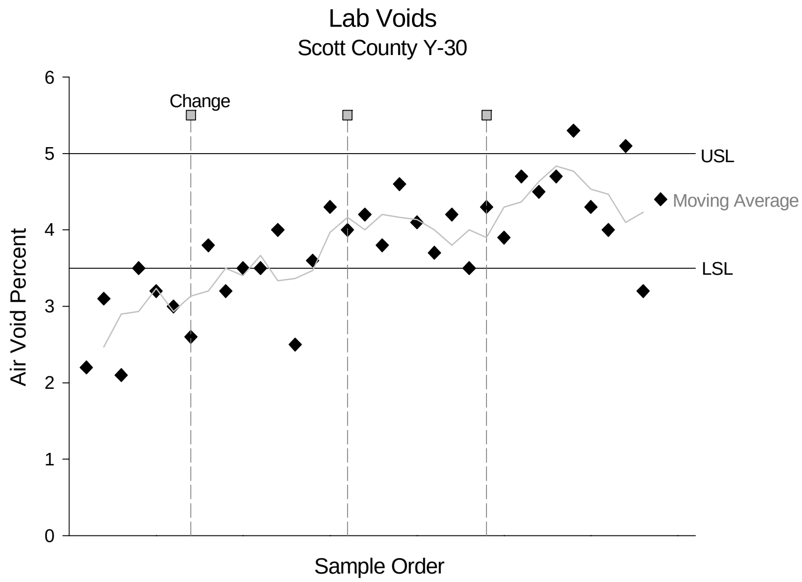


Mix Design Changes and Challenges

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 binder content from 5.0 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.

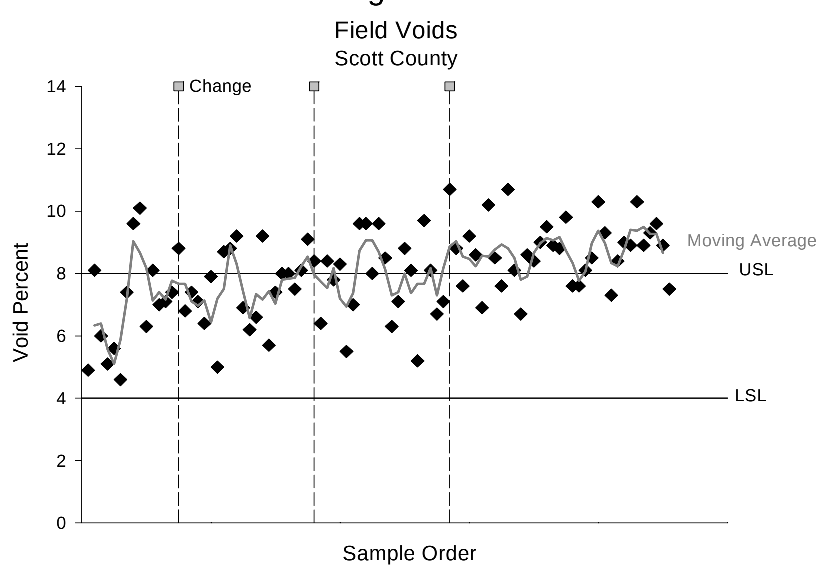
Figure 2 shows the percentage of lab voids recorded during this project. The upper and lower specification limits (USL and LSL respectively) are shown. Generally it is the value of the moving average which determines the timing of a mix design change. The data clearly show the efforts to increase the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

Figure 2



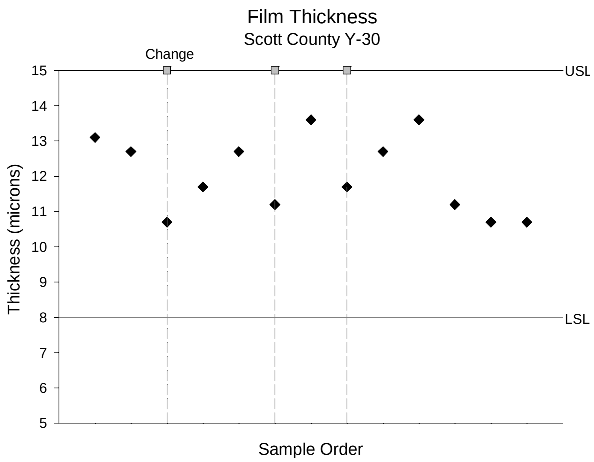
The term Field Voids refers to the void content measured in samples cored from the road after paving. Figure 3 shows the data from this project. While the lab voids began too low and progressed into the specified zone with adjustments to the mix; the field voids began within specified limits and progressed above the upper limit. This upward trend in field voids may be an indication of the increasing difficulty of compacting an increasingly coarse mix.

Figure 3



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 was expected to have a positive effect on the load carrying capability of the pavement but probably also result in higher levels of thermal cracking.

Construction Issues

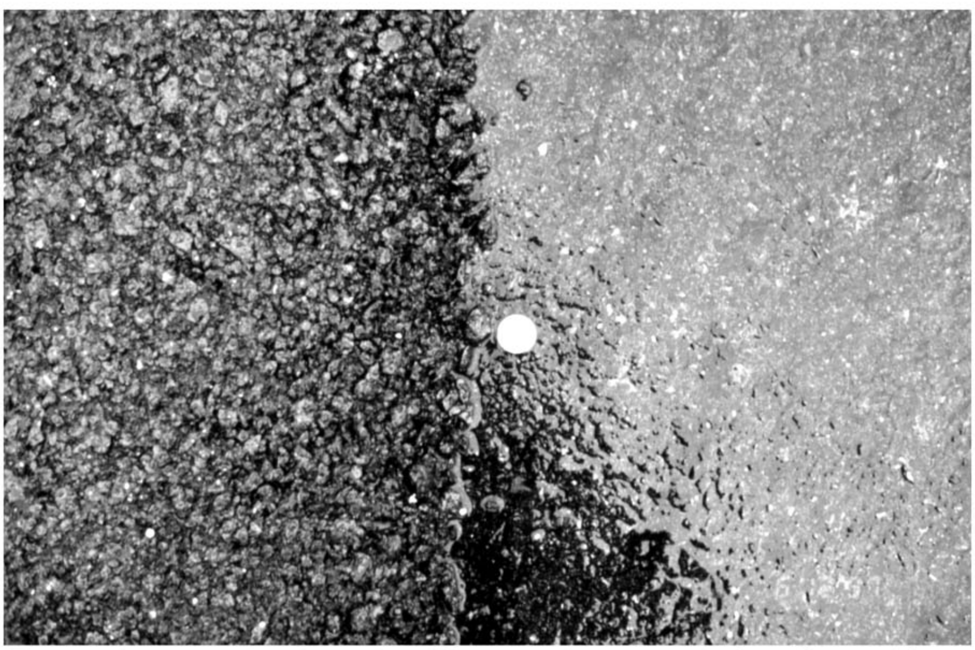
The majority of placement issues with this project had to do with stiffness and workability. This was because the contractor used 100 percent manufactured sand in the fine portion of the gradation. Compaction was difficult and required that the breakdown roller proceed immediately behind the paver. Handwork 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 colloquially 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 vs. 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.

Figure 5

Scott County Highway Y-30



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.

Performance

Road Rater results for this project are shown in Figures 6 and 7. The Road Rater provides a measurement of the structural support exhibited by a pavement. Figure 6 shows the structural data by station along the road while Figure 7 contains histograms by date of the same data. In Figure 6, the high values around station 130 are a result of the paving around the truck stop and on the bridge approaches. Figure 7 shows overall structural values over time. There is no significant evidence of any changes in structure values over time.

Figure 6

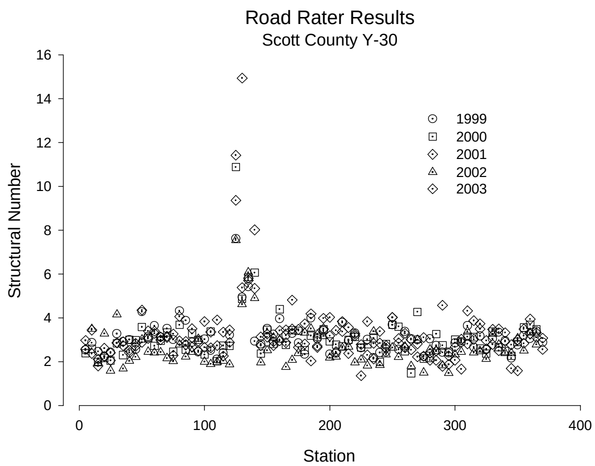


Figure 7

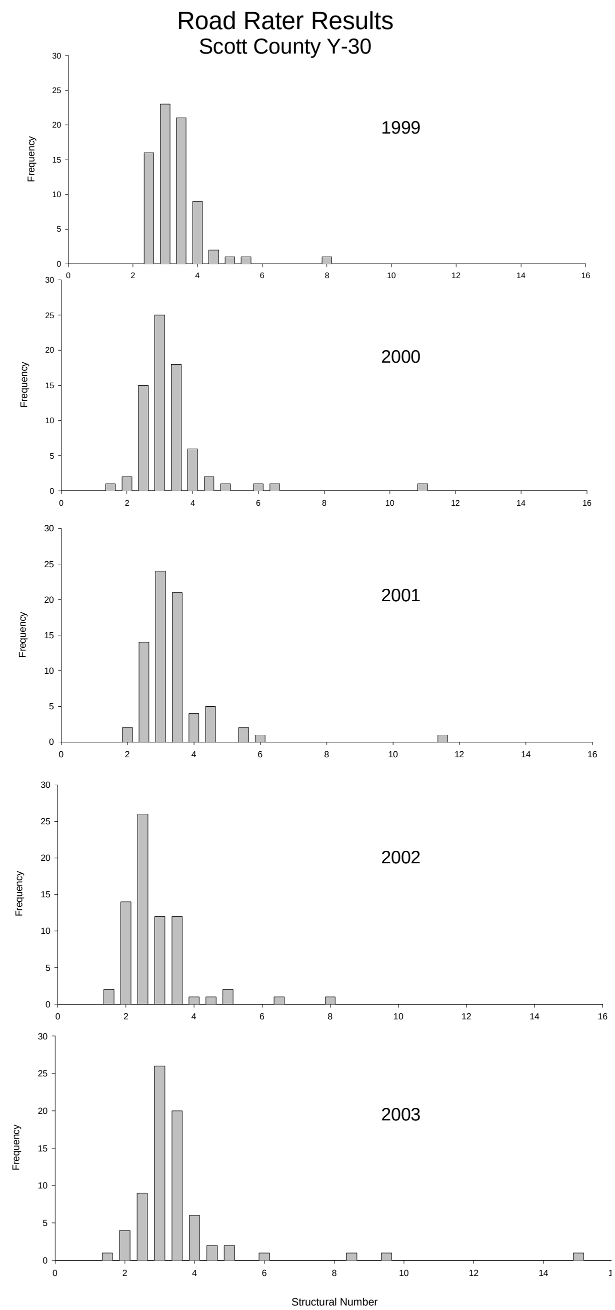
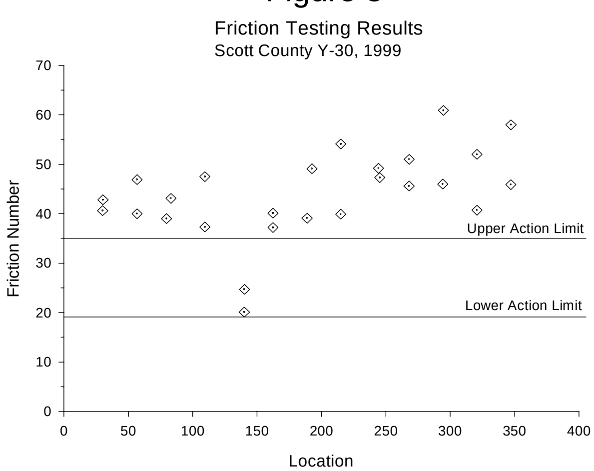


Figure 8 shows the results of friction testing on this project. There are lower limits for friction set in the Iowa DOT Policies and Procedures manual (Policy No. 600.01). Any result below 35 results in review by the assistant district engineer. Values less than 19 may merit installation of "Slippery When Wet" signs.

Figure 8



Two other important performance measures are smoothness and rutting. Smoothness is one of the main qualities that the traveling public cares about in a highway. Rough road can also deteriorate more quickly and have safety implications. Severe rutting can have significant safety implications.

The smoothness and rutting measurements for these projects were performed with a "South Dakota" profilometer. This consists of laser distance indicators mounted on the front bumper of a van. Measurements can be made with a variety of wavelengths and dense coverage, and at highway speeds.

Results for Scott county are shown in Figures 9 and 10. In both cases smaller numbers mean better performance.

Smoothness data are broken into inside and outside wheel-path data (crosses and dots respectively) plus an overall running average (line) using three samples per average. Most of the peaks in the smoothness data occur at bridges—the large one at approximately 2.5 miles is the bridge and approaches for the overpass of I-80. Note that the inside and outside wheel-path average values are different. The inside wheel-path tends to be smoother because of added support in the center of the pavement.

Rutting seems to be related to the location of at least the large bridge and approaches. This could place some doubt on the effectiveness of the asphalt additive. However, no detailed analysis has been performed on the short section of treated pavement. Also, until closure of the truck stop, there was a large amount of truck traffic in that short segment. Even there, the deepest of the ruts was just over 0.10 inch. As a rule-of-thumb, rutting is not considered significant until it is at least that deep.

Figure 9

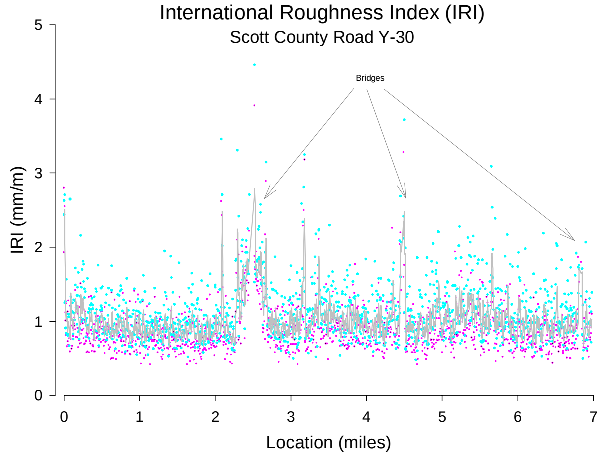
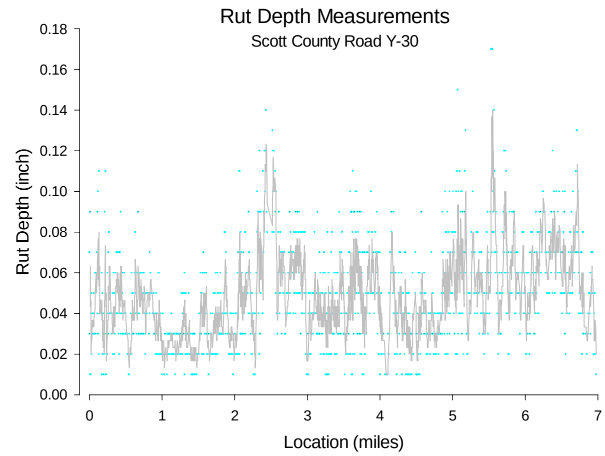


Figure 10



Crack surveys indicated no significant cracking during the first five years after placement. There was some cracking in the area around the truck stop during the second year. And some transverse cracks showed up in the first 0.5 km on the south end of the project. Other than that, there was insufficient cracking to warrant a detailed survey.

Note on Crack Surveys

Three basic types of cracks are discussed in this report: transverse cracks, longitudinal cracks, and fatigue-type cracking.

Transverse cracks are often the result of thermal effects or reflection of cracks from the underlying pavement. Since most of these projects (with the exception of Cass county) were built over rubblized or crack-and-seat concrete pavements, or cold-in-place recycled ACC pavement, any transverse cracks are likely to be the result of temperature effects. One of the main intents in developing the Superpave mix design specifications was to minimize thermally induced cracking of the pavement. Use of performance graded binders has resulted in a large decrease in the amount of thermal transverse cracking.

Longitudinal cracking and fatigue-type cracking (and sometimes associated rutting) tend to imply weak subgrade rather than a distress related to pavement performance. Fatigue-type cracking tended in these projects to occur in the wheel-paths and longitudinal cracks tended to occur in wheel-paths and along the center joint. Center joint cracking is an area of research in its own right, outside of the scope of this project; So centerline cracks were ignored for the purposes of this research.

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 4.5 miles. The original pavement consisted of six inches asphalt treated base overlaid with two inches ACC. This existing pavement was recycled using cold-in-place recycling to a depth of approximately four inches then overlaid with nominally three inches of ACC in two lifts. Several areas had localized problems with poor subgrades and pavement distress. These were addressed with full depth ACC patching and strengthening courses. Subdrains were also installed as part of the project.

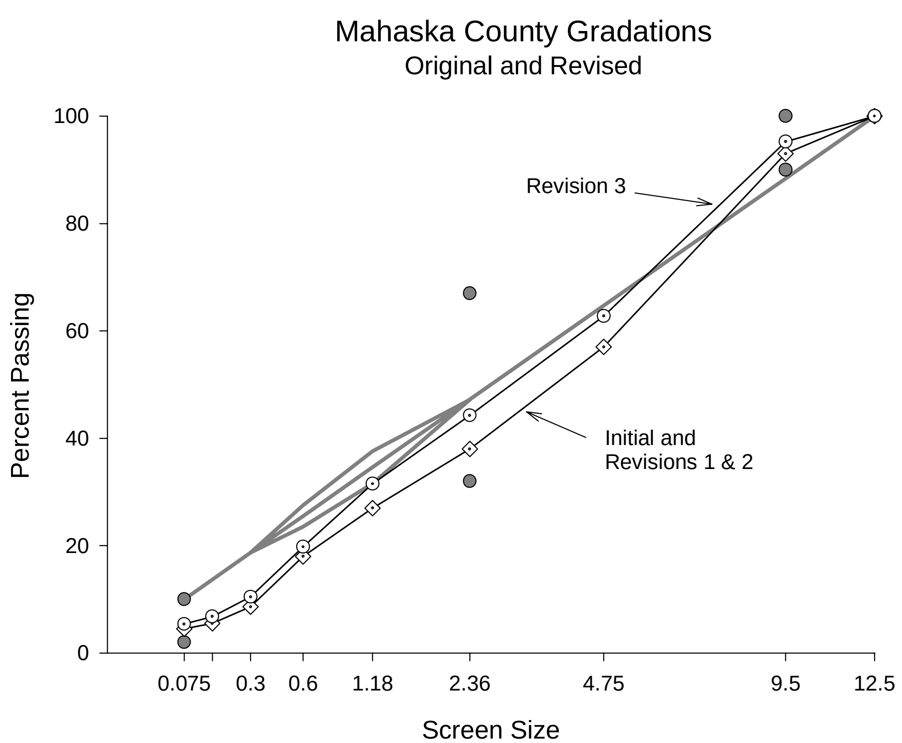
Design Considerations

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 11 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 11



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 11. 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 overshadowed any effect.

Graphs of the void data are shown in Figures 12 and 13. 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, especially lift thickness.

Figure 12

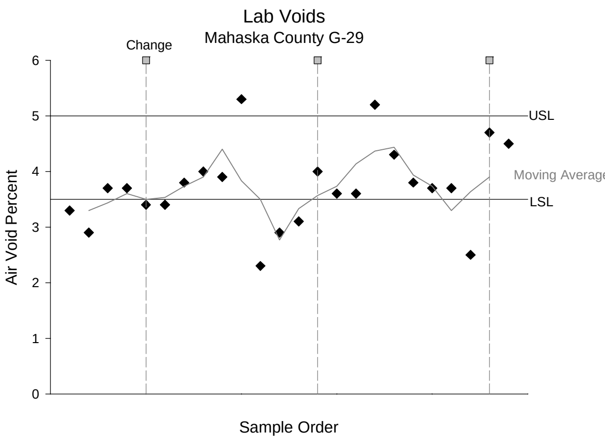
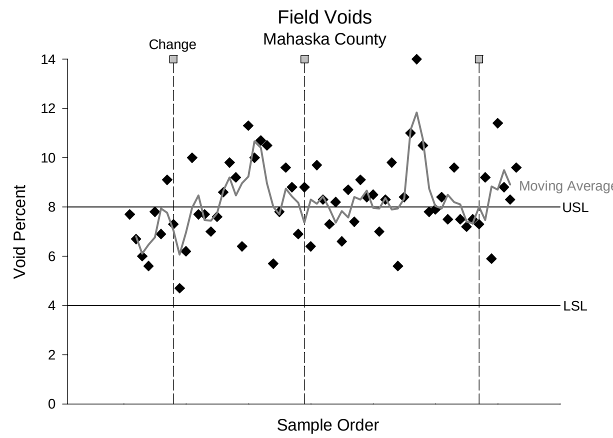
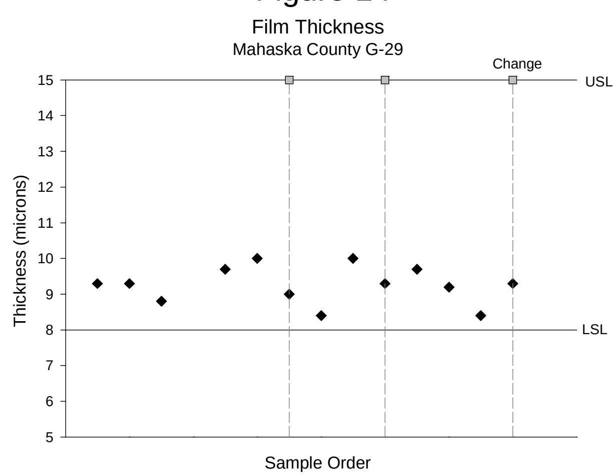


Figure 13



Film thicknesses (Figure 14) 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 41) - a large and fine mix. For a discussion of mix sizes see Appendix B.

Figure 14



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. A few examples are listed below:

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.

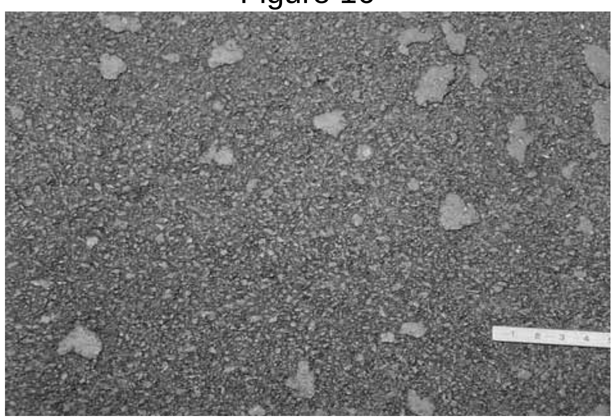
Cold-in-place recycling did not adequately provide crown and cross section correction to the road bed in some locations. These corrections were left to the paving operation. This resulted in lifts in some locations that exceeded four inches in thickness (for a total pavement thickness on the order of eight inches). Many of the excessively high field void values are likely due to poor compaction in these thick lift areas.

There were no reports of problems with placement compared to a conventional mix. However, this project provided a good test of ACC pavement under unusual conditions. Photographs of some of the conditions are shown in Figures 15 and 16.

Figure 15

Rutting in the newly-placed first lift.

Figure 16



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

Performance

Graphs of Road Rater data are shown in Figures 17 and 18. Note the increased ratings with a gap at approximately station 140 and the overall increase in structural rating from approximately station 175 onward. In the former case, the gap is due to a bridge over the railroad tracks near Lacey and the increase is due to the pavement composition inside the city limits. In the latter case, the increase is most likely correlated strongly to excess pavement thickness. The histograms in Figure 18 show no evidence of a change in average structural ratings over time.

Figure 17

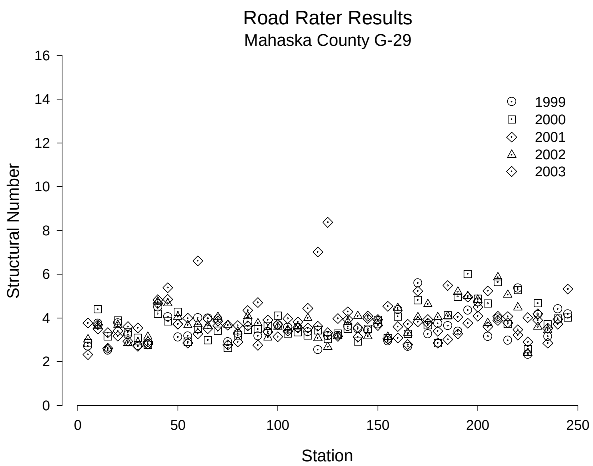
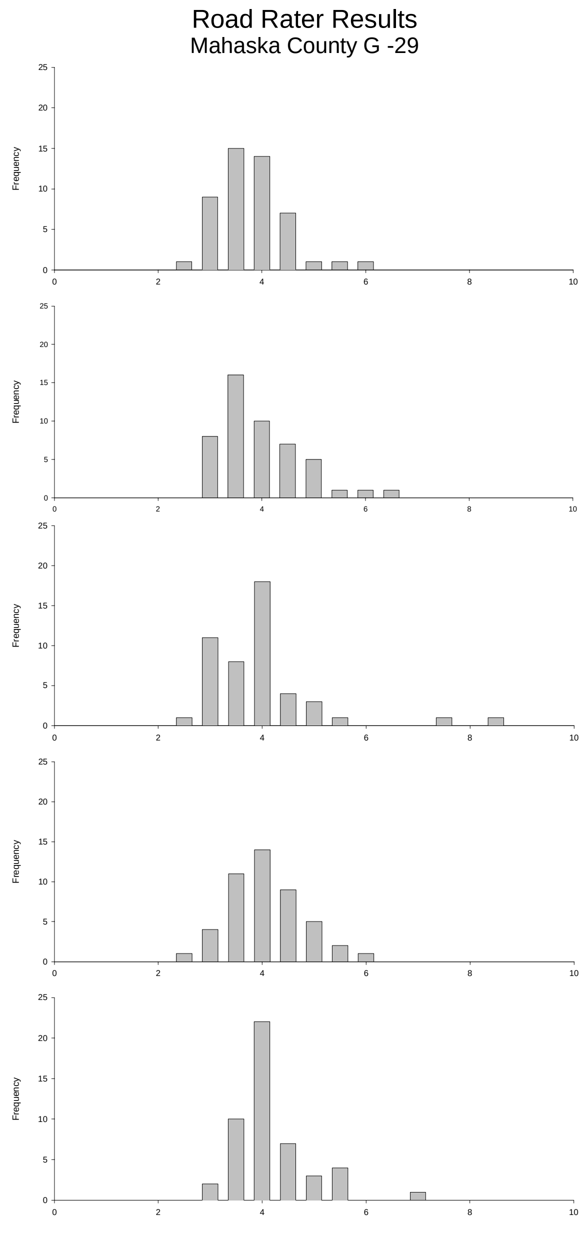
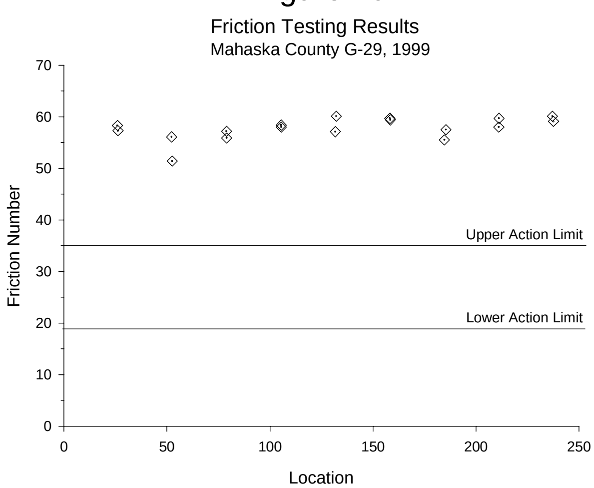


Figure 18

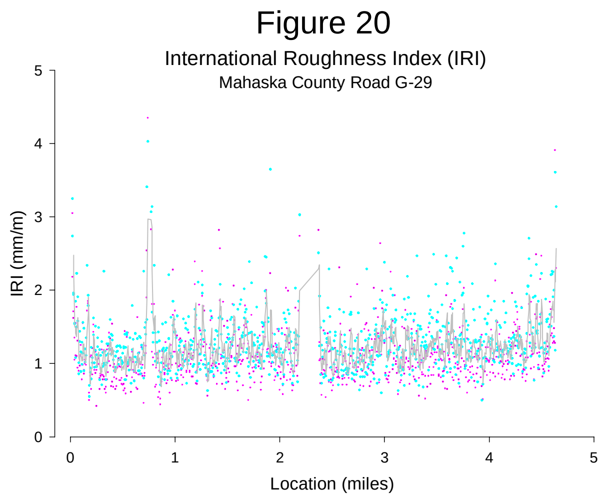


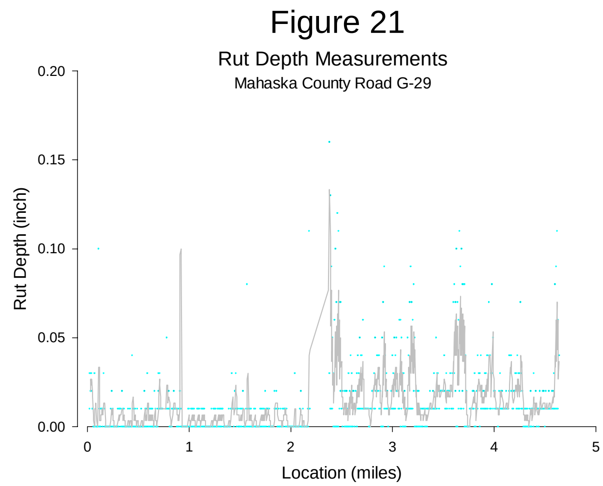
Friction data are shown in Figure 19. All of the values are well above the minimum thresholds.

Figure 19



Smoothness and rutting data are shown below in Figures 20 and 21. The two large peaks in the smoothness data represent two major bridges, one over the railroad tracks east of Lacey and the other a bridge with concrete approaches approximately two miles east of Lacey. Rut depth measurements strongly indicate the thickness change in the latter half of the project. Very thick lifts are more difficult to compact and compaction by traffic tends to occur in the wheel-paths as rutting. However, even here, the ruts are well below 0.1 inch.





Crack surveys showed no significant cracking for the first four years. By summer 2004, a few cracks had appeared. Of interest in this project are the transverse, full-width cracks that are presumably related to temperature effects. G-29 had just 14 of these cracks over the four-mile project. There were very few random cracks and no fatigue-type cracks in evidence.

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 6 inches of ACC, with a nominal width of 22 feet and variable width shoulders.

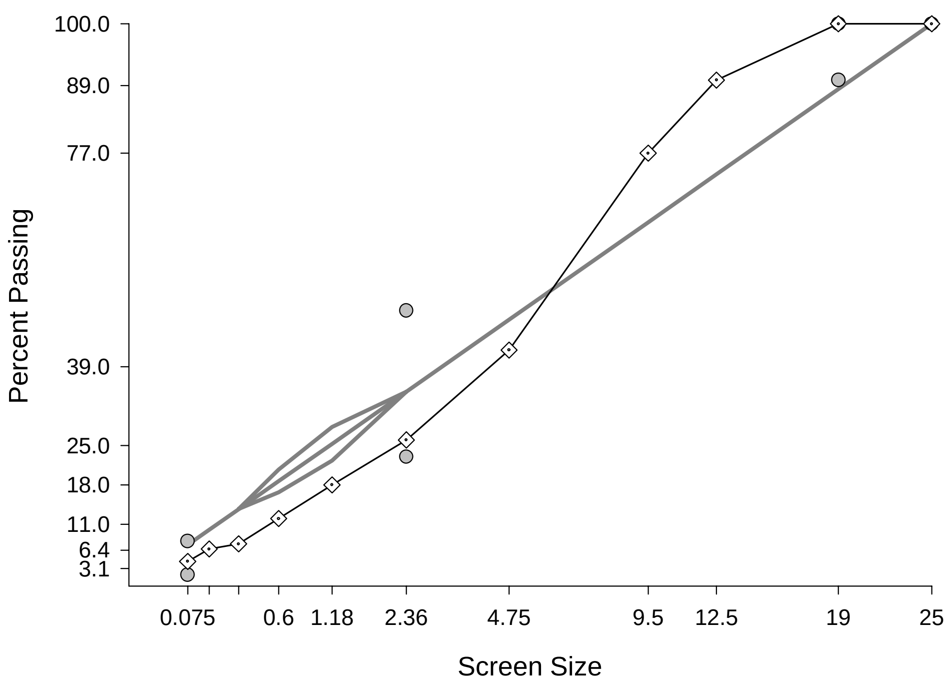
Design Considerations

The AADTs were 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 1.5 inches thick. The final road remained at nominally 22 feet wide but now with fixed 4-foot granular shoulders.

Mix Design Details

Because the two projects were paved at the same time with the same materials, the data will be evaluated as if from one project. These projects used a 19 mm mix. Figure 22 shows a graph of the gradation power curve for the mix.

Figure 22
Cerro Gordo County Gradation



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.

Figure 23

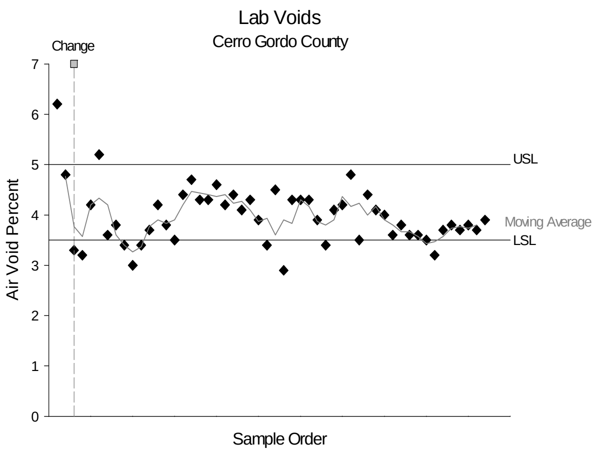
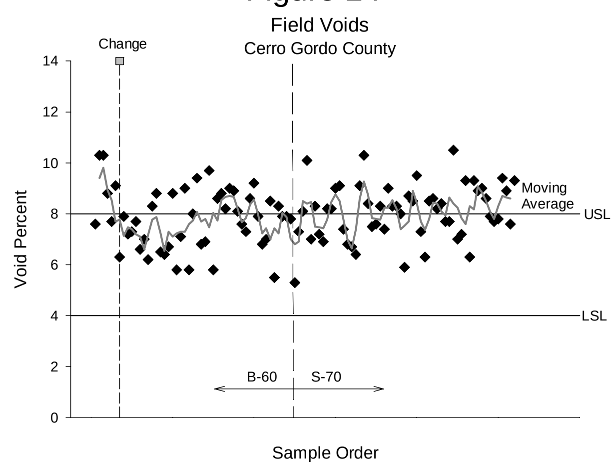


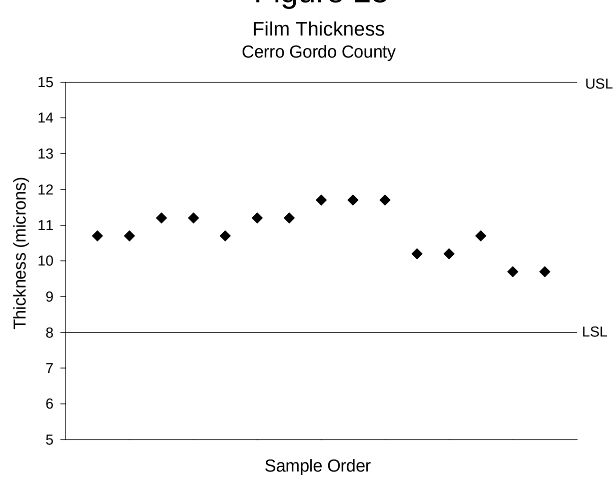
Figure 24



Field voids were distributed around the upper limit. See Figures 23 and 24. Film thicknesses (Figure 25) were within limits throughout both projects.

The mix design change marked on the graphs near the beginning was due to high void values (both lab and field). If those initial data points are not included in the analysis, the S-70 field voids average slightly higher than those from B-60.

Figure 25



Construction Issues

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

Performance

Graphs of Road Rater data are shown in Figures 26 and 27. Though the paving projects used the same mix and were paved one immediately after the other, there is a significant difference between the two (averaging about 0.6 structural number higher for the B-60 portion of the project. There is also a larger variation in the data from S-70.

Road Rater data can be affected by subgrade, which could be the cause of the differences here, but the increase in variation of the data implies a different (or additional) cause. Review of the paving diary indicates that part of the surface course of the S-70 project was paved across the full width of the road as compare to the B-60 project which was paved one lane at a time. This could have resulted in less satisfactory compaction in the field. The lab and field voids shown in Figures 23 and 24 do indicate a lower level of compaction (higher field voids) in the latter project. That is to say, the lab voids decrease or remain steady while the field voids increased between the projects.

We've seen in several of the projects covered by this report that careful compaction is important, especially initial or break-down compaction. If full width paving is used, compaction efforts will probably need to be modified as well.

Figure 26

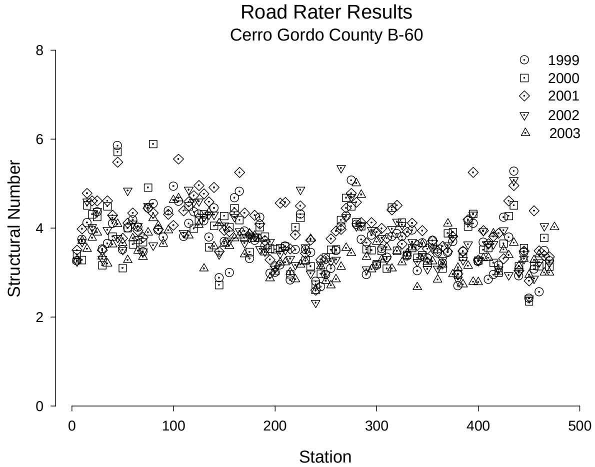
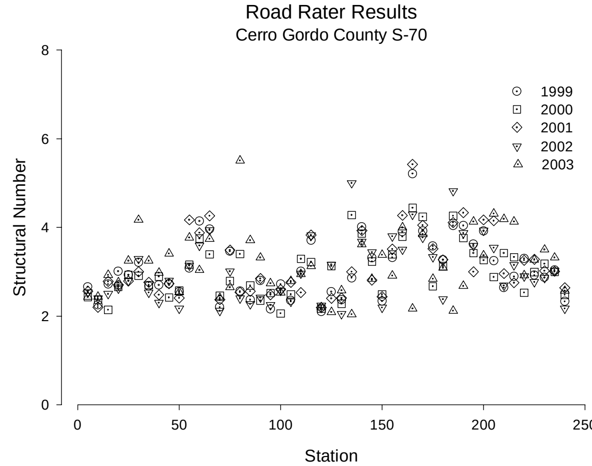


Figure 27



The histograms of Road Rater data (Figures 28 and 29) do not indicate any significant change in structural values over time. They do indicate a significant difference in structure between the two projects with structural numbers on B-60 averaging about 4 and on S-70 averaging about 3. This is most notable in the histograms.

Figure 28

Road Rater Results
Cerro Gordo County B - 60

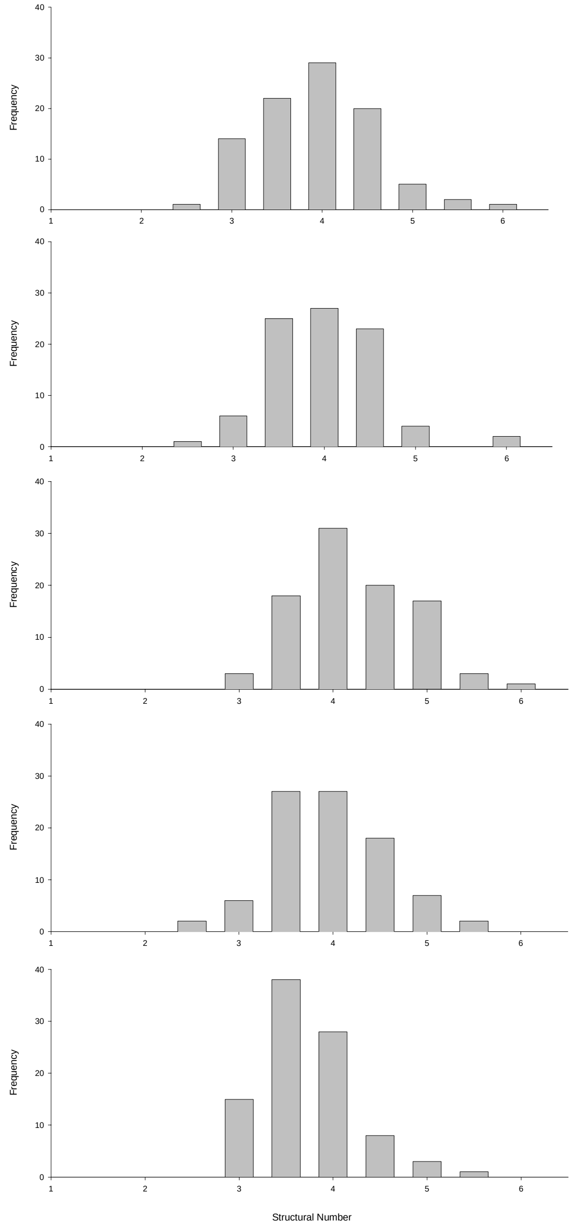
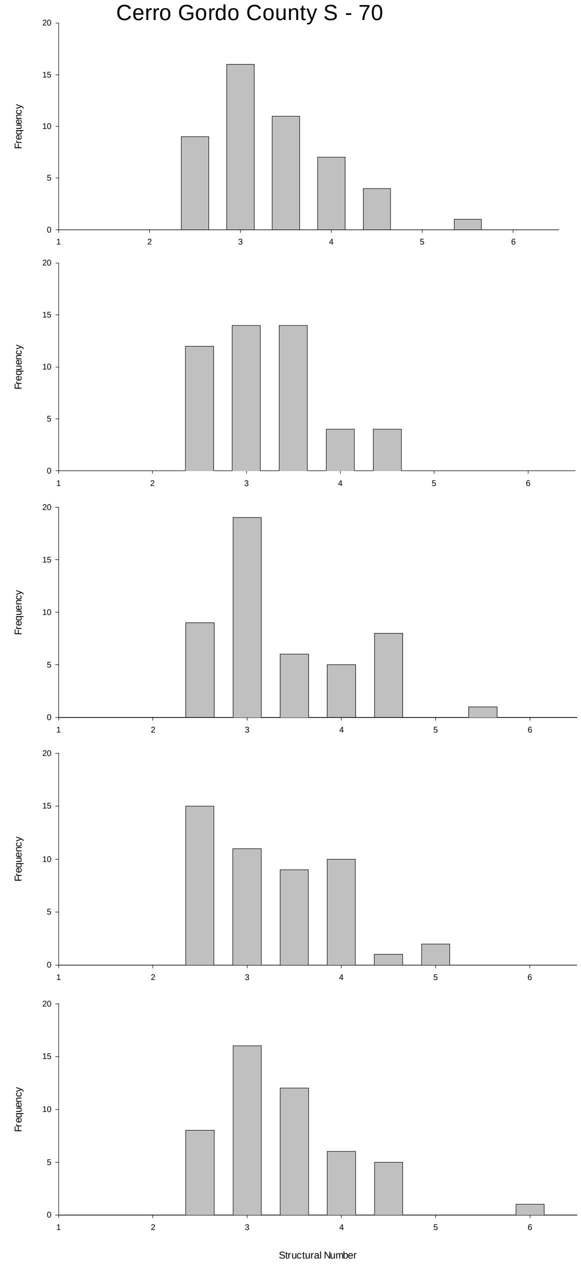


Figure 29

Road Rater Results
Cerro Gordo County S - 70



There was no significant difference in the smoothness data between the two projects (Figures 30 and 31). As before, the spikes visible in the data involve bridges and intersections.

Rutting and crack data present a more complex picture. In the project on B-60, other than some minor cracking on bridge approaches, there were no cracks visible at all. Rutting on this road was not significant either (Figures 32 and 33).

Figure 30

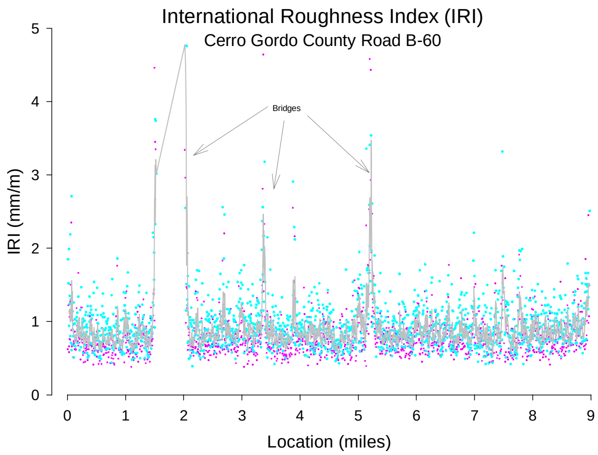


Figure 31

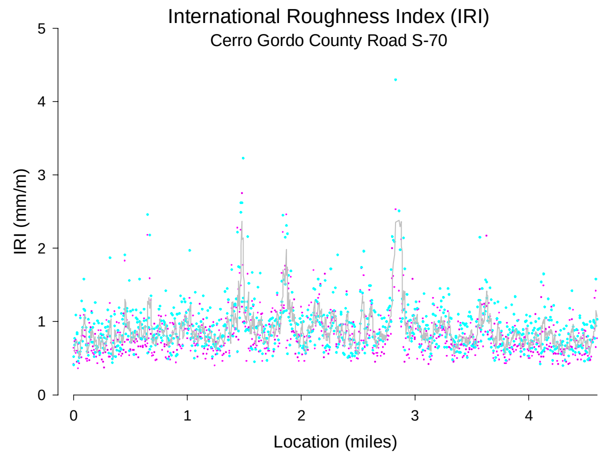


Figure 32

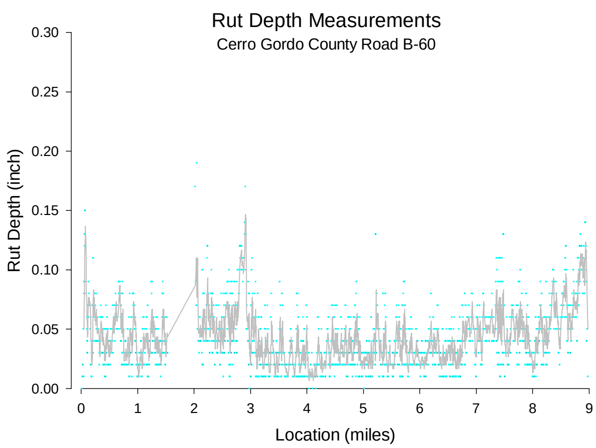
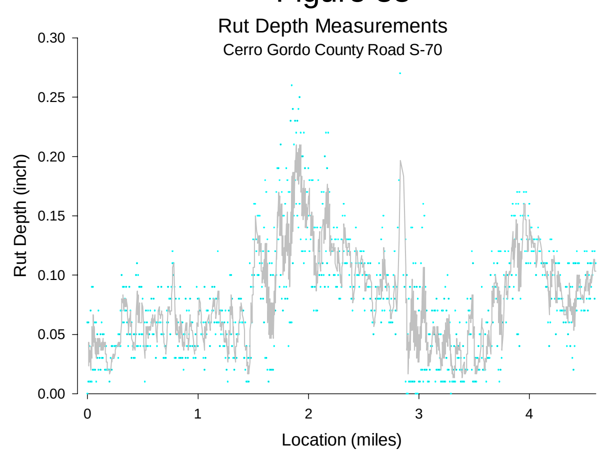


Figure 33



On S-70, there was some longitudinal cracking in the first half of the project. Most of the cracks were along the centerline (see Figure 34). In addition there were three full transverse cracks.

From approximately station 108 to 134 (corresponding to the peak in rutting visible in Figure 33), was a long relatively steep hill. This hill had lots of longitudinal cracking near the centerline. Photographs of the two situations are shown in Figures 34 and 35. We're not at all certain of the cause of this cracking. The rutting is expected because of the long hill, but the cracks represent a puzzle. Figure 36 shows a slightly modified plot of the Road Rater data. The two vertical grey lines indicate the location of the hill. One can see that the entire first half of the project has weaker values than the second half (where there were no cracks). But the hill doesn't seem to display lower structural values than the rest of the first half. The road from near this point north had the surface lift placed full-width (in Figure 35, no central joint is visible compared to Figure 34). All of the cracks in this project were routed prior to being filled with crack sealant.

Figure 34

Figure 35

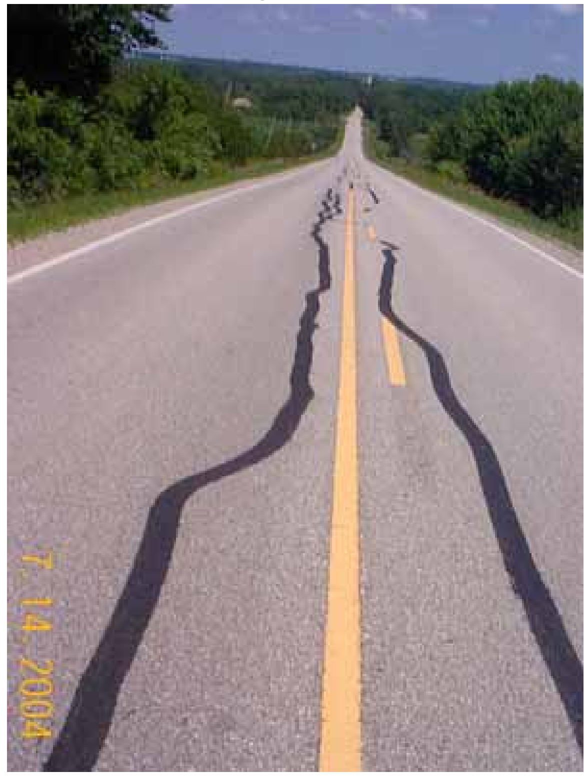
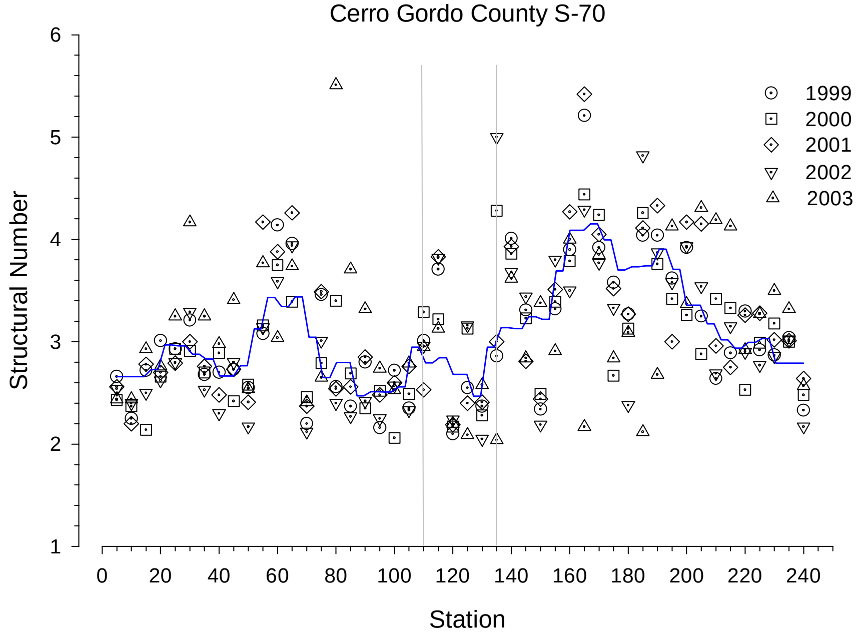


Figure 36

Road Rater Results

Cerro Gordo County S-70



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 10-inch PCC, 18 feet wide with a 1.5 inch ACC overlay. The overlay was milled off and the pavement was rubblized and covered with three inches 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. Subdrains were also installed as part of the project.

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 37 and 38 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 37

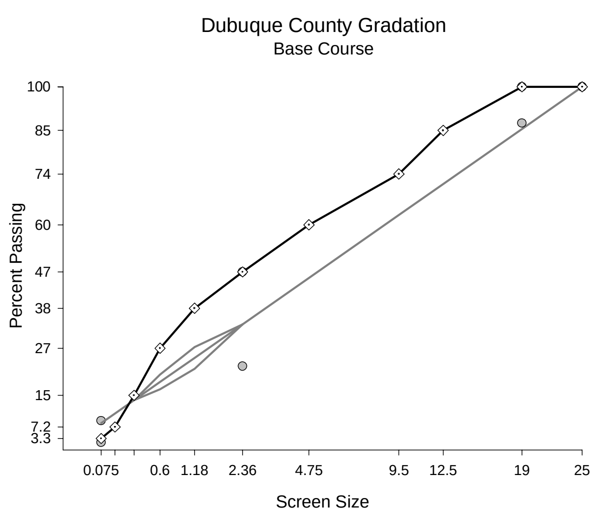
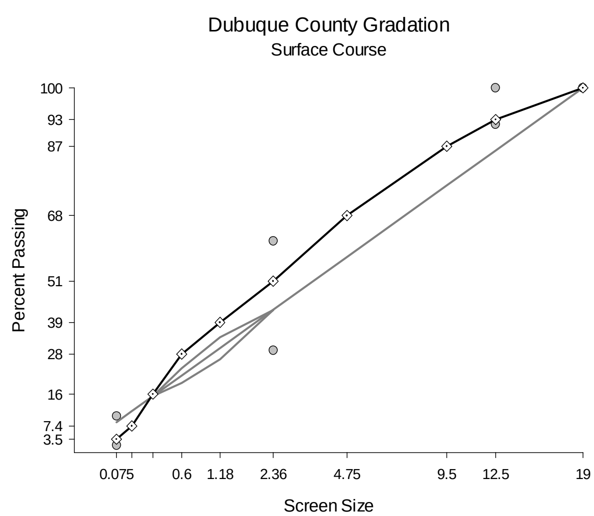


Figure 38



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 in this county. As with some of the other projects, lab voids were generally within specified limits and field voids ran high (see Figures 39 and 40). 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 39

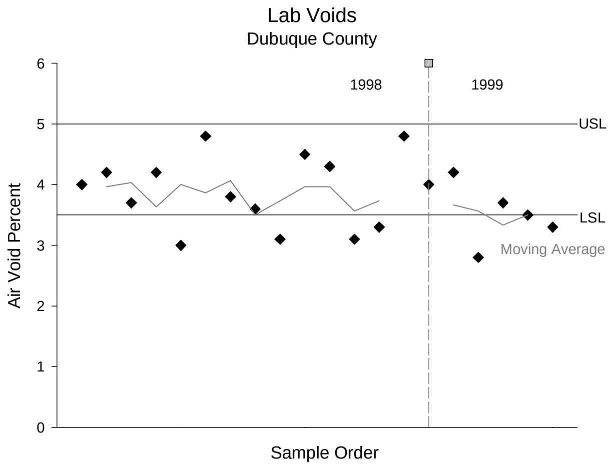
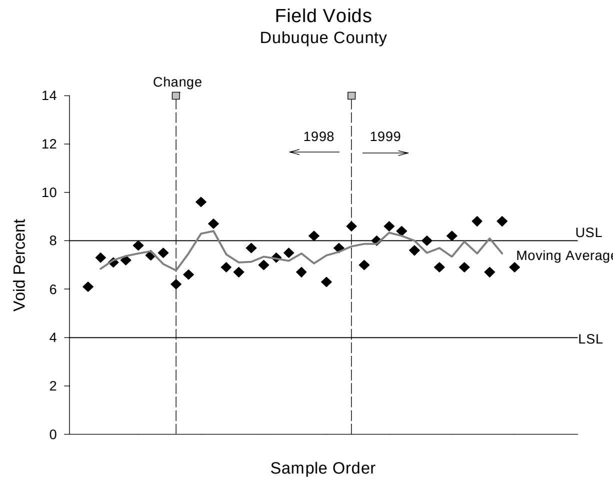
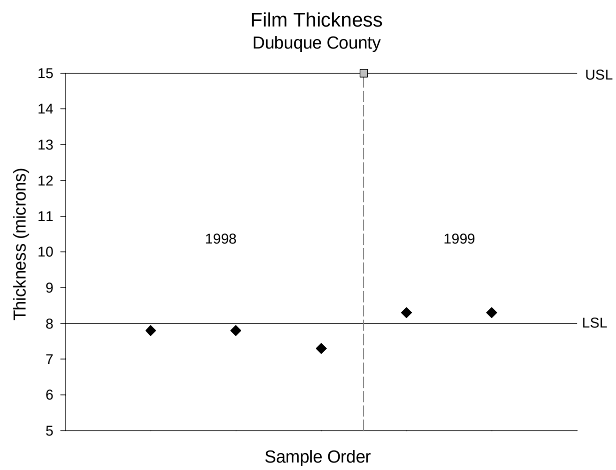


Figure 40



Film thickness data for this project are shown in Figure 41. These values are quite low, which is consistent with a very fine mix.

Figure 41



Construction Issues

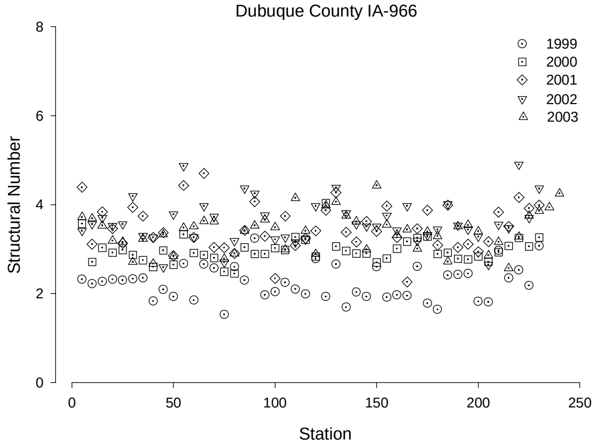
There were no issues involving the mix design mentioned by the contractor or county on this project. However, there were several placement issues having to do with the road width, poor subgrade and drainage.

Performance

Graphs of Road Rater data are shown in Figures 42 and 43.

Figure 42

Road Rater Results
Dubuque County IA-966



Note that the data for 1999 are significantly lower than those for the other years. This is because the data was obtained in May of that year, before the surface course had been placed. So the graph is showing rather directly the amount of support being provided by the top lift of ACC pavement.

Friction data (Figure 44) were nominally above the action limits.

Figure 44

Friction Testing Results
Dubuque County 966, 1999

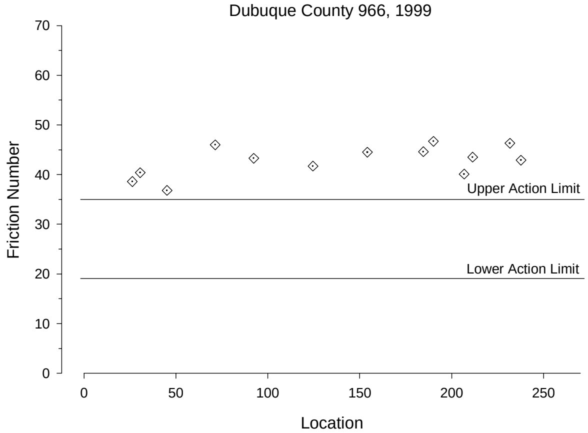
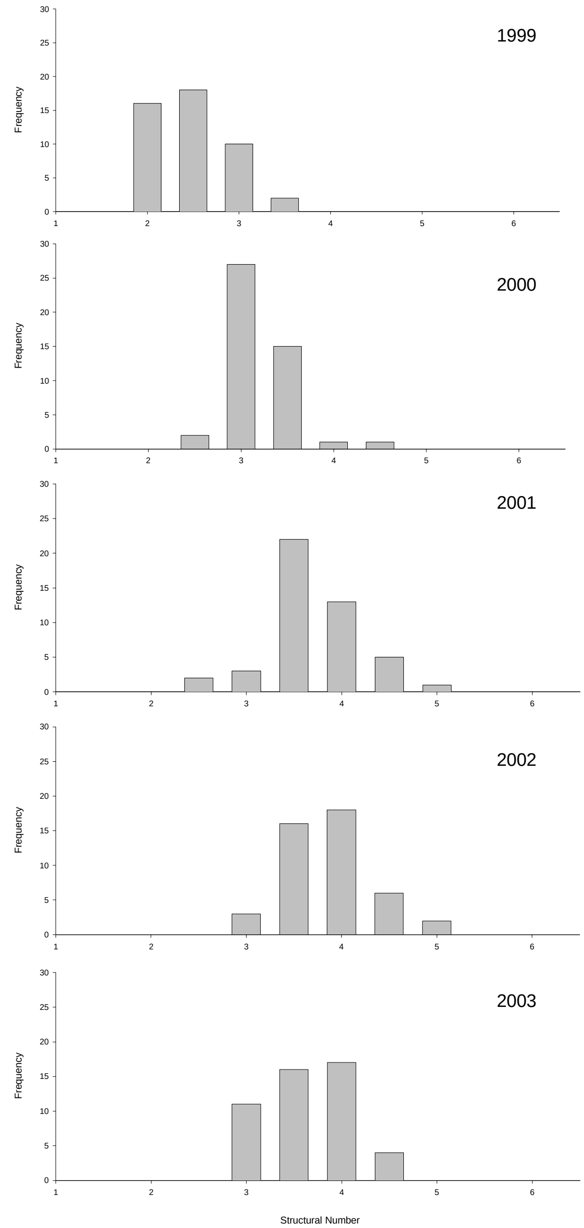
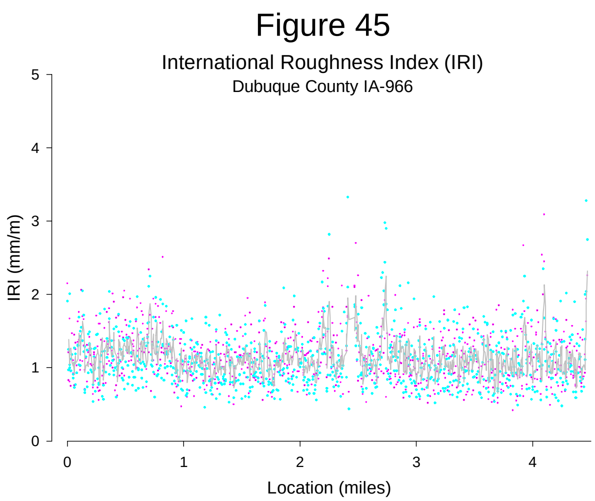


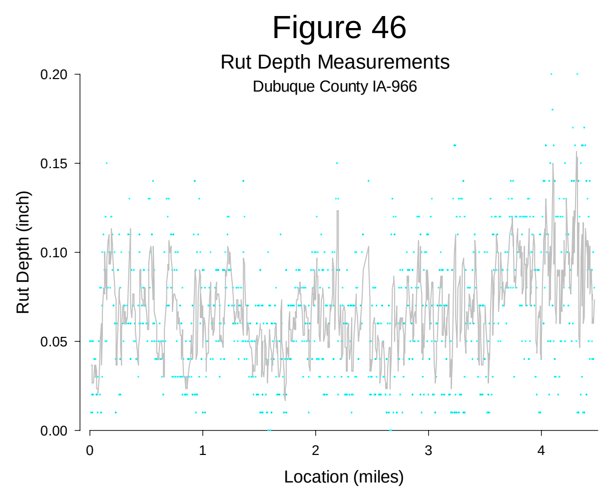
Figure 43

Road Rater Results
Dubuque County 966



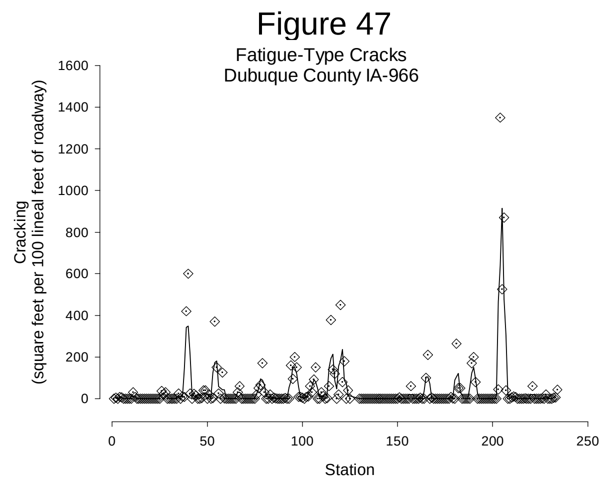
Smoothness and rutting on this project (Figures 45 and 46) were mostly unremarkable. Rutting was significantly worse in the eastern third of the project. This is likely due to heavy truck traffic and a hill along that portion as well as some areas with weak sub-grade (described below).

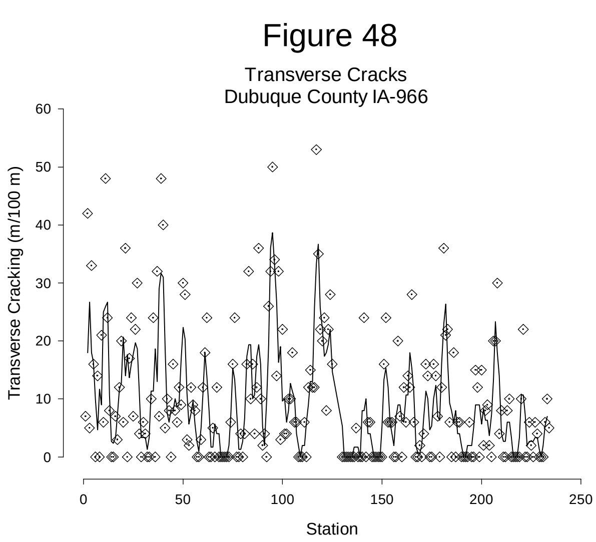


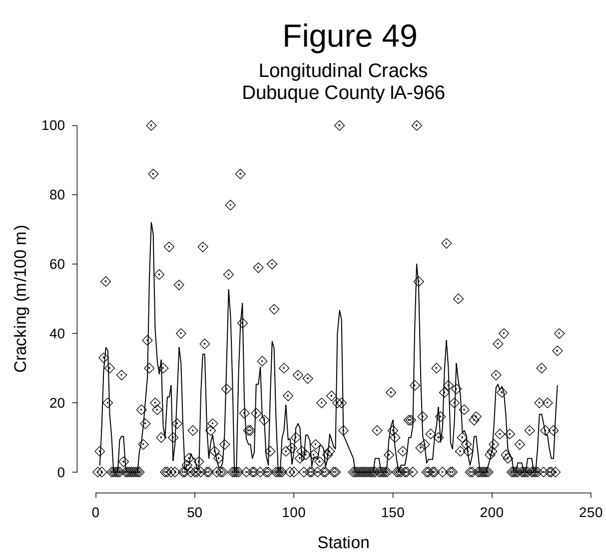


Very little cracking showed up in this project for the first four years. The data shown in Figures 47 to 49 are from a comprehensive crack survey performed in 2004.

Around station 121 are an aggregate/concrete plant and an petroleum storage/distribution facility. These plants (which were not located there at the time of paving) produce a large amount of heavy truck traffic. The larger amount of fatigue type cracking in this area is probably strongly related to that truck traffic, most of which travels to the east (up-station).







There are several important items to note in the fatigue crack data. The fatigue cracking graph is the only one showing a distinct pattern of cracked and non-cracked areas—the cracked areas are quite localized. This is consistent with the local environments. To the west of station 120 (down-station) is a long, steep hill (~1.5 miles, 6 percent grade). Trucks traveling up this hill do so at a very slow speed, which puts the pavement and subgrade under considerable stress. Cracked areas other than these two are likely to be areas of localized weak subgrade. The county excavated and replaced many weak spots at the time of paving. It's quite plausible to think that these localized fatigue-type cracks are related to additional areas with weak subgrades.

Cass County Road N16

Project Description

This project extended from just north of Atlantic north approximately six miles. The original pavement was six-inch PCC with a three-inch ACC overlay. It was to be overlaid with a two-inch 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.

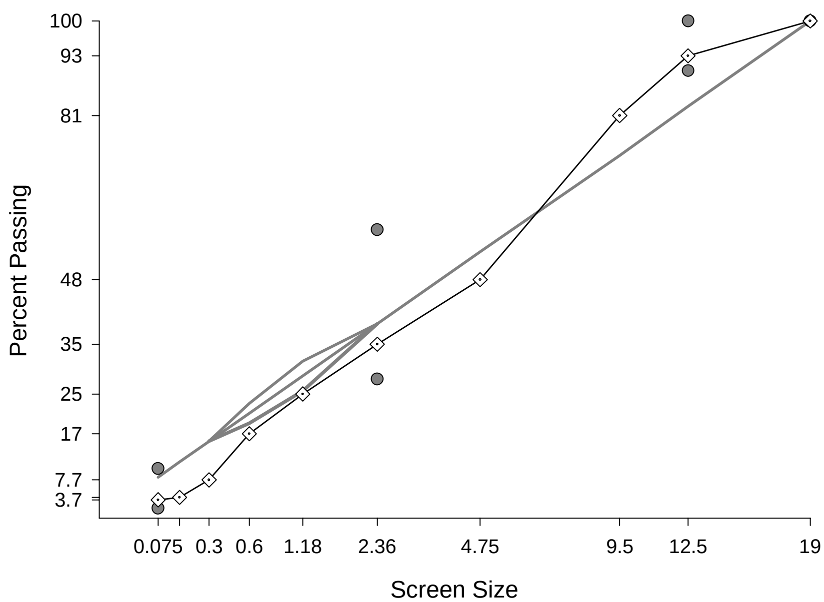
Mix Design Details

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.

The gradation power curve for this mix (Figure 50) 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.

Figure 50

Cass County N-16 Gradation



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 1.5 inch (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 1.5 inches thick with a resulting overlay thickness of 3 inches. The additional inch of ACC, when extended over the six mile project length, represented considerable added cost.

In the end, the county chose to place a nominal 0.75 inch thick scratch coat prior to the 2 inch overlay. This alleviated the problem at a somewhat lower cost.

Figure 51

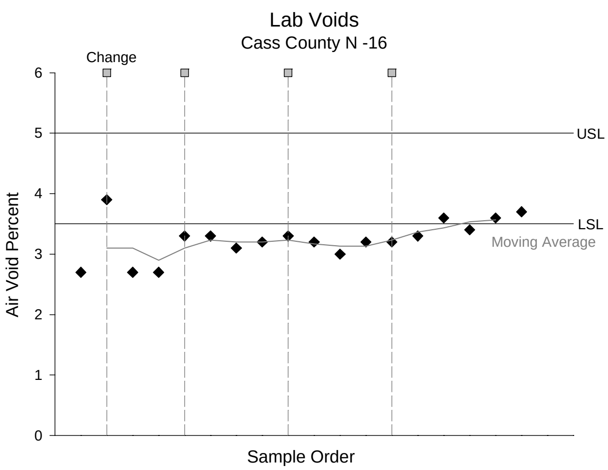
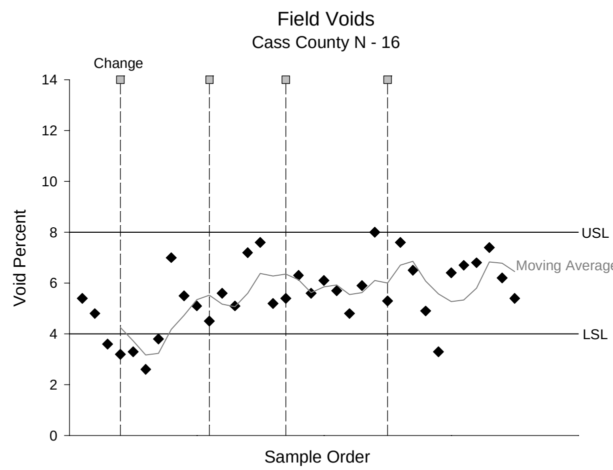


Figure 52



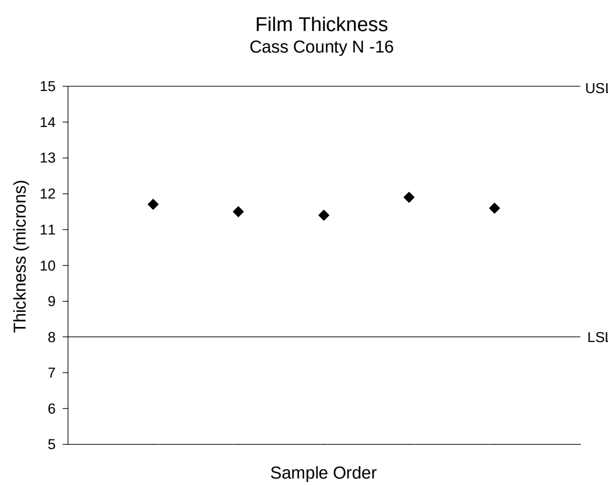
Mix Design Changes and Challenges

The lab voids were low throughout this project (see Figure 51). The AC percent was decreased by 0.1 in each of the three changes attempting to increase the lab voids. Field voids (Figure 52) remained consistently within specified limits after the first few samples and film thicknesses were unremarkable.

Construction Issues

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

Figure 53



Performance

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

Figure 54

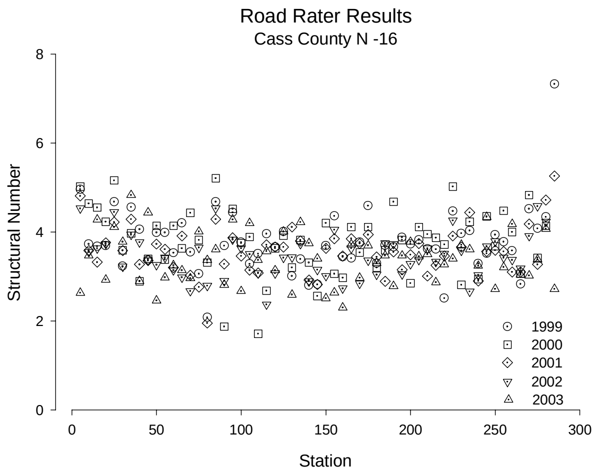
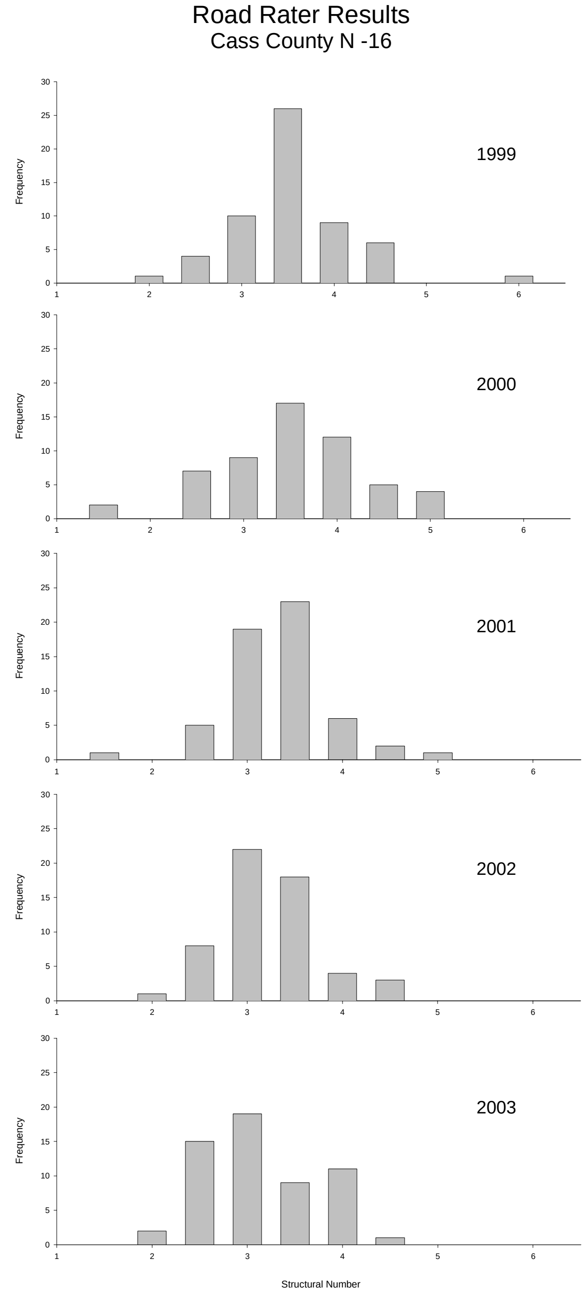


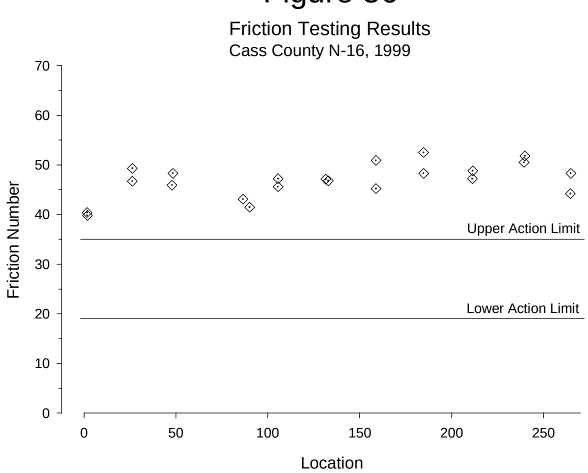
Figure 55



The Road Rater data are unremarkable. There is not a lot of variation in results along the length of the project, which is reasonable. The structure is being provided mostly by the underlying PCC pavement. The histograms indicate a slight downward trend in structural numbers over time.

Friction values were adequate and unremarkable.

Figure 56



Cass County Road M56

Project Description

This project started at the junction with IA 48 and extended 4.8 miles 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 granular sub-base, with a nominal width of 22 feet and variable width shoulders.

Design Considerations

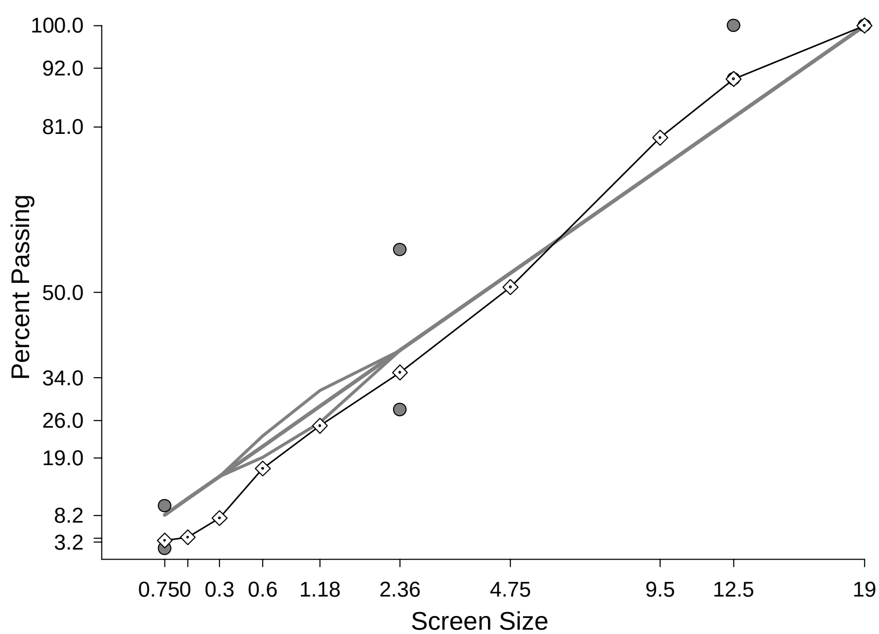
The AADT for this project was 470 vpd, with an unknown, but small, percentage of trucks. Current paving consisted of four inches of ACC placed in two equal lifts and widening to 26 feet. Some areas had severe deterioration due to drainage problems and construction truck traffic. These were excavated to six inches 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 0.6 mile 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 57 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 57

Cass County M-56 Gradation



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 binder content (see Figures 58 and 59). The changes were most likely made to increase lab voids.

Figure 58

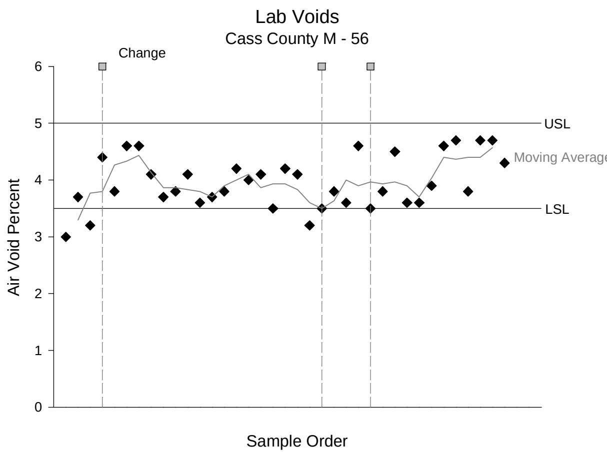
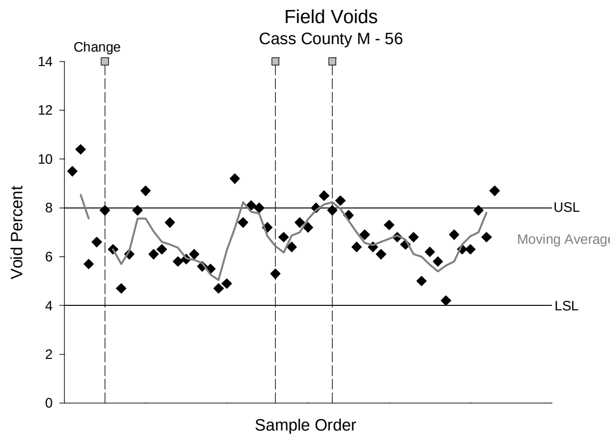
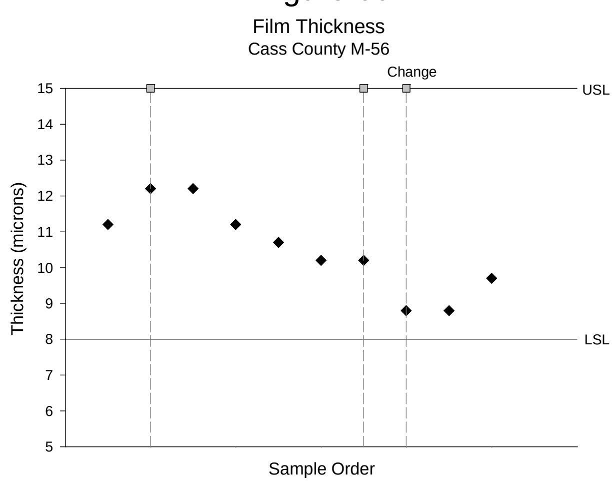


Figure 59



The film thickness varied considerably during this project, but remained within specifications (see Figure 60).

Figure 60



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 poor subgrade, high water and construction truck traffic (see photographs in Figure 61). The county engineer decided to excavate all of the distressed areas down to approximately six inches below grade and replace with two-inch minus stone.

Before the new pavement was placed, a 0.75 inch scratch coat was laid. 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.

Figure 61

Cass County Highway M-56

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

Performance

Road rater data are shown in Figures 62 and 63. The structural numbers over the length of the project and from one year to the next are quite stable.

Figure 62

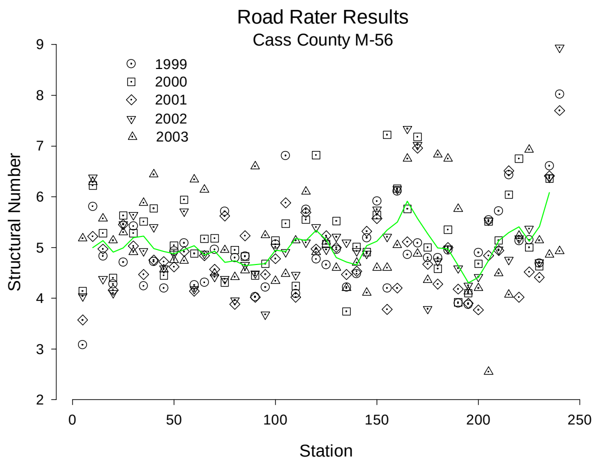


Figure 63

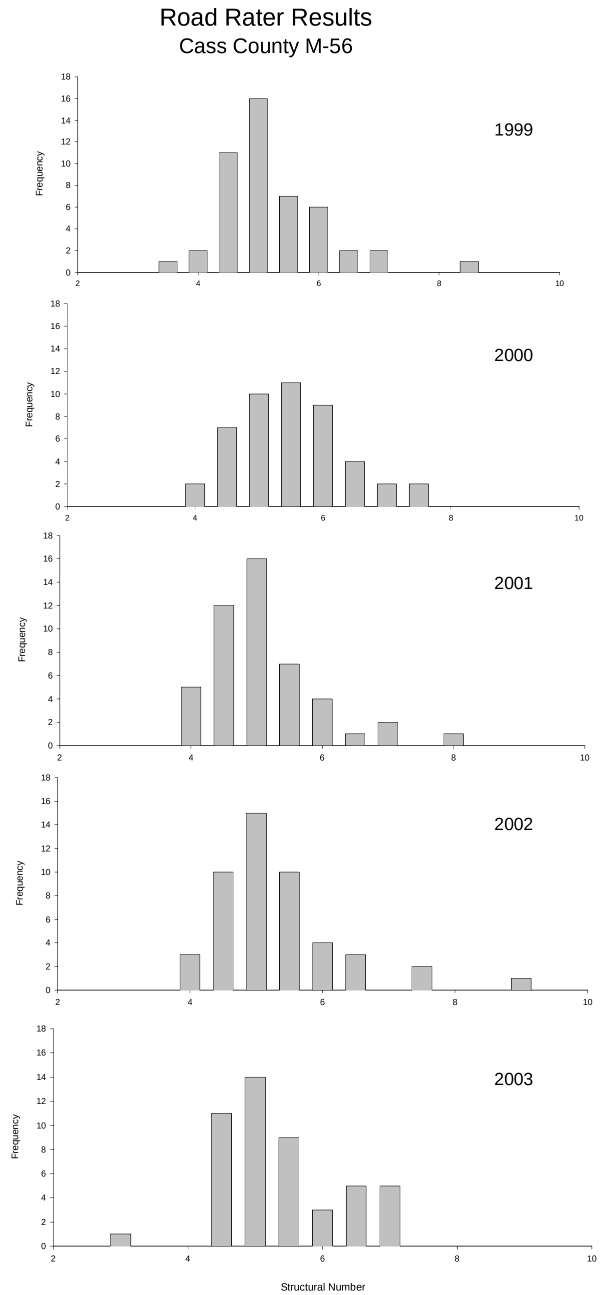
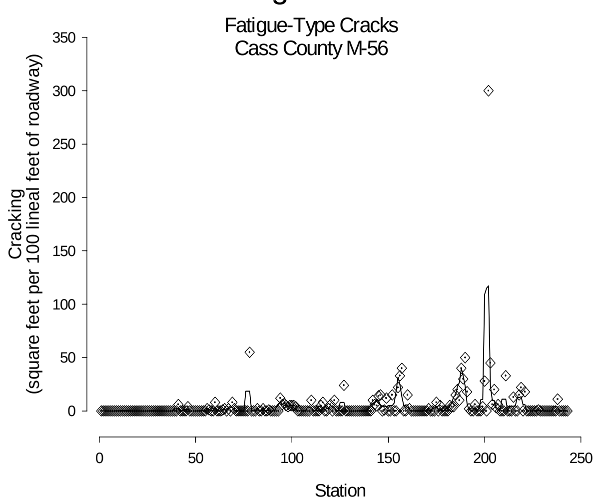


Figure 64



The Road Rater data are interesting when viewed in context with the fatigue-type crack survey data in Figure 64. They are shown above vertically aligned for easier comparison. The area around station 200 is most heavily cracked and that corresponds to the weak area shown in the Road Rater data. The curious part about this is that the area in question is also where the excavation, replacement, and fabric were used.

This project exhibited almost no cracking for the first three years after paving. After that, significant cracking developed over the course of a year.

The most significant type from the point of view of the Superpave mix design, is transverse cracking (shown in Figure 65). Along with feet of cracking per 100 feet of roadway, this graph shows the approximate spacing of transverse cracks. Transverse cracks caused by temperature effects often form in regular intervals. Looking at the length of these intervals gives a good measure of the quality of the pavement. In this case the majority of the transverse cracks occurred at an interval of approximately 100 feet. Just as a comparison, a very poorly performing asphalt pavement (that is to say, susceptible to thermal cracking), might have crack spacing of 15 to 20 feet. Note that this discussion is specifically covering just transverse cracking.

Figure 65

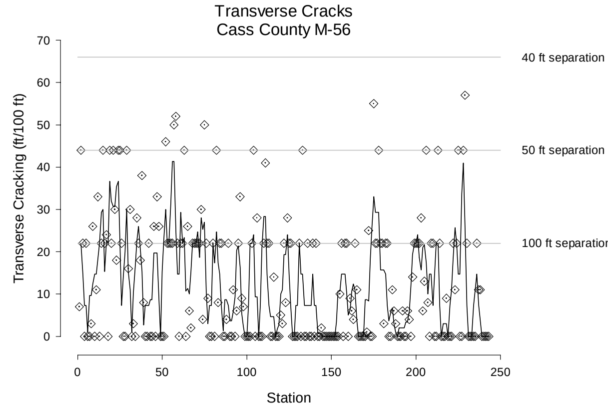
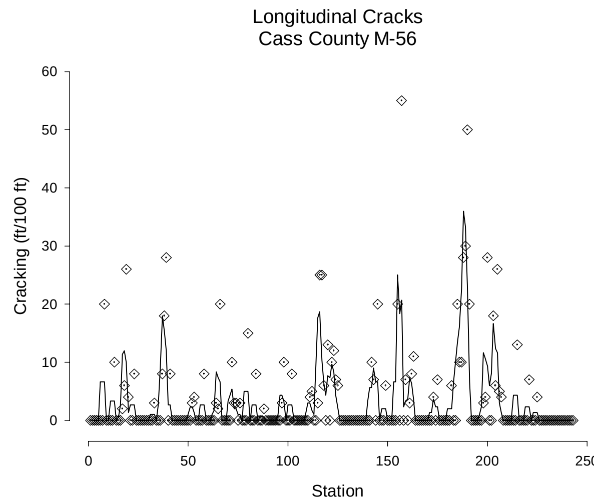


Figure 66



This pavement exhibited a large number of aggregate 'pop-outs', where aggregates on the surface have fractured and/or come loose from the ACC mixture. This was apparent throughout the length of the project (see Figures 67 and 68). From a visual examination, it appeared that all of the top sized aggregate on the surface had left the pavement. Cores from this pavement, along with the mix design containing aggregate sources (Appendix C) were evaluated by the IDOT geologists. The pop-outs are likely due to freeze-thaw susceptibility of some of the coarse aggregate. Performance of the pavement to-date appears unaffected.

Figure 67

Figure 68

Photographs of the pavement surface on Cass County M-56 showing “pop-outs” of large aggregate pieces.

Friction, smoothness and rut depth measurements (Figures 69 to 71) were unremarkable.

Figure 69

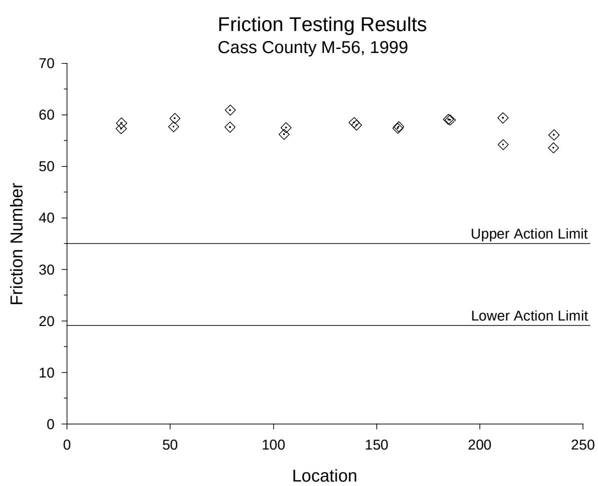


Figure 70

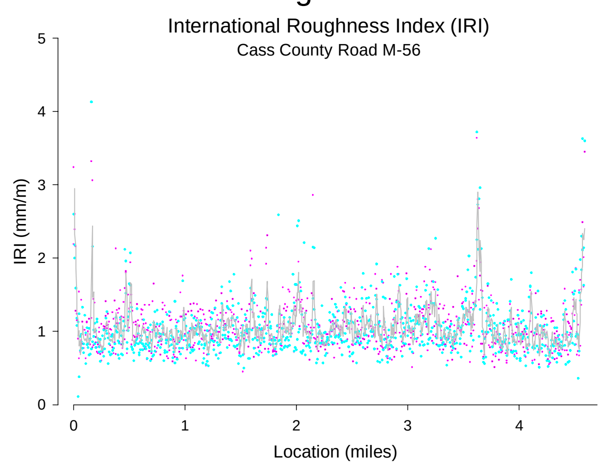
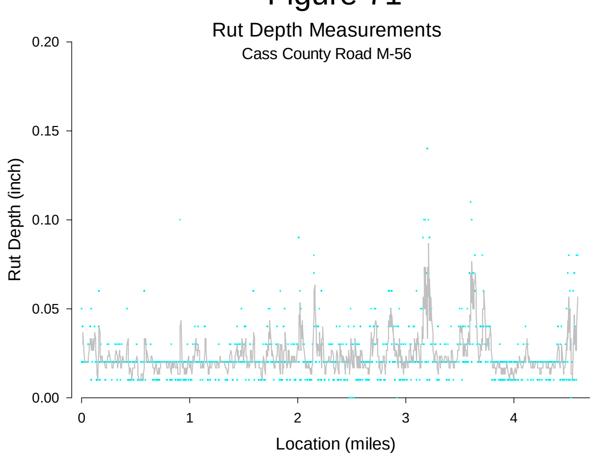


Figure 71



Louisa County Road X-17

Project Description

This project on X-17 began at the junction with Louisa County road G62 and extended northerly approximately 5.7 miles to just inside the corporate limits of Columbus City. The existing road consisted of six inches ACC, with a nominal width of 22 feet and variable width granular shoulders.

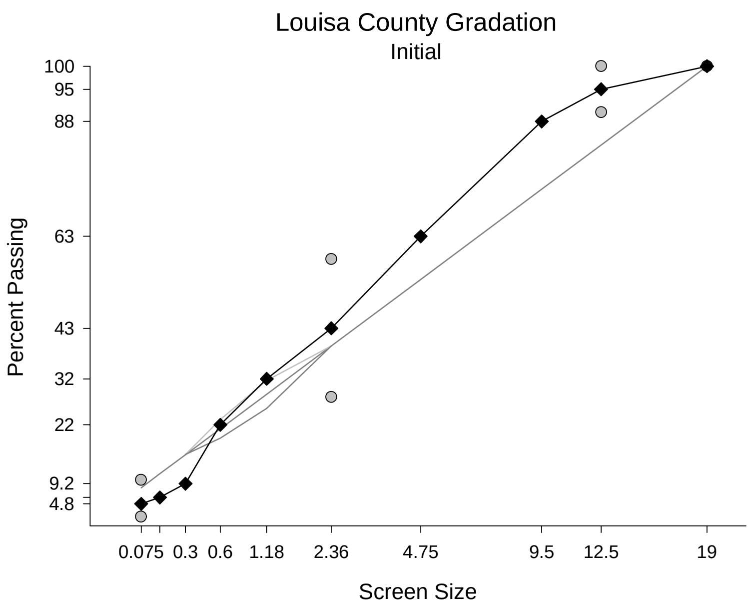
Design Considerations

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 3 inches of ACC placed in two lifts of 1.5 inches each. The final road remained at 22 feet wide with fixed 5-foot granular shoulders. For the last approximately 0.5 mile, 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 72 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 72



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 with placement. As a result, until the AC percentage was lowered, there were areas rich in AC that resulted in bleeding in places on the pavement, and void levels were extremely low (Figure 73). 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 74) started out low and migrated to the upper specification limit.

Figure 73

Air Voids

Louisa County X-17

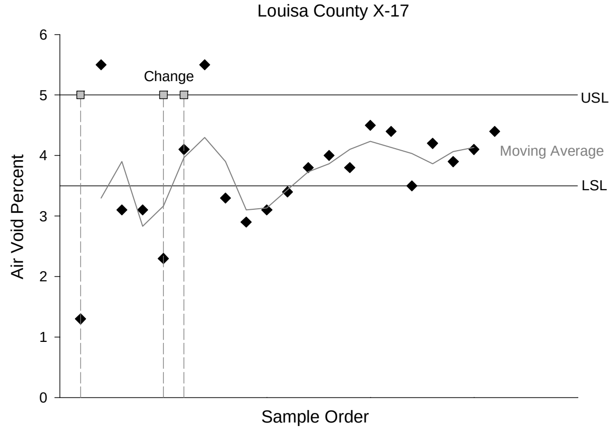
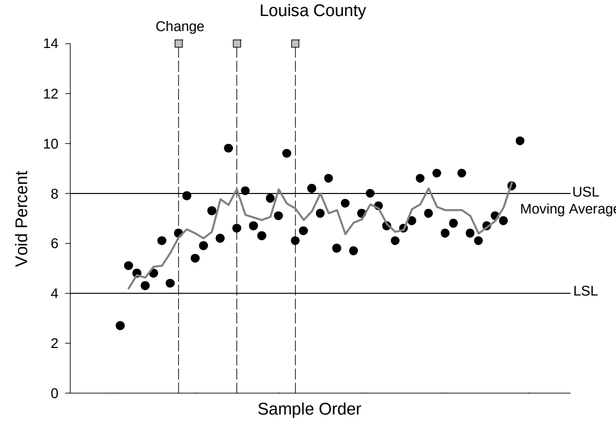


Figure 74

Field Voids

Louisa County

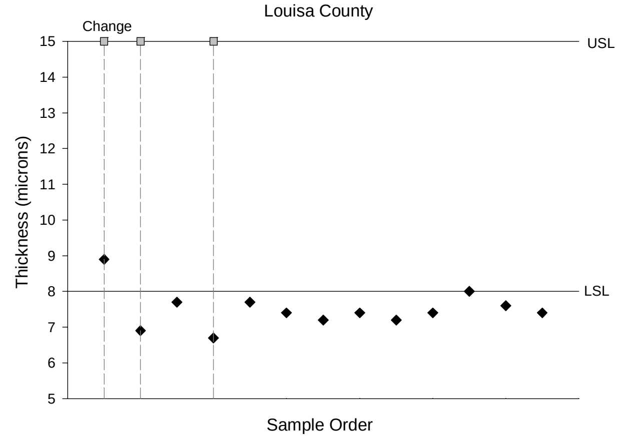


Film thicknesses were below specification throughout (Figure 75), despite the high asphalt content. The cause for this is unclear, however, is probably due to high absorption on the material heated and tested in the lab.

Figure 75

Film Thickness

Louisa County



Construction Issues

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

Performance

The northern portion of the project, inside the city limits, was overlaid over existing (not recycled) pavement. This area had considerable reflective cracking. Not counting the portion inside the city limits, there were a total of nine full and nine half transverse cracks. These are the type of cracks generally associated with performance of the mix. There was considerable longitudinal cracking and some very minor fatigue cracking—both of which were probably related to subgrade.

Figure 76

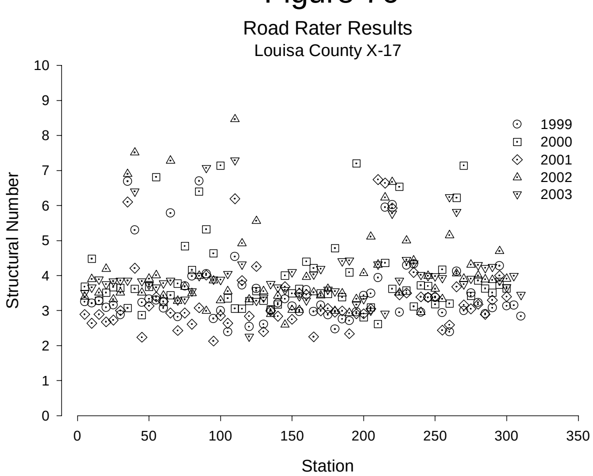
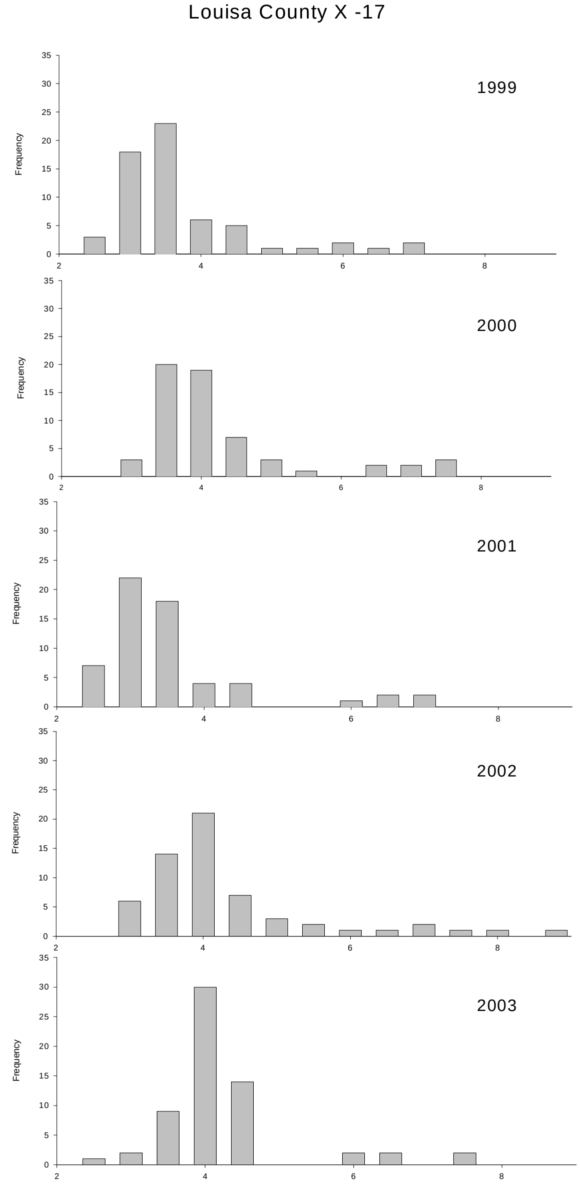


Figure 77



The Road Rater data have a somewhat puzzling scatter in the first third of the project. The higher values around stations 120 and 220 are probably due to bridges. But the reason for the high values intermittently between stations 30 and 120 is unknown. There are sometimes seasonal effects on the subgrade, but that would generally result in variation by year, which is not evident here. Junctions with side roads seem to correlate with some of the scatter.

Figure 78

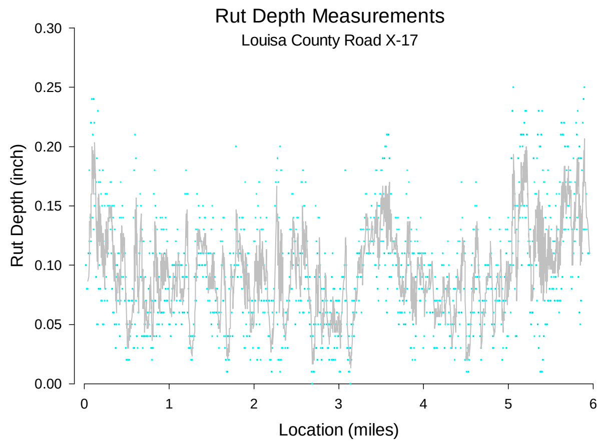
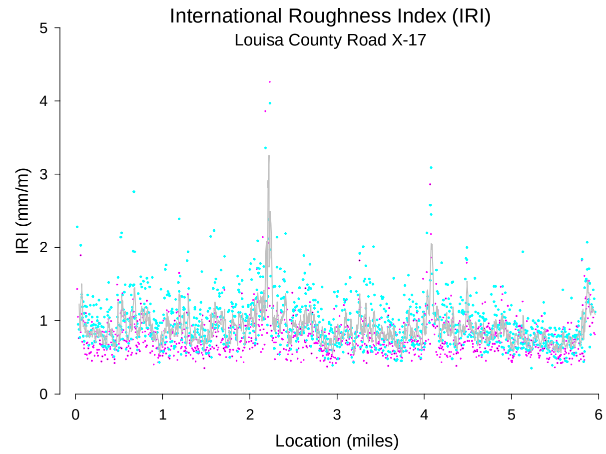
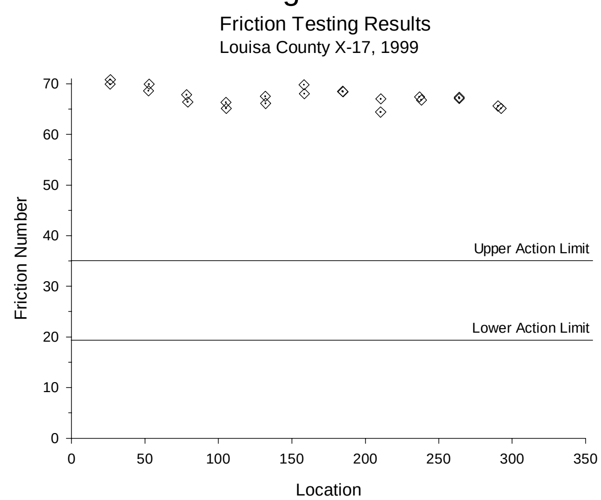


Figure 79



Rut depth measurements were higher for this project than for most of the others. However, with an average depth of about 0.10 inch, these values were quite reasonable. Smoothness and friction test results were unremarkable.

Figure 80



CONCLUSIONS

Performance

The primary performance enhancements promised by Superpave mix designs are reduction in thermal (transverse) cracking and rutting. With the exception of reflected cracks in Cass County N-16, all of the pavements constructed for this research exhibited excellent transverse crack resistance. Additionally, all of the pavements showed rutting well within the range of acceptability. Most were under 0.1 inch.

PROJECT COSTS

It became clear early on that it would be difficult if not impossible to obtain an objective measure of project costs in comparison to the costs of paving with conventional mixes. Primarily because these projects were let under competitive bidding. Subjective evaluation by the county engineers and contractors indicated that using Superpave on these low-volume roads, at most did not cause any significant increase in price.

Because the entire state of Iowa was moving toward using performance graded asphalts, 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 these levels of traffic. And, of course, those requirements have been relaxed for low-volume roads since this research commenced.

ACKNOWLEDGEMENTS

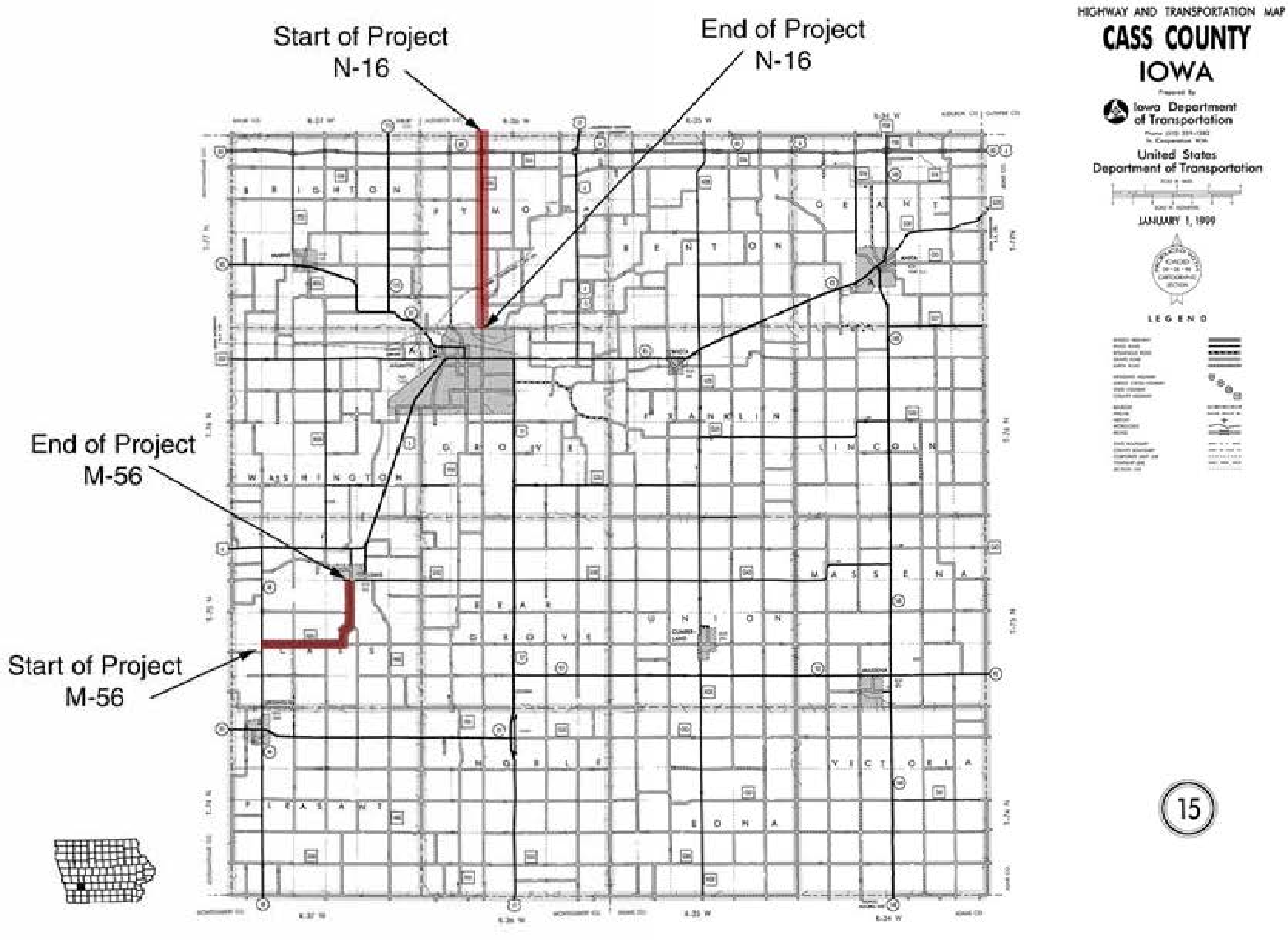
Research project TR-414 was sponsored by the Iowa Highway Research Board and the Iowa Department of Transportation. Partial funding for this project was provided by the Secondary Road Research Fund.

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 for providing considerable technical advice.

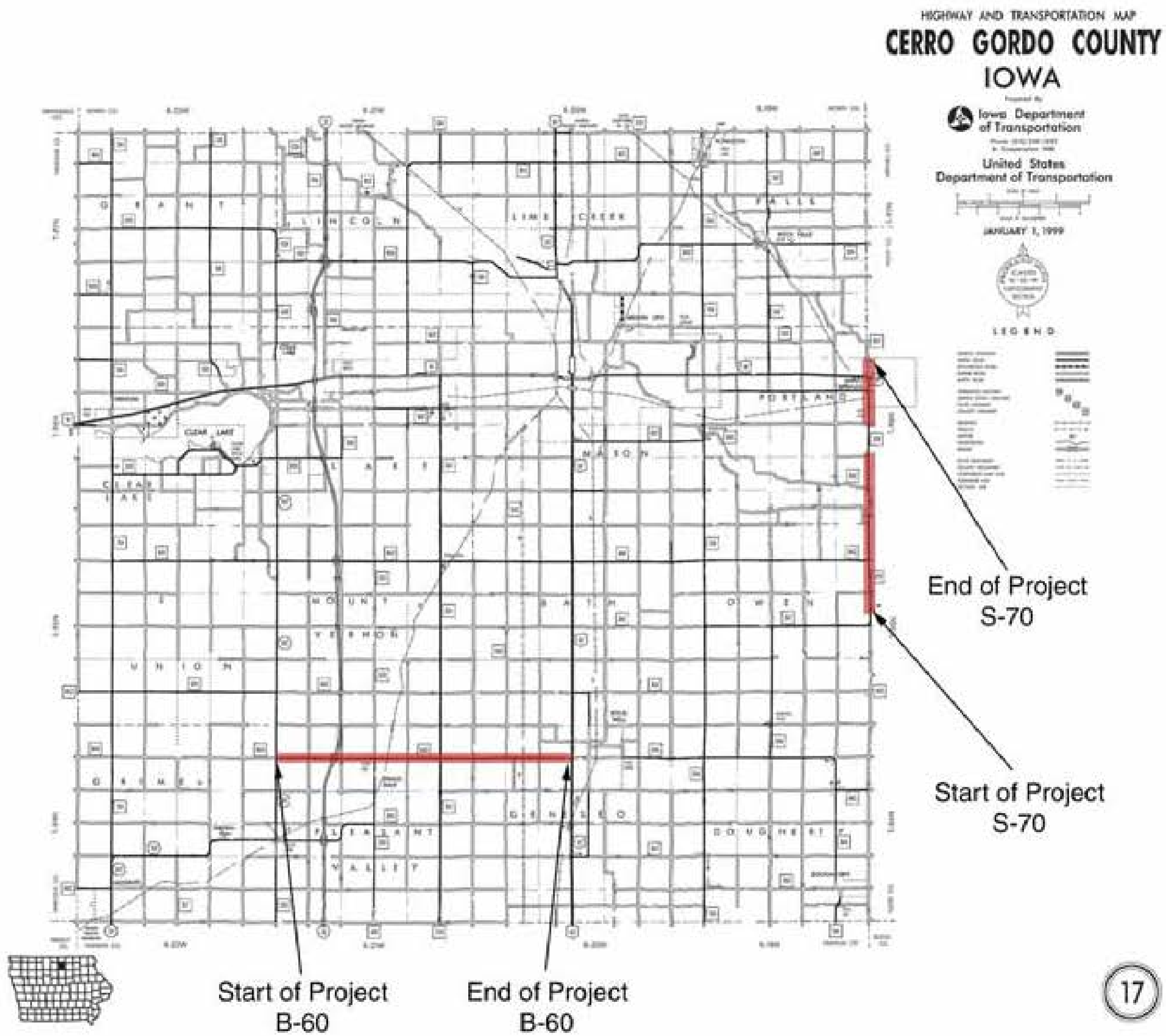
REFERENCES

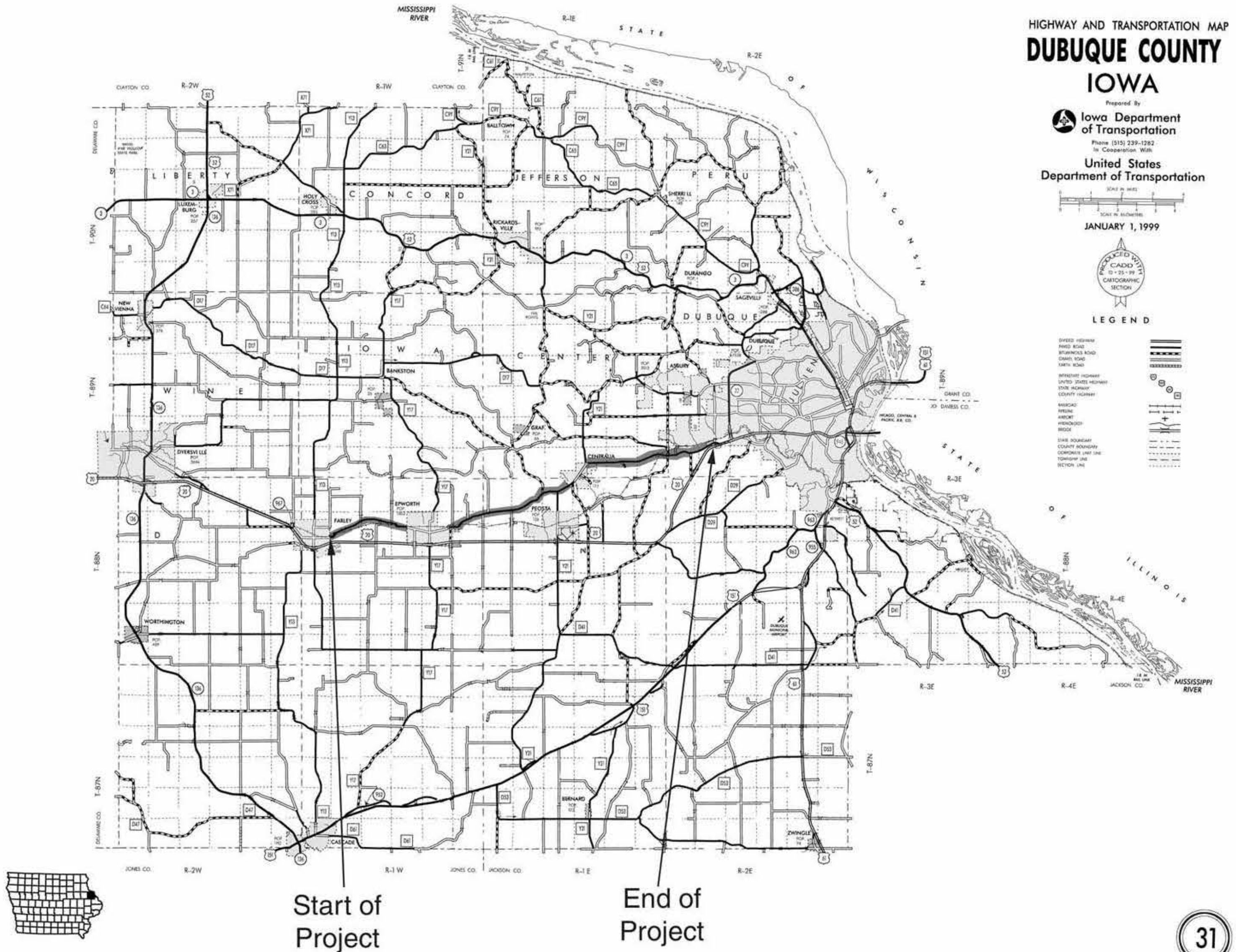
1. Specification for Superpave Hot Mix Asphalt, AASHTO Provisional Standard MP2-96, American Association of State Highway and Transportation Officials, 1996.
2. McGennis, R.B., Anderson, R.M., Kennedy, T.W., Solaimanian, M., *Background of Superpave Asphalt Mixture Design and Analysis*. Report No. FHWA-SA-95-003.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

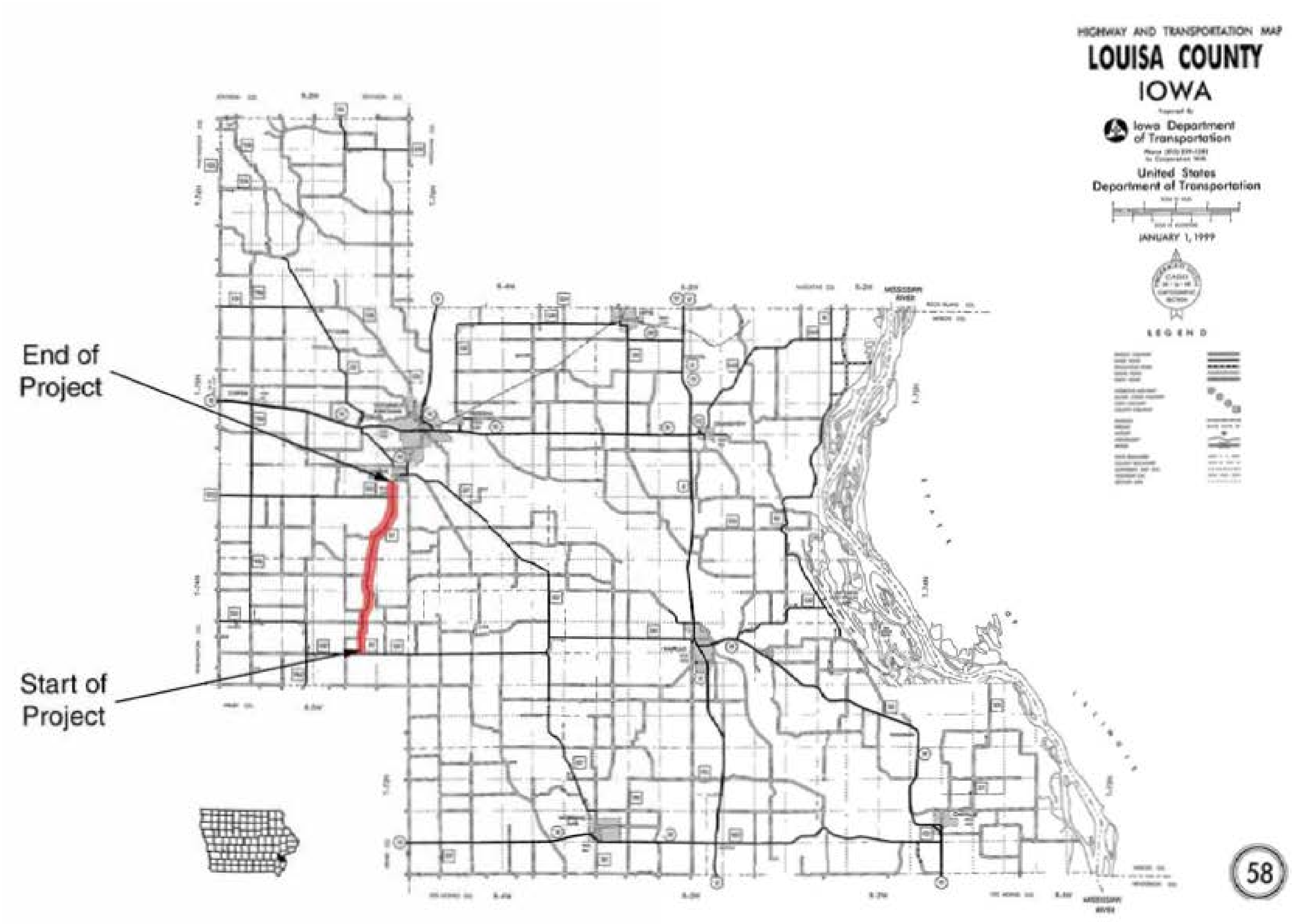
Appendix A
Project Location Maps

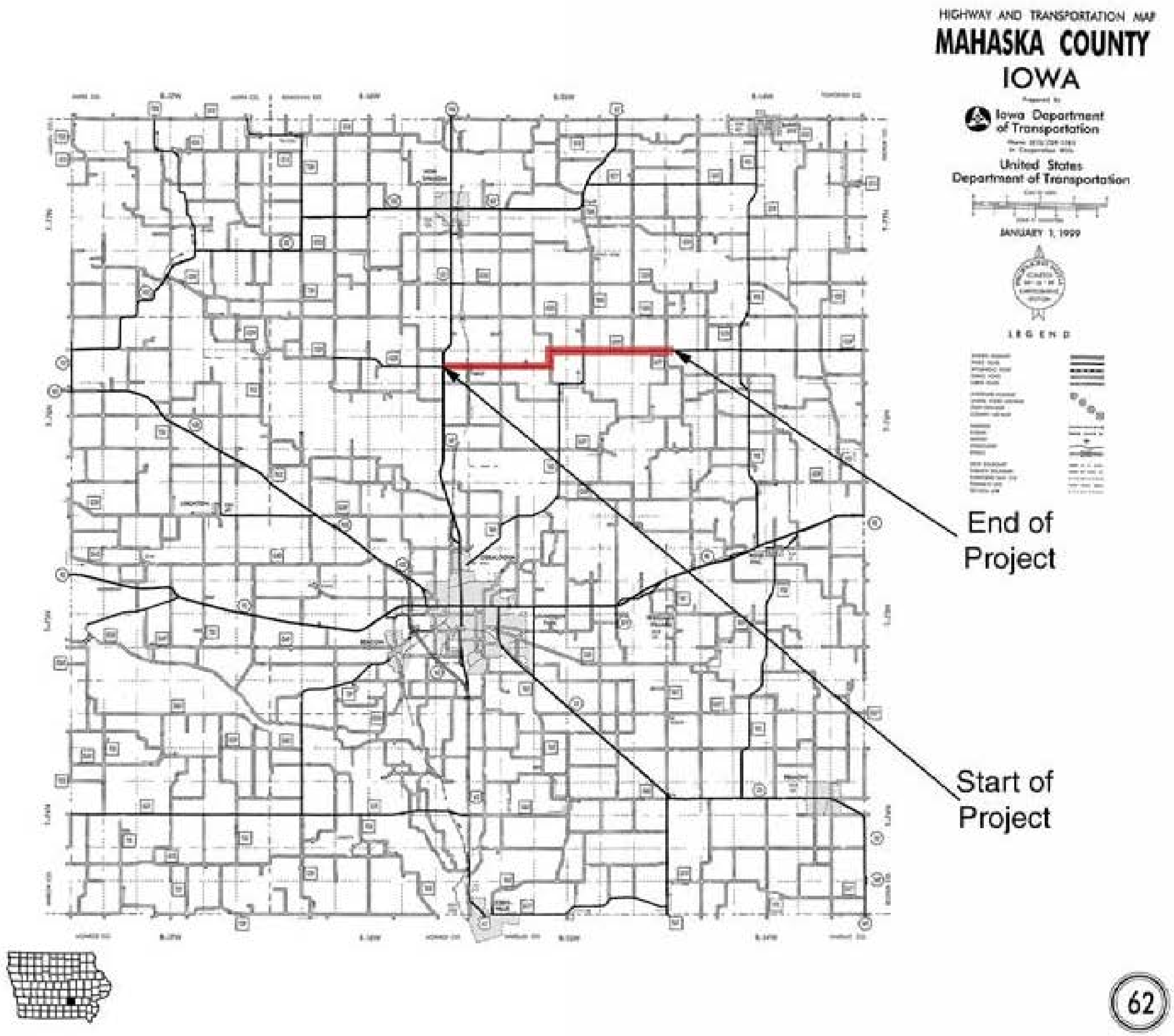


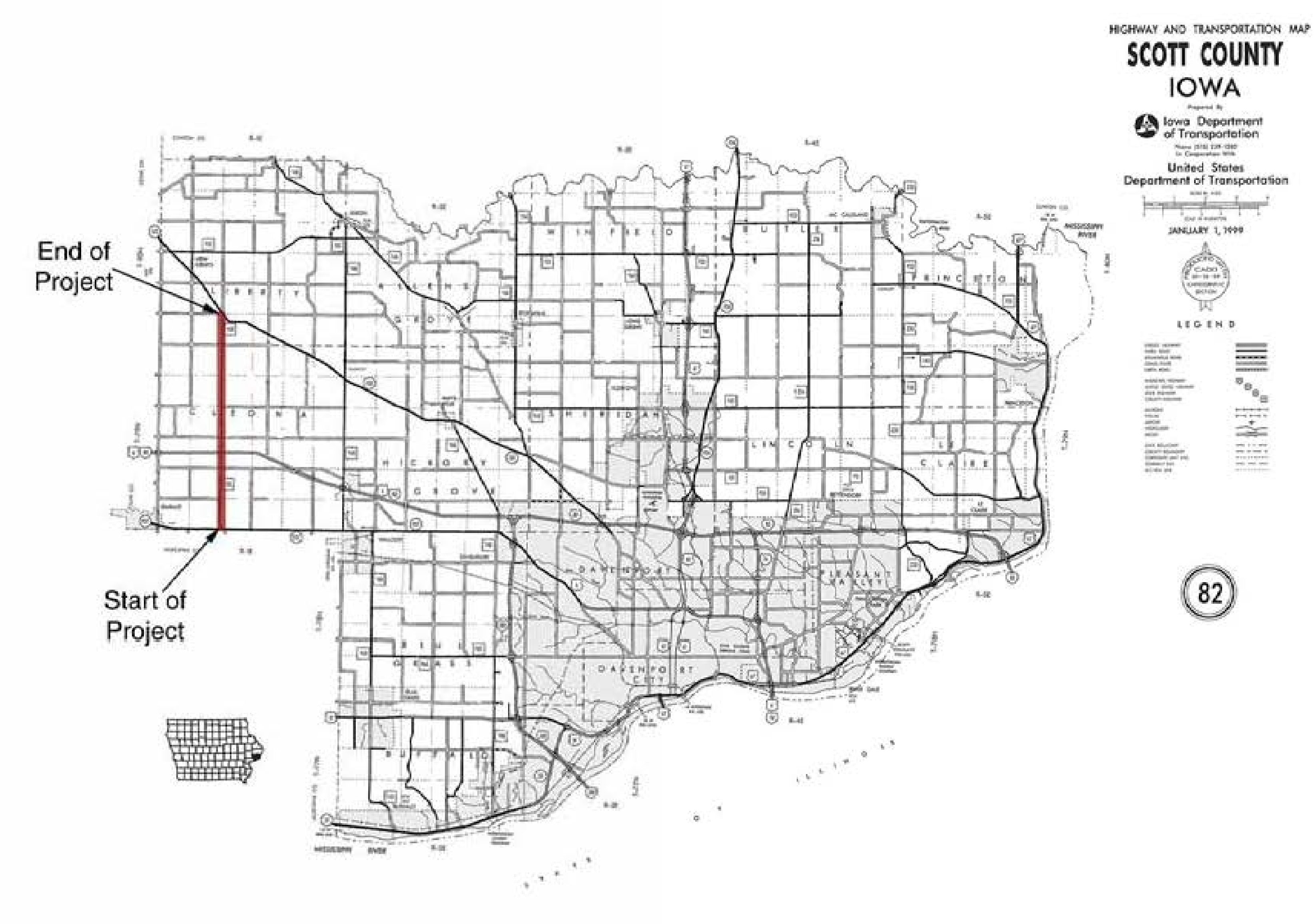
Start of Project
N-16
End of Project
N-16
End of Project
M-56
Start of Project
M-56
HIGHWAY AND TRANSPORTATION MAP
CASS COUNTY
IOWA
Iowa Department of Transportation
United States Department of Transportation
JANUARY 1, 1999
LEGEND
BRIGHTON
PYMOSA
BENTON
GRANT
FRANKLIN
GROVE
LINCOLN
WASHINGTON
MASSENA
BEAR GROVE
UNION
NOBLE
VICTORIA
PLEASANT
EDNA
15


HIGHWAY AND TRANSPORTATION MAP
CERRO GORDO COUNTY
IOWA
Iowa Department of Transportation
United States Department of Transportation
JANUARY 1, 1999
LEGEND
GRANT
LINCOLN
LIME CREEK
FALLS
PORTLAND
CLEAR LAKE
LAKE
MASON
MOUNT VERNON
BATH
OWEN
UNION
GRIMES
PLEASANT VALLEY
GENESEO
DOUGHERTY
End of Project
S-70
Start of Project
S-70
Start of Project
B-60
End of Project
B-60
17


HIGHWAY AND TRANSPORTATION MAP
DUBUQUE COUNTY
IOWA
Prepared By
Iowa Department of Transportation
United States
Department of Transportation
JANUARY 1, 1999
LEGEND
MISSISSIPPI RIVER
LIBERTY
CONCORD
JEFFERSON
PERU
DUBUQUE
IOWA
CENTER
WINE
DYERSVILLE
FARLEY
EPWORTH
PEOSTA
CENTRALIA
WORTHINGTON
CASCADE
BERNARD
ZWINGLE
Start of Project
End of Project
31


HIGHWAY AND TRANSPORTATION MAP
LOUISA COUNTY
IOWA
Iowa Department of Transportation
United States Department of Transportation
JANUARY 1, 1999
LEGEND
End of Project
Start of Project
58


HIGHWAY AND TRANSPORTATION MAP
MAHASKA COUNTY
IOWA
Iowa Department of Transportation
United States Department of Transportation
JANUARY 1, 1999
LEGEND
End of Project
Start of Project
62


HIGHWAY AND TRANSPORTATION MAP
SCOTT COUNTY
IOWA
Iowa Department of Transportation
United States
Department of Transportation
JANUARY 1, 1999
LEGEND
End of Project
Start of Project
82

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 (Reference 2). Also note that many of these requirements are in flux and have changed since this research was started.

Performance Graded AC

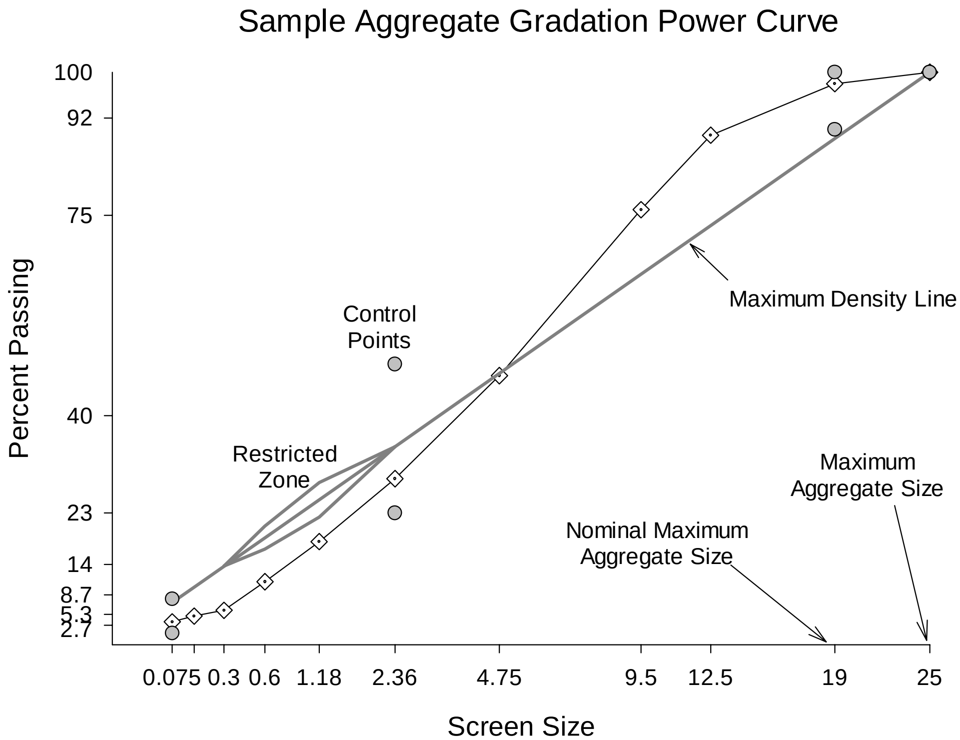
The use of performance graded AC provides the pavement with a binder that is strong at high temperatures to resist rutting and yet soft enough at cold temperatures to resist thermal cracking. A performance graded asphalt such as 58-28 is designed to maintain these properties at +58ºC and -28ºC. There 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 on the next page. 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 lower 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

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 : ______________________

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 Attlantic 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
Lower Tolerance	100	100	90			28					2

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

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 Schoenstock
For Gary Schoenstock

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	LR49800: A79002 MALCOM ST. BEDS 10-13	@ 40.0%
	3/8 CHIP	03	LR49800: A79002 MALCOM ST. BEDS 10-13	@ 20.0%
	M. SAND	06	LR49800(A50002 MARTIN MARIETTA BEDS	@ 20.0%
	SAND	05	LR49800: 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
Lower Tolerance	100	100	100	90		32					2

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
Max. Sp.Gr. (Gmm)	2.433	2.420	2.390	2.378	2.425
% 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
% Air Voids	4.60	3.64	1.76	1.30	4.00
% VMA	15.39	15.44	15.32	15.81	15.42
% VFA	70.11	76.42	88.51	91.78	74.05
Film Thickness	10.38	11.32	12.92	13.83	10.97
Filler Bit. Ratio	0.94	0.86	0.75	0.70	0.89
Gsb	2.562	2.562	2.562	2.562	2.562
Gse	2.694	2.700	2.683	2.690	2.692
Pbe	4.77	5.20	5.93	6.35	5.03
Pba	1.96	2.05	1.81	1.91	1.93
% 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
% Water Abs	2.59	2.59	2.59	2.59	2.59
S.A. m^2 / Kg.	4.59	4.59	4.59	4.59	4.59
% +4.75mm Friction Agg.	0.0	0.0	0.0	0.0	0.0
Angularity-method A					
% Flat & Elongated					
Coarse Agg. Angularity	0	0	0	0	0
Sand Equivalent					

Avg. Design High Air Temp. C
<39

mm from Surface
0

Number of Gyrations
N-Initial
7
N-Design
68
N-Max
104

Gsb for Angularity Method A
2.647

Slope of Compaction Curve
12.53

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
Pbe	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 Hinrichsen 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
Lower Tolerance	100	90				23					2

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, A.C. TECH.
ASSURANCE,, MARTIN/MARIETTA
BECKER,

Signed : Keith E. Norris 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, Jim Webb, John Hinrichsen, Cent. Lab., Louisa Co. Eng.

Signed :

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 : ____________________