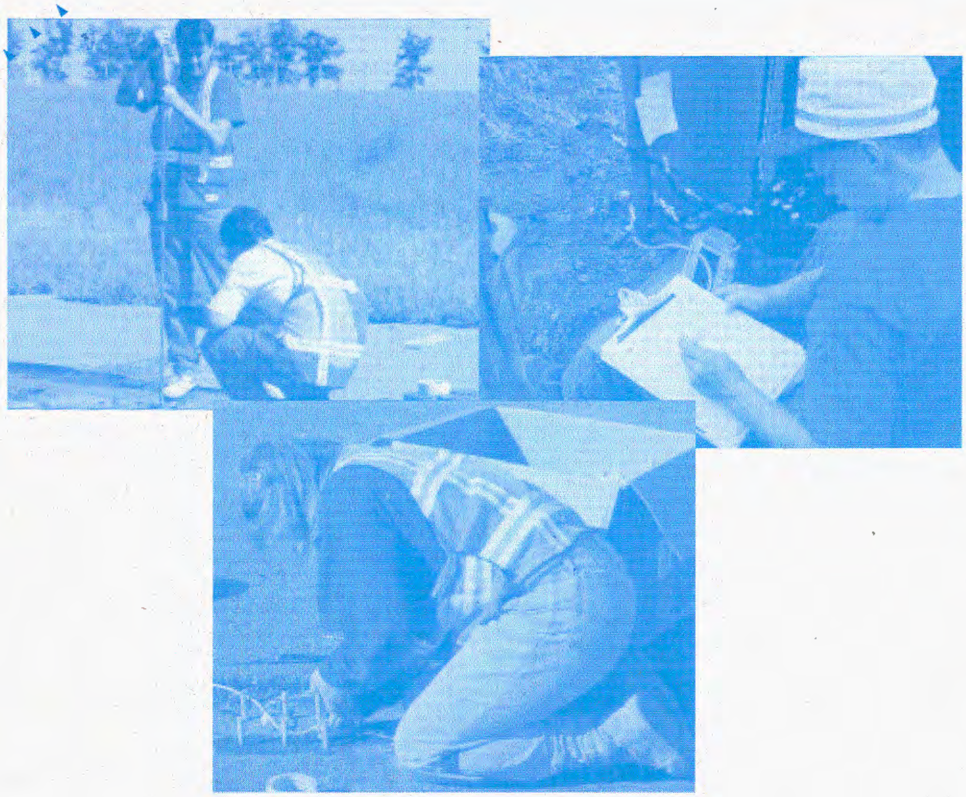
Final Report 2000-29



Evaluation of Aggregate Sections at Mn/ROAD

Mn/ROAD

Office of Minnesota Road Research

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This project focuses on the second construction phase of the Minnesota Road Research facility (Mn/ROAD) and evaluates three typical, locally available, surfacing aggregates along with a rollover section from the initial phase for performance.

The project results indicate that the adsorption test did not predict the performance of the sections in this experiment. All of the aggregates were characterized as marginal in terms of moisture and frost susceptibility. The sections with the greatest percentage of fines typically performed better than sections with a low percentage of fines. The Minnesota Department of Transportation (Mn/DOT) issued a technical memorandum to change the specification from 0-15 percent to 8-15 percent passing the No. 200 sieve for Class 1 surfacing aggregate.

The project also compared freezing and thawing rates on the aggregate sections to nearby hot mix asphalt (HMA) sections. Soil at any particular depth froze four to five days before HMA sections. The aggregate sections also thawed at exponential slower rates as depth increased from 11 to 35 days, which means that an aggregate surfaced road will freeze sooner and thaw slower than an HMA surfaced road. This information impacts the management of spring load restrictions and winter load limits.

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Evaluation of Aggregate Sections at Mn/ROAD

Final Report

Prepared by:

Gregory D. Johnson
David Baker

Minnesota Department of Transportation
Office of Materials and Road Research
1400 Gervais Avenue
Maplewood, MN 55109

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EXECUTIVE SUMMARY

The Minnesota Road Research Facility (Mn/ROAD) was constructed with four aggregate surfaced test sections on the two-lane Low-Volume Road (LVR) loop, which is loaded by a five-axle semi-tractor trailer. The truck runs 4 days per week with an 80,000 lb load in the inside lane and one day per week in the outside lane with 102,000 lb on an oval test loop.

The test sections have gone through two phases of construction. This report focuses on the second phase of construction. The objective of the second phase was to evaluate three typical, locally available, surfacing aggregates along with a rollover section from the initial phase for performance. Two aggregate test methods developed by the Finnish Road Administration were used to predict performance of aggregates used as surfacing. An evaluation of the adsorption test, which uses a measurement of the amount of moisture that the fines (minus No. 200) portion of the aggregate adsorbs from the air. The other test (surface dielectric) is a capillary rise test in which dielectric measurements are made and used to predict the moisture and frost susceptibility of the aggregate base material. The tractor/trailer combination, which provides the loading on Mn/ROAD LVR, creates accelerated ESALs, not accelerated traffic. Therefore, the results of this study will only represent a structural evaluation of the material.

The results of the project indicate that the adsorption test did not predict the performance of the sections in this experiment. This may be due to the aggregates in these sections only being in the satisfactory and poor range of the criteria. Also, the test was developed in Finland, which has a different type of climate. While the total rainfall between Finland and Minnesota is the same, Finland can be characterized as having regular small precipitation events, whereas Minnesota has irregular events in terms of intensity, frequency, and duration. The surface dielectric test was run on three of four aggregates used in this experiment. All of the aggregates were characterized as marginal in terms of being moisture and frost susceptible. The aggregate did perform marginally with periods of rutting during spring thaw and high precipitation periods. Therefore, the test may be useful in predicting the performance of aggregates. An evaluation using more aggregate samples, which have a wide range of performance, needs to be completed before a definite answer can be given.

The sections with the greatest percentage of fines (passing No. 200 sieve) typically performed better than sections with a low percentage of fines with a decrease in severity of washboarding as compared to the lower fines content sections. Aggregate-surfacing material used around the state is typically a modified Minnesota Class 1,2, or 5 (mostly dependent on local availability). It is modified to increase the amount of fines in the aggregate. This was not reflected in Mn/DOT aggregate surfacing specifications prior to 1999. An increase in the percentage of the minus No. 200 sieve has been changed in Technical Memorandum No. 99-08-MRR-04. The specification changed from 0-15% to 8-15% passing the 75 µm (No. 200) sieve for Class 1 surfacing aggregate.

A comparison of the freezing and thawing rates on the aggregate sections to nearby hot mix asphalt (HMA) sections indicated that the soil at any particular depth, froze 4-5 days before the HMA sections. The aggregate sections also thawed at exponential slower rates as depth is increased from 11 to 35 days. Therefore, an aggregate surfaced road will freeze sooner and thaw slower than an HMA surfaced road. This will effect how aggregate roads should be managed by spring load restrictions and winter load limits.

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CHAPTER 1

INTRODUCTION

Minnesota has approximately 69,300 miles of aggregate surfaced roads and 45,000 miles of paved roads. Aggregate roads make up 61% of the road network in Minnesota. These roads are important to the rural community, because they provide a vital link between field, farm, recreation, and community. Traffic on these roads can be seasonally dependent and the condition of the roads can change quickly.

SCOPE OF REPORT

This report communicates results of an evaluation of four common, locally available, surfacing aggregates at the Minnesota Road Research Facility (Mn/ROAD). These sections were replaced with new paved research sections, during the summer of 1999. This report will serve as the final report for the aggregate surfaced sections.

WHAT IS Mn/ROAD

The Mn/ROAD research facility was created as a testing facility for evaluating structural design criteria and materials used in Minnesota pavements. The Mn/ROAD low volume road test facility is closed to normal traffic and is constructed in a loop format for accelerated loading. It is loaded by a five-axle semi-truck trailer combination. The sections are loaded so they receive approximately the same amount of Equivalent Single Axle Loads (ESAL) in both lanes. The inside lane is loaded with the truck carrying 80,000 LB (356 kN) for four days each week. In the outside lane the truck runs one day each week with 102,000 LB (456 kN). Therefore, this is a test using an actual truck to load the test sections a known amount on a daily basis. Long term environmental effects on the aggregate sections cannot be measured since the sections were only in place for seven years. The truck carries the same load year round, and is not limited during the spring thaw.

CHAPTER 2

INITIAL SECTIONS AT Mn/ROAD

PURPOSE OF AGGREGATE SECTIONS AT Mn/ROAD

The initial phase of the project was to build four test sections to identify or develop evaluation procedures for use on aggregate and chip seal roads. These procedures would then be used to evaluate the performance of the sections at Mn/ROAD. A second phase was begun in September of 1996 to compare the performance of common surfacing aggregates. Part of the evaluation was to evaluate two aggregate tests that were developed by the Finnish Road Administration to predict performance. The aggregate sections were removed from service in August of 1999.

INITIAL CONSTRUCTION

A Minnesota Class 1 aggregate is defined as having a top size of ¾ inch, being uniformly graded, but having wide gradation bands. Two of the initial test sections were constructed with a Minnesota Class 1C (coarse). This aggregate gradation was to follow the coarse side of the gradation limits. The other two sections were constructed with a Minnesota Class 1F (fine) aggregate that was to follow the fine gradation limit of the Mn/DOT specifications. Each gradation type was to be divided, with one section being covered with a double chip seal and another left to act as a surfacing aggregate. The aggregate was placed 12 inches thick over the naturally occurring silty/clay subgrade (R=12). The sections were crowned to a 1.5% slope to match the paved sections on the project.

WHAT WAS LEARNED FROM INITIAL TEST SECTIONS

A consultant held the contract for evaluating and writing a report on the test sections for the first two years. The results of this report are summarized as follows. A complete description can be found in the report [1].

1. Aggregate gradation alone is not a reliable predictor of performance.
2. The most common deterioration modes for the sections were rutting or washboarding. Washboarding depends on the number of truck passes rather than ESALs.

3. Most rutting occurred in the aggregate, not in the subgrade.
4. Laboratory tests (Dynamic Cone Penetrometer, resilient modules, and shear tests) completed at the University of Illinois predicted that Class 1C would perform worse than Class 1F aggregate, this was confirmed in the field.
5. A simple test is needed for specifying aggregate surfacing.
6. Future research should include different aggregates.

REPAIR OF SECTION 33 (USE OF GEOTEXTILE)

Shortly into the test on the initial test sections, two soft spots appeared. The spots were deep bladed to remove the aggregate and then replaced in lifts with compaction and watering. The aggregate surface was contaminated with clay from the subgrade to within 1 inch of the surface.

The following day the spots began to yield again within a few passes of the truck. A discussion with the aggregate committee indicated that a location from 66+08 to 33 would be repaired. A geotextile was used. Unfortunately the author could find no detailed information on what was done, except for a few pictures. The repair was successful since these locations did not pose any future problems.

CHAPTER 3

RECONSTRUCTION OF AGGREGATE SECTIONS

AGGREGATE SELECTION

The aggregate committee recommended that the next phase of research would evaluate the performance of additional surfacing aggregate material. Three locally available surfacing aggregates were chosen. Section 35, which performed best in the initial phase of research was held over into the second phase.

CONSTRUCTION SPECIFICS

The phase one sections were cut to a 5% percent cross slope to a depth of 6 inches below original grade. Then three locally available aggregates were added and compacted into sections 32, 33, and 34 appropriately. Section 35 just had aggregate added to the surface to bring the cross slope to 5%. This was completed in August and September of 1996. A complete set of laboratory aggregate tests was run (appendix A).

The exact aggregates used will be discussed fully in the following chapter.

CHAPTER 4

FinnRA LABORATORY TESTS

The Finnish National Road Administration (FinnRA) developed two tests that they have related to the field performance of aggregate surfacing and base material. These two tests have been evaluated using the aggregates that were placed at Mn/ROAD.

ADSORPTION TEST

This test measures the amount of water that the fines (minus No. 200) portion of the aggregate will adsorb from the air. FinnRA has related this to performance (figure 1) [2]. A complete description of the test procedure is given in Appendix B. Their research indicates that aggregates with fines, which have low adsorption values, perform best. The test requires a precision scale and laboratory equipment. It requires at least seven days after the minus No. 200 material has been sieved out of the aggregate matrix to determine the results. Of the three aggregates chosen, two had a high proportion of fines and one material was close to the FinnRA adsorption criteria. The Class 1F material from the initial test was also carried over into the second phase, as the best performing section from the initial construction. The results can be seen in Figure 1.

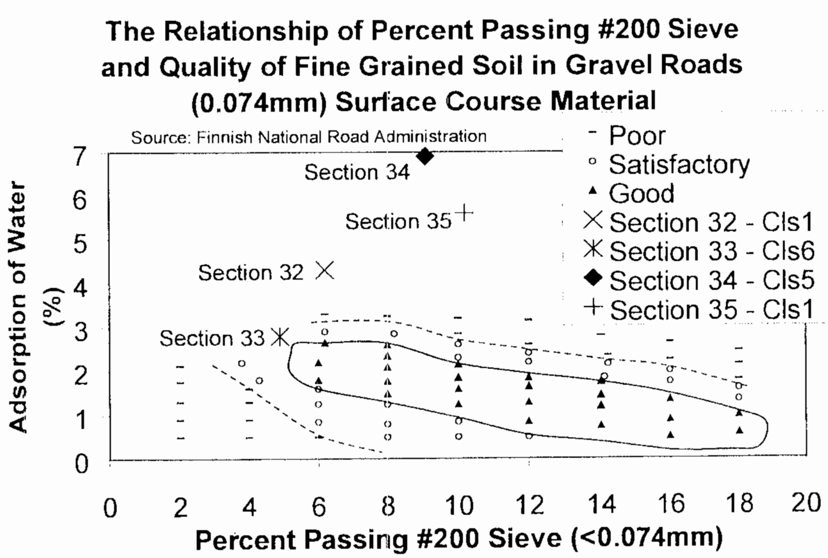

Figure 1. Adsorption Performance

A Class 1 material was used in Section 32. This aggregate had a lower percentage of fines (6.2%) and most closely matches the Class 1F aggregate used in Section 35.

A Class 6 aggregate was selected for Section 33. This material only had 4.9% fines, but the adsorption values were closest to the criteria.

A Class 5 aggregate was used on section 34. The fines content was high (9.1%), and the adsorption values were also greater than the FinnRA criteria.

Section 33 aggregate came closest to the desired performance envelope. But, this was only in the satisfactory range. Sections 32, 34, and 35 all had the desired percentage of fines, but they are more adsorptive than what would be desired thus are ranked as poor. The author had to expand the published graph to include the high adsorption values that were found with these aggregates.

SURFACE DIELECTRIC

This is a FinnRA laboratory test for evaluating aggregate base materials. The test measures the surface dielectric values of a material in a 300-mm capillary rise chamber. Poor performing aggregates are those that reach saturation quickly or have a high surface dielectric [3]. This test usually takes between 5 and 8 days to complete. A complete description of the test can be seen in Appendix C. From work that has been done in Finland and Texas, a dielectric of 10 is the upper limit for non-moisture and frost susceptible aggregate. According to the criterion that has been established, Section 33 would be borderline acceptable for being non-moisture and frost susceptible. Sections 32 and 34 would be in the susceptible range. The aggregate from Section 35 was not tested. This test is meant to test aggregate base material and not aggregate surfacing, therefore will probably not correlate to performance. A surfacing aggregate with a larger percentage of fines and therefore likely a large average dielectric value rise may be desirable.

Section	Average Dielectric Value
32	11
33	10
34	13
35	Not Tested

Table 1. Surface Dielectric Test Results

CHAPTER 5

MONITORING

DISTRESS SCALE

The amount of washboarding and rutting was recorded before every maintenance grading to determine the amount of distress to the sections. Washboarding and rutting were measured according to the criteria in Table 2.

Distress Level	Washboarding Peak to Trough (inches)	Rutting Depth of Depression (inches)
Light	< 0.5	< 0.75
Moderate	0.5 to 1.0	0.75 to 1.5
Severe	> 1.0	> 1.5

Table 2. Distress Threshold Levels

ANALYSIS PERIOD

Data was collected between October 1996 and May 1998 (except September 1997 through March 1998, when no records of distress measurements could be found). Therefore, the following analysis and discussion in chapters 5 and 6 were based on these direct measurements. In July of 1998 the truck drivers began rating the sections and no direct measurements were taken. This was more observational information instead of direct measurements of the road surface. A discussion of this data can be found in chapter 7.

PRECIPITATION

The quantity, intensity, and type of precipitation effect the performance of aggregate surfacing material. Extremely wet conditions will bring rutting, and extended dry condition will promote washboards. The actual precipitation varied widely from the 30 year normal (Figure 2).

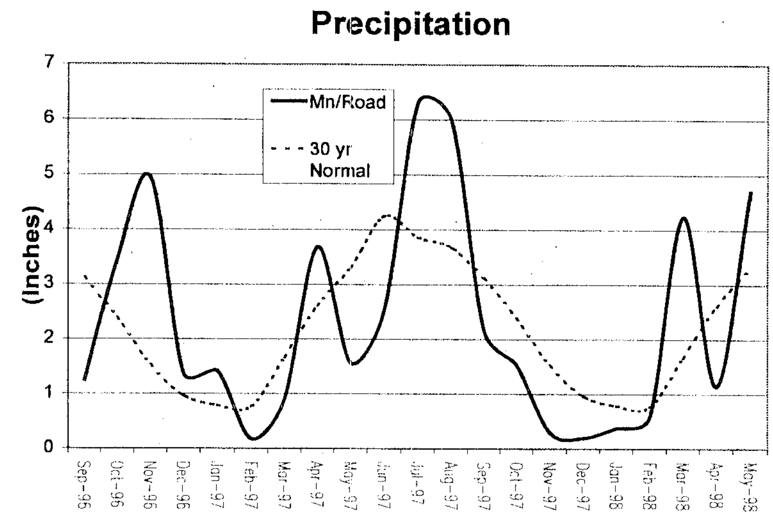

Figure 2. Precipitation at Mn/ROAD

VEHICLE PASSES

The tractor/trailer truck at the Mn/ROAD facility runs four days per week with an 80,000 lb load and one day per week with a 102,000 lb load. Each is isolated to its own lane. The gap in data between September 1997 and January 1998, in Figure 3, was due to a lack of loads during that time period.

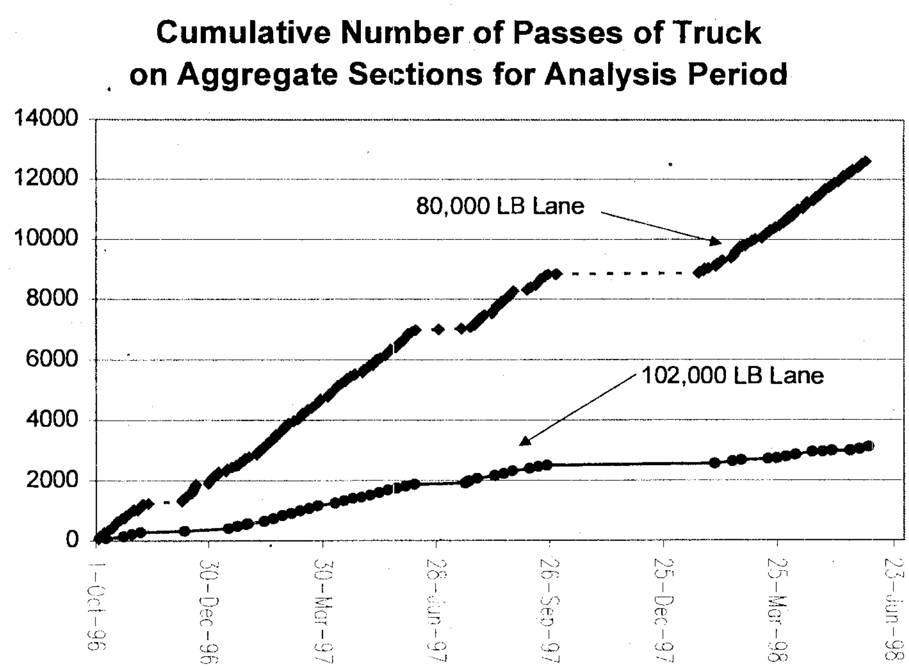

Figure 3. Truck Passes on Mn/ROAD Sections

CHAPTER 6

SECTION PERFORMANCE

PERFORMANCE OF ADSORPTION CRITERIA

The sections with the greatest percentage of fines (passing No. 200 sieve) typically performed better than sections with a low percentage of fines. The higher fines were between 9 and 10% and the lower was 5-6%. The adsorption graph (Figure 1) indicates that the lowest percentage recommend is 5.5%. This increases to 19% depending on the adsorption value of the fines portion of the aggregate. Therefore, Sections 32 & 33 are just within the criteria, but Sections 34 & 35, with their 9-10% fines are closer to the typical range of fines. Unfortunately, the adsorption values are too high.

Section 34 had the least amount of distress in 9 out 12 rating periods (Figures 4 & 5). This was followed by Section 35, 33, and finally Section 32. These results are contradictory to the results from the FinnRA adsorption test. While according to the adsorption test, section 33 should perform better than the other sections, which were in the poor performance range. This may be due to the sand and gravel type aggregates, which are common to Minnesota. The fines in these aggregates have typical properties associated with silt and clay particles, which is a high adsorption rate. In Finland where this test was developed, their aggregate sources tend to be quarries. Therefore, their fine sized particle would not be clay, but crusher fines. These would have a lower adsorption rate. In Minnesota, this would require sources to consist of trap rock, quartzite, taconite tailings, or granite. This aggregate is generally more expensive and the number of quarries throughout the state is limited. Therefore the more common sand and gravel aggregate would continue to be used on aggregate roads in the state because of economic considerations. It would be interesting to research the performance of a high quality aggregate that would meet the FinnRA criteria in areas where an acceptable material is more readily available.

During periods of high precipitation, November 1996 and August 1997 (Figure 2), Section 33 performed the best in either loaded condition (Figures 4 & 5). This may be due to the high

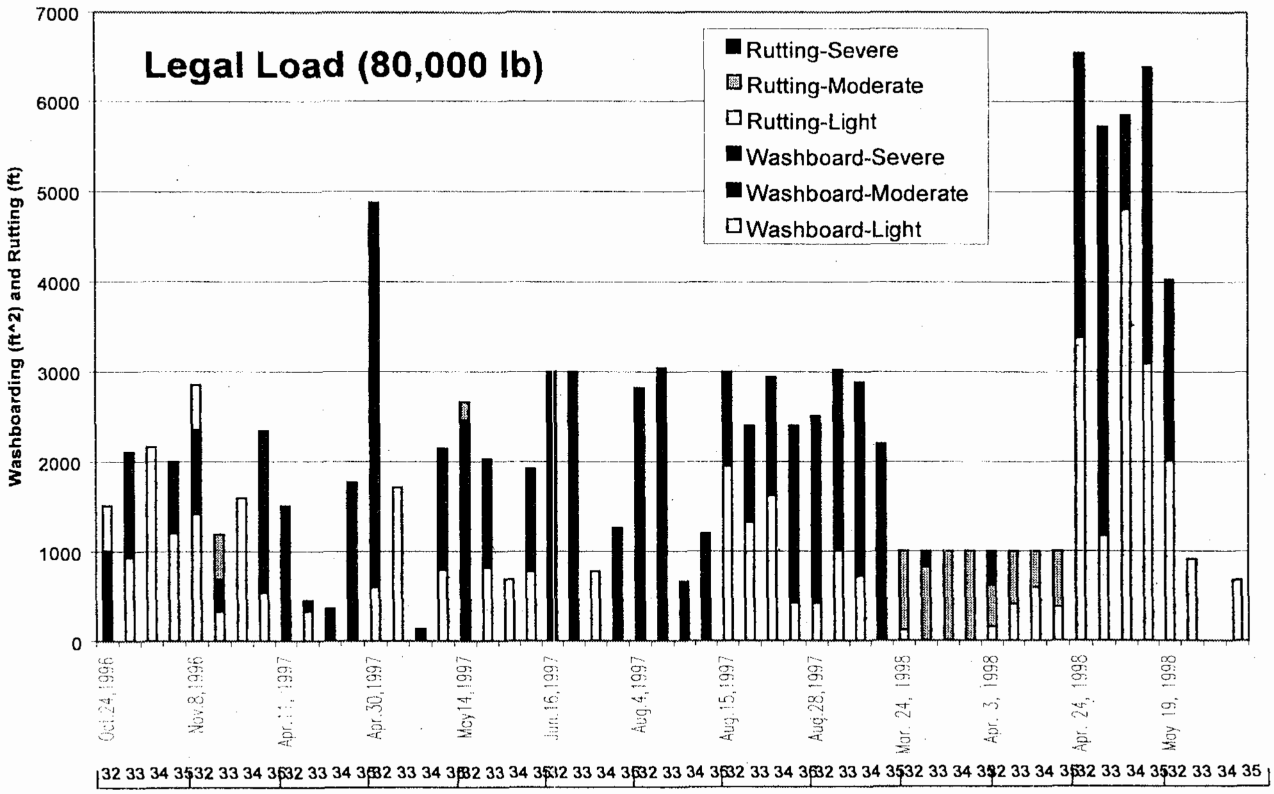

Figure 4. 80,000 lb Lane Distress Rating

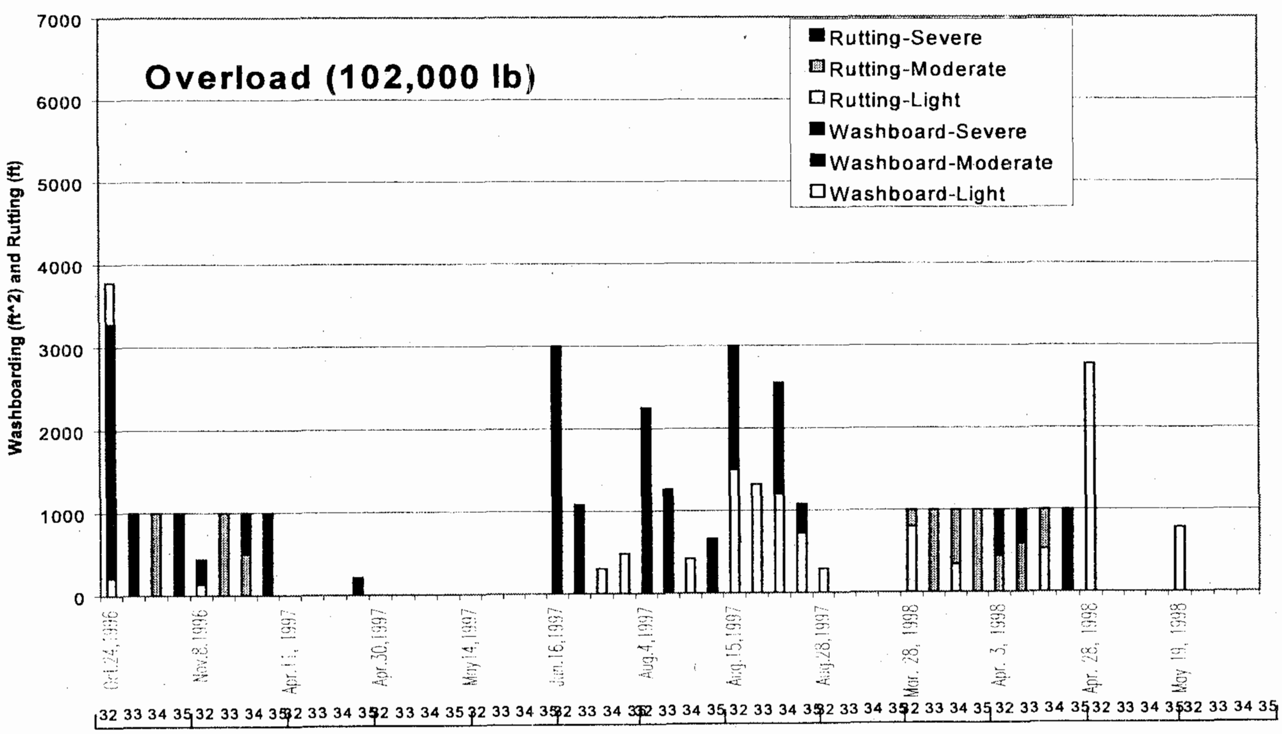

Figure 5. 102,000 lb Lane Distress Rating

percentage of fines in the other sections and the lower percentage of fines and adsorption rate of that particular aggregate. The clay fines tend to hold the moisture and weaken the structure. This continuous moist condition is more typical of the Finnish climate where this test was developed. While the total rainfall between Finland and Minnesota is the same, Finland can be characterized as having regular small precipitation events, whereas Minnesota has irregular events in terms of intensity, frequency, and duration.

There was no aggregate tested that fell in the good performance envelope of Figure 1. The closest aggregate was only satisfactory. From the field performance, the predicted poor performance aggregates did better than the satisfactory predicted aggregate. Therefore, the test did not indicate performance as well as was expected. This may be due to the type of aggregates typically found in Minnesota where the minus No. 200 aggregate (fines) are highly adsorptive. If a quarry aggregate was evaluated, the result may have been different.

SURFACE DIELECTRIC TEST PERFORMANCE

The surface dielectric test indicated that all the sections would be marginal in terms of moisture and frost susceptibility. After analyzing the data in Figures 4 & 5, this agreed with the distress results that were measured. All of the sections rutted during spring thaw and extremely high precipitation periods. From the results of the testing in Table 1, Section 33 had the lowest average dielectric value of 10. This would be borderline between marginal and good. Section 33 performed second to Section 34 during spring thaw. Inadequate drainage from the ditches surrounding the section and the subgrade remaining moist for a longer period of time may be the cause of the poor performance. However during high moisture periods Section 33 performed better than Section 34. Sections 34 and 35 were well drained with no water visible in the ditches. This test could be used as a screening tool for flagging frost and moisture susceptible aggregates before they are used, but more research would be needed.

TRAFFIC

A comparison of the amount of washboarding in the 80,000lb lane (Figure 4) as compared to the 102,000lb lane (Figure 5). The washboarding occurred mainly in the lane that had the most traffic (80,000lb lane). The lane with the overload weight (102,000lb), had one-quarter the number of passes, and less washboarding. It is noticeable that the number of passes is more critical to the amount of washboarding and not the weight of the truck. Rutting is dependant on the weight and not repetitions. This can be seen by comparing the amount and level of rutting during the spring of 1998 in Figures 4 & 5.

STABILIZING SECTION 32

In June of 1997, the poorest performing section at the time was Section 32. It was determined to try a stabilizer incorporated with the aggregate to increase the performance. A product by Soil Stabilization, Inc. (EMC SQUARED) was tried. The product is an enzyme catalyst type material that is delivered in a concentrated form and mixed with water and applied with a water truck. The procedure required that the aggregate be scarified, mixed, brought to optimum moisture content and recompacted with a vibratory roller. Due to worn out moldboard on the grader, a fine grading could not be accomplished during the initial compaction period. It required a weekend wait before the moldboard was replaced. The following week the grader returned to do the final grading, but was unable to smooth all the surface irregularities due to the very stiff surface condition. After completion of the final grading the surface appeared smooth and well compacted except some loose float on the surface. The EMC SQUARED product provided only minimal improvement of dust generation, which is not the product's intended purpose. There was never much improvement in the performance of the section after the application. The surface washboarded and rutted with the same frequency as before the application according the results shown in Figures 4 & 5. This section continued to be the worst performing of the group. This may be due to construction problems, that the surfacing aggregate in Section 32 having a minimum percentage of minus No. 200 material and clay portion of that material in the aggregate necessary for the product to react with to perform properly, or inadequate product performance. A specific conclusion cannot be made. Therefore more research will be needed to understand the proper use and performance of stabilizers.

DUST SUPRESSANT APPLICATION

On July 8, 1998 all of the aggregate sections were treated with 0.3 gal/yd^2 of magnesium chloride and compacted with a rubber tire roller. The chemical was applied for the safety of the public because some dust from aggregate sections was blowing across the adjacent interstate roadway. Since there was no daily record of the amount of dust before application, the author can make no direct comments on the results. The author's personal observation was that the treatment had a substantial reduction in the amount of dust generated.

CHAPTER 7

DRIVER RATINGS

From July of 1998 to June 1999 the truck drivers rated each section for its condition on a daily basis. Each day they gave each section a score of 1 to 10 in terms of the distress condition. This type of rating was used because it was thought that a daily condition rating would indicate how the sections changed dynamically instead of just one point in time. There was very little rutting in these sections during the rating period. The University of Minnesota was conducting a load study during the spring of 1999 when the aggregate sections were not loaded on a regular basis. Most the observational data was from the fall of 1998 and the late winter 1999 when the controlling distresses were washboarding and dust.

WASHBOARDING

The rating of the sections with washboards decreased at a faster rate on the 80,000lb lane, than on the 102,000lb lane (Appendix A). This is consistent with what was found in the previous chapter while taking direct measurements. Washboarding was the mode of distress that caused the driver to call for a regrading of the sections. This is the same result as was found in a National Forest Service study, where during dry weather, washboarding was the distress that was the trigger for maintenance [4].

Washboarding is weather and traffic dependent. The application of magnesium chloride and frequent precipitation events allowed the sections to perform with no distresses for three weeks. Then during periods of no precipitation, the sections would washboard quickly.

The 102,000lb lane sections were typically very similar to each other. This is due to the single day of traffic that these sections receive each week. When there was a noticeable difference, Section 33 performed best, and Section 34 performing worst. The 80,000lb lane sections also performed excellent right after the magnesium chloride application and regular precipitation events. However, as the precipitation became less frequent during the fall of 1998, the washboards increased. All of the sections generally had similar amounts of distress during this time period. Section 33 had the least amount of washboarding, and Section 34 had the most.

During the fall of 1998 and late winter of 1999, Section 33 performed best and Section 32 was worst. All of the sections washboarded during periods of dry weather. Section 33 may have performed best, since that section remained moist longer than the other sections, because of the lack of drainage of the subgrade. During the winter months the sections performed excellently, as would be expected when the aggregate is frozen. Unfortunately during the spring of 1999 the truck did not run on the sections on a consistent basis. Therefore there was no rutting encountered and only light washboarding. The apparent change in the success of Section 33 during the driver ratings and only being the third best during the period of direct measurements is a concern to the author. No reasons are apparent for the change.

DUST

Aggregate loss through dust and throw off is a problem on any aggregate road. A study by the Iowa State University [5,6] indicated that the amount of aggregate that is lost from a gravel road due to dust is approximately one ton/mile/vehicle/year. Throw off accounts for another 0.15 tons/mile/vehicle/year according to a study by Bergeson et al [7]. On a road with an ADT of 70, the aggregate lost in one year would be 80.5 tons/mile/year. Therefore, between two and three years the road would have to regraveled. The study also found that an aggregate with more fines generated less dust because of surface crust formation [6].

The rating of dust on the sections shows that the sections are very consistent in terms of dust generation. There were no measurements taken of the amount of dust generated, reduction in the aggregate thickness, or change in gradation. The dust was rated excellent if there were consistent precipitation events or if the sections were frozen (Appendix E). Section 32 had the least amount of dust generated and Section 35 the most. The success of Section 32 may be due to combination of stabilizer/dust suppressant that added to the section. There was usually very little difference in ranking for dust on the 102,000lb lane sections.

CHAPTER 8

AGGREGATE SECTIONS WRAP-UP

FREEZE/THAW PROGRESSION

An analysis of the environmental data from the sections indicates a unique thaw pattern compared to an asphalt concrete surfaced roadway. Frost data was collected from the Resistivity Probes and Watermark Blocks. The sensors are installed 12 inches to 96 inches below the surface of the aggregate. Therefore, the measurements are of the subgrade under the sections and not of the aggregate itself. The data was analyzed for the past five years. The aggregate surfaced sections (as compared to hot mix asphalt (HMA) surfaced sections) froze at any given depth sooner than HMA sections. The aggregate sections also thawed differently than the HMA sections in the spring.

Depth Beneath Surface (inches)	Aggregate Sections Frozen Before AC (Days)	Aggregate Sections Thawed After AC (Days)	Extended Frozen Period (Days)
12	0	1	1
18	5	9	14
24	5	8	13
36	4	7	11
48	11	24	35
60	4	30	34

Table 3. Freeze/Thaw Progression Comparison between Aggregate and Asphalt Sections

Twelve inches below the top of the roadway surface thawed at nearly the same rate as a HMA surfaced road. From Table 3, it can be seen that the aggregate sections froze at any depth 4 to 5 days before the HMA sections. (If 48 inches is considered an outlyer.) In the thawing condition, as depth is increased the aggregate sections thawed 9 to 30 days later. This extended the frozen condition by between 11 to 35 days. In future research, strength measurements need to be compared on aggregate versus HMA roads to determine if delay in spring thaw is detrimental.

Currently road restrictions are typically placed and removed on aggregate roads in the state of Minnesota at the same time as the paved roads are. Although local authorities may post restrictions on a case-by-case basis. A new Local Road Research Board study is investigating this situation to determine what direction should be taken in the future.

REASONS FOR AGGREGATE SECTION RESEARCH LEAVING Mn/ROAD

It was determined that the future goals of Mn/ROAD facility would not include aggregate sections for the following reasons.

1. Longer test sections are preferred to evaluate aggregate road performance
2. A variety of subgrade types needs to be evaluated
3. High maintenance of aggregate sections
4. Damage to Mn/ROAD truck
5. Materials need to be evaluated under the varied traffic of a normal low-volume road
6. Test sections need to tested using a greater variety of materials and environments
7. Premature damage to HMA section in HMA/gravel transition
8. Research into the use of surface treatments for low-volume roads.
9. Dust for test sections could become a safety problem for traffic on interstate and the Mn/ROAD Facility

Future research on aggregate roads will continue, but not at Mn/ROAD. Various projects are currently in progress for Minnesota using Local Road Research Board funding on rural roads. They include an evaluation of base stabilizers and dust control products and an evaluation of a Spring Load Restriction standard for aggregate roads.

CHANGE IN GRADATION SPECIFICATION

The Minnesota Department of Transportation, Office of Materials and Road Research initiated a survey of Minnesota's county engineers to provide information on the current practices into the design and maintenance of aggregate roads around the state. From the survey, it is clear that aggregate-surfacing material used around the state is typically a modified Minnesota Class 1,2, or 5 (mostly dependent on local availability). As it has been found in practice, there needs to be a high percentage of fines in the aggregate to act as a binder. This will decrease the amount of maintenance needed because a tight crust will form on the surface. This was not reflected in Mn/DOT aggregate surfacing specifications prior to 1999. An increase in the percentage of the minus No. 200 sieve has been changed in Technical Memorandum No. 99-08-MRR-04. The specification changed from 0-15% to 8-15% passing the 75 μm (No. 200) sieve for Class 1 surfacing aggregate. This change was due to a fact that many county engineers were already modifying the Class 1 specification, and the results seen at Mn/ROAD.

CHAPTER 9

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

ADSORPTION

The aggregate sections at Mn/ROAD provided a means of evaluating the structural performance of aggregate roads. The adsorption test was used to predict the performance of the aggregate surfacing material. There were no aggregates found locally which fell in the good range of the criteria with high enough fines, yet low adsorption values. The aggregate in Section 33 was in the satisfactory range. The aggregates used in Sections 32, 34, and 35 are rated poor according to the criteria. The field performance of these sections determined that the sections with higher fines (passing the No. 200 sieve), Sections 34 and 35 performed better except when there were high precipitation periods. Section 33, the aggregate in the satisfactory adsorption range, performed best (least washboarding and/or rutting) during periods of frequent, regular precipitation. Small regular precipitation events are typical of Finland, where the criteria was developed. Minnesota's minus No. 200 portion of aggregate material is typically clay particles, which have a higher adsorption value as compared to quarry material of the same size. The section in the satisfactory range did not perform as well as the sections with higher fines. Therefore, the adsorption test cannot be recommended to predict the performance of aggregate surfaced roads at this time. Further testing is needed with aggregates that fall in all three ranges of criteria to determine if the test or type of aggregate affected this experiment.

SURFACE DIELECTRIC

The surface dielectric test was performed on three of the aggregates (Sections 32, 33,and 34). The test criteria indicated that the performance all three aggregates would be marginal in terms of the aggregate base being moisture and frost susceptible. (Section 33 was on the border between good and marginal.) All of the sections rutted during spring thaw and high precipitation periods. Section 33, which was between good and marginal, performed no better than any of the other sections. An aggregate with a dielectric constant of less than 10 (good range) needs to be evaluated to give this test a better evaluation along with more aggregates across the expected range. The test is really meant to evaluate base aggregates and not aggregates used for surfacing. Therefore, the test may not have been totally applicable as a predictor of performance. Therefore, the surface dielectric test cannot be recommended to predict the performance of aggregate surfaced roads at this time.

FREEZE/THAW PROGRESSION

A comparison was made between nearby Mn/ROAD sections, which are surfaced with HMA, and the aggregate sections. This provided insight into the rate of freezing and thawing progression in the subgrade beneath the test sections. (The closest sensor to the surface was 12 inches.) The subgrade under the aggregate sections froze at any particular depth 4-5 days before the HMA sections. The subgrade under the aggregate sections also thawed at a very different rate, 11 to 35 days later, increasing with depth. This indicates that length of time to completely thaw the subgrade under an aggregate road could be one month behind an HMA surfaced road. This could have serious impacts since all roads in Minnesota are generally under load limits for the same length of time.

PRECENTAGE OF FINES

The sections with the greatest percentage of fines (passing No. 200 sieve) typically performed better than sections with a low percentage of fines. The severity of washboarding was less in the sections with the greater amount of fines. Aggregate-surfacing material used around the state is typically a modified Minnesota Class 1,2, or 5 (mostly dependent on local availability). It is modified to increase the amount of fines in the aggregate. This was not reflected in Mn/DOT aggregate surfacing specifications prior to 1999. An increase in the percentage of the minus No. 200 sieve has been changed in Technical Memorandum No. 99-08-MRR-04. The specification changed from 0-15% to 8-15% passing the No. 200 sieve for Class 1 surfacing aggregate.

RECOMMENDATIONS FOR FUTURE RESEARCH

1. Further research is needed to determine what characteristics of a surfacing aggregate are required for good performance.
2. Determine if the structural strength of aggregate roads is decreased for a longer length of time than HMA surfaced roads due to the one month delay in thawing of the subgrade.
3. A laboratory Dynamic Cone Penetrometer (DCP) test should be evaluated for its use in predicting the performance of aggregate used on aggregate roads.

RESEARCH IN PROGRESS

Currently the LRRB is funding three projects that involve aggregate roads.

1. Participating in an evaluation of dust suppressant and base stabilization products by the Environmental Technology Evaluation Center (EvTEC)/ Highway Innovative Technology Evaluation Center (HITEC). This national project will evaluate six types of products that are being marketed currently to determine their performance characteristics and environmental impacts.
2. Construction of a surface treatment over an existing aggregate road to determine the performance and cost/benefits to upgrade an existing aggregate road.
3. Improve guidelines for the duration of the spring load restricting that are appropriate for aggregate surfaced roads.

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3. Scullion, T., and T. Saarenketo, "Using Suction and Dielectric Measurements as Performance Indicators for Aggregate Base Materials," Submitted for Presentation and Publication at 1997 Annual Meeting of Transportation Research Board, Washington, D. C., July 1996.

4. Greenfield, P.H., and S.C. Ashmore, "Effects of Vehicle Type and Tire Pressure on Dry-Weather Road Maintenance," Proceedings for the Sixth International Conference on Low-Volume Roads, June, 1995: p291-301.

5. Moore, J., and E.V. Easley, "Iowa's Granular Surfaced Roads," Iowa Limestone Producers Association (Des Moines), Survey and Report, May, 1971.

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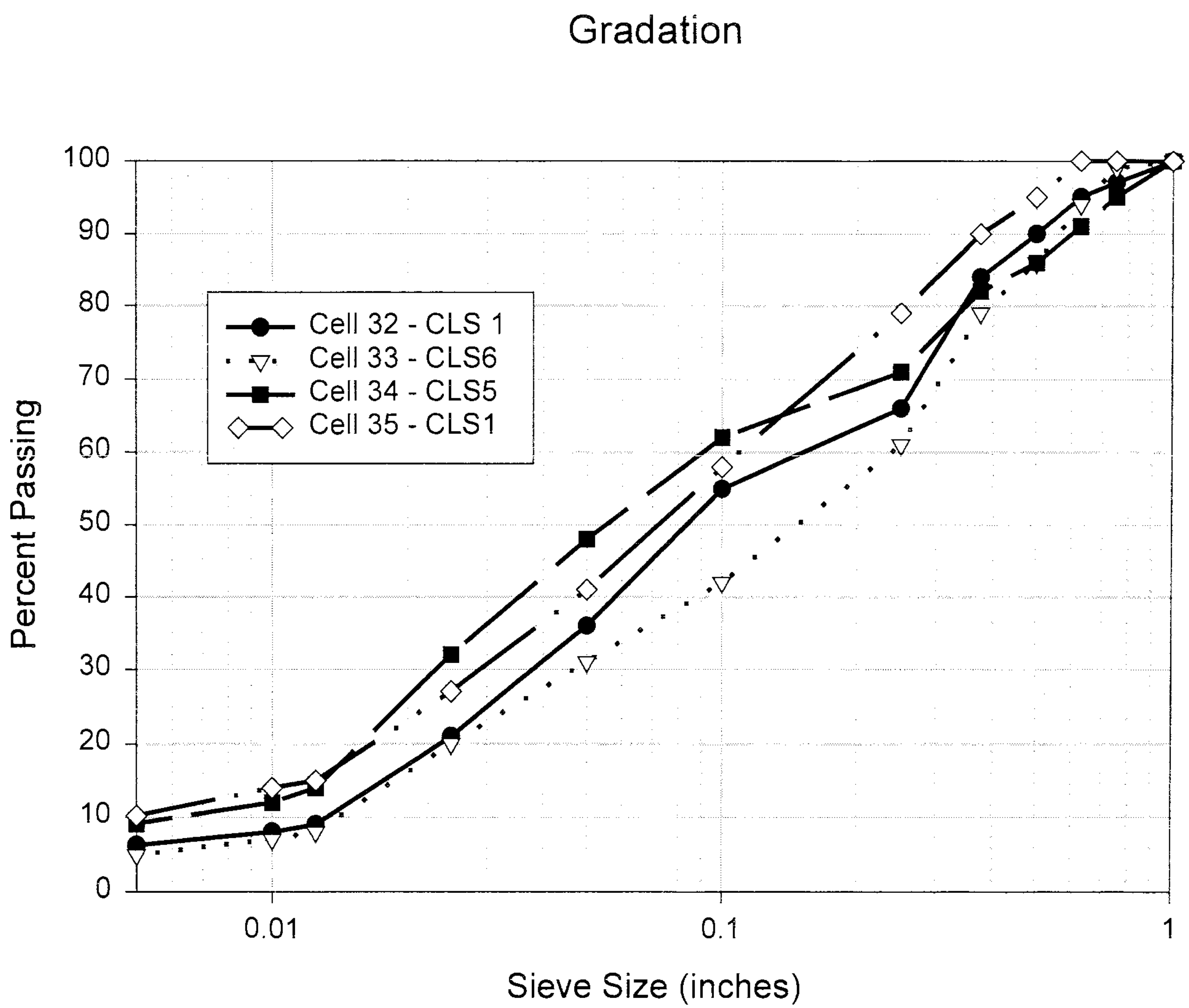
Appendix A

Aggregate Testing Results

Appendix A

Aggregate Testing Results

ggregate Type	Class 1 Coarse	Class 1 Fine	Class 5	Class 6	Class 1
ection #	Old 34	35	34	33	32
hickness (in.)	12	12	6	6	6
it Location	Goetzky	Buffalo	Bauerly – Elmore	Shiely – Elk River	Bauerly - Bu
5.0 mm (1in.) %	100	100	100	100	100
9.0 mm (3/4in.) %	99	100	95	99	97
6.0 mm (5/8in.) %	-	100	91	94	95
2.5 mm (1/2in.) %	-	95	86	86	90
.5 mm (3/8in.) %	79	90	82	79	84
.75 mm (#4) %	63	79	71	61	66
.0 mm (#10) %	53	58	62	42	55
.85 mm (#20) %	40	41	48	31	36
.425 mm (#40) %	23	27	32	20	21
.18 mm (#80) %	-	15	14	8	9
.15 mm (#100) %	9.6	14	12	7	8
.075 mm (#200) %	7.8	10.2	9.1	4.9	6.2
hale, ½ in. +		1.77	1.15	0	0.17
hale		4.2	2.74	0.05	0.16
ther Rock		95.8	97.26	99.95	99.84
pall, ½ in. +		1.77	1.15	0	0.17
pall, #4 +		4.2	2.74	0.05	0.16
pall + Soft Rock, #4 +		4.2	2.74	0.05	0.16
oft, Iron Oxide		0	0	0	0
rushed Rock		32.61	67.75	65.73	56.25
hale in Sand		2	1.8	Trace	Trace
% Silt	6.8	8.8	5.1	4.7	8.5
% Clay	1.3	1.9	2.3	0.8	2.8
A.A.S.H.T.O. Group	A-1-b	A-1-b	A-1-b	A-1-b	A-1-b
Optimum Moisture % by wt.	6.2	9.6	9.3	8.2	6.7
Maximum Density (lb/ft^3)	136.4	130.0	128.4	133.1	137.2
Liquid Limit	N/P	N/P	22.1	N/P	N/P
Plastic Limit	N/P	N/P	20.2	N/P	N/P
Plasticity Index	N/P	N/P	1.89	N/P	N/P
Adsorption		5.6	6.9	2.8	4.8


Gradation
Percent Passing
Sieve Size (inches)
Cell 32 - CLS 1
Cell 33 - CLS6
Cell 34 - CLS5
Cell 35 - CLS1
0
10
20
30
40
50
60
70
80
90
100
0.01
0.1
1

APPENDIX B

Adsorption Test Procedure

APPENDIX B

Adsorption Test Procedure [11]

Equipment:

- Desiccator with 20-30 mm deionized water on the bottom
- China crucibles (6 pieces/desiccator)
- Oven (105°C constant temperature)
- Laboratory scale with 0.001 g accuracy

Material

- Dry sieved <200 mesh (<0.074 mm) aggregate or soil fines

Pretest Arrangements

1. Number china crucibles and place them in 105°C oven for 24 hours.
2. Weigh the crucibles immediately after removal from oven. **(Dry Container)** (first stable reading after 10-20 seconds)
3. Place crucibles into desiccator for 24 hours. (make sure water is on bottom of desiccator [100% humidity])

   Note: Laboratory temperature should be stable between 20-22°C.

4. Remove from desiccator and reweigh crucibles. **(Adsorbed Container)**
5. Calculate the amount of moisture that each crucible has absorbed. (This amount will used in the final adsorption test)

Adsorption Test

1. Place about 1 g of test material. (<#200 material) into crucible
2. Place crucibles with samples into 105°C oven for 24 hours.
3. Remove each crucible (one by one) and weigh. **(Dry Sample)**
4. Place crucibles in desiccator.
5. Weigh the adsorbed samples daily after 3 days adsorption time until weight does not increase. **(Adsorbed sample)**

   Note: Notice that the temperature, air pressure, and salts have an effect on the adsorption.

6. Calculate the water adsorption % =(((Adsorbed Sample-Dry Sample)-(Adsorbed Container-Dry Container))/(Dry Sample-Dry Container))

APPENDIX C

SURFACE DIELECTRIC TEST PROCEDURE

APPENDIX C

SURFACE DIELECTRIC TEST PROCEDURE

Apparatus:

1. 6 inch x 12 inch cylinder mold, with 1/16th inch holes drilled at ½ inch intervals around the circumference approximately ¼ inch from the bottom. Four additional holes are drilled in the base.
2. Water reservoir
3. Scale
4. Vibratory Compactor
5. Drying Oven
6. Percometer (Measures Dielectric and Conductivity values)

Compaction:

1. Compact samples in plastic cylinder molds using a vibratory compaction method.
2. Compact samples at optimum moisture content, to approximately 100% relative density.
3. Compaction is done in 6-8 layers depending on material density.
4. The height of compacted sample should be between 7.0 and 7.8 inches.
5. Place samples in 113°F for drying until weight stabilization occurs. (2-4 weeks, depending on material)
6. Allow samples to cool 2 days at room temperature prior to being placed in water bath.

Surface Dielectric Test

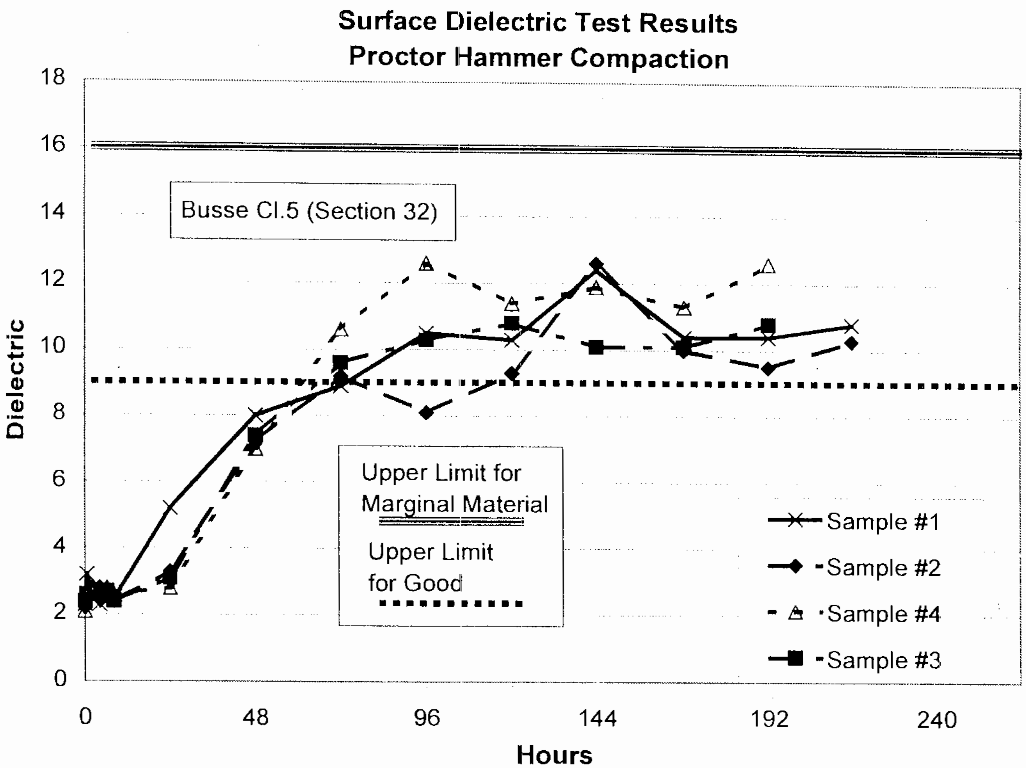
1. Take initial measurement of dielectric and conductivity.
2. Immerse sample in 10-20 mm bath of distilled water.
3. Measure the dielectric of the sample by taking six readings at each time interval. The highest and lowest are thrown out, and the other four averaged together.
4. Weight the sample.
5. Continue to do Steps 3 & 4 at the following intervals. (30,120,240,360,480 minutes and daily thereafter)
6. Continue to take the above measurements until a stable is taken for three consecutive days.
7. Graph the results, with the dielectric value on the vertical axis and time on the horizontal.

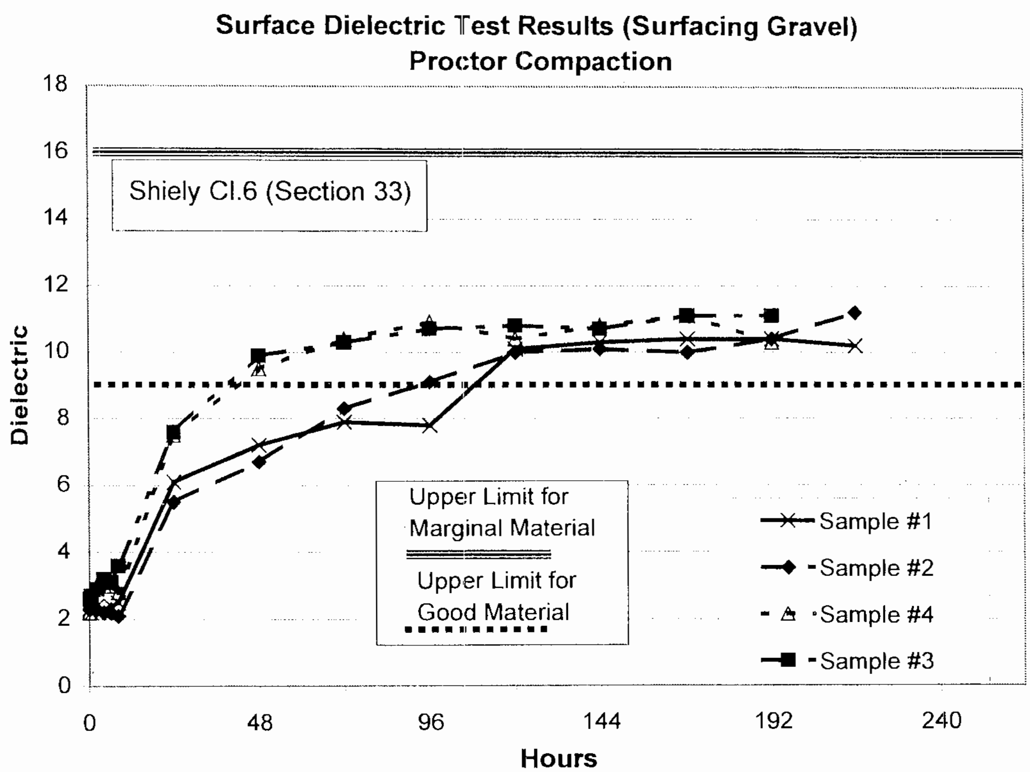
APPENDIX D

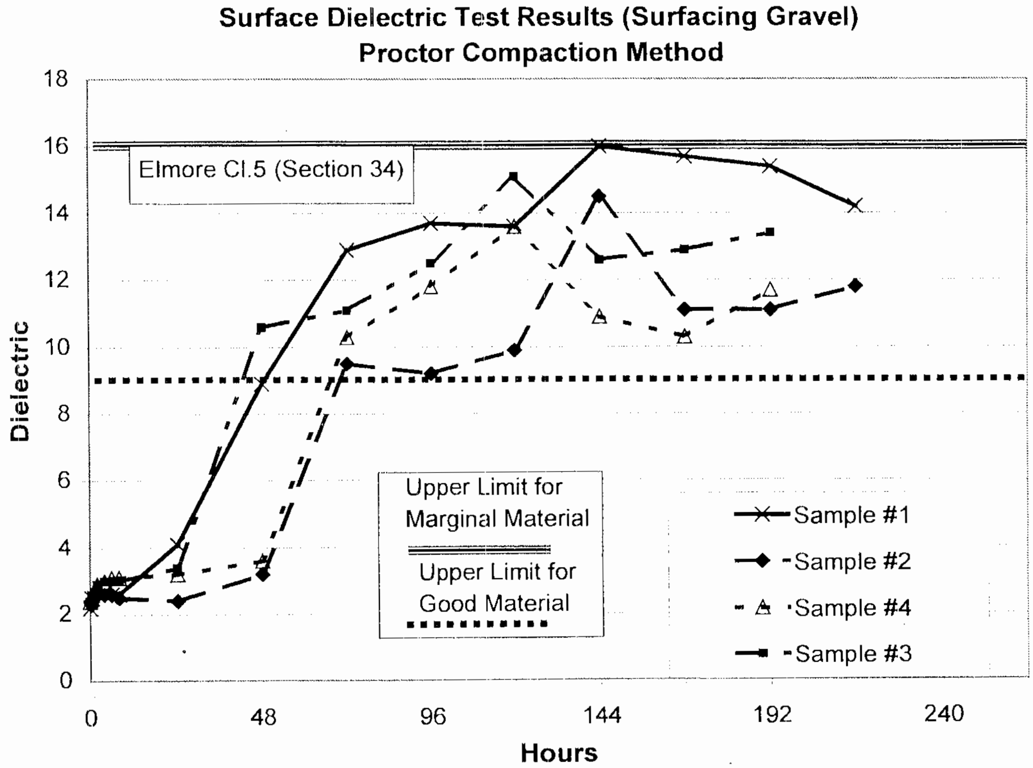
SURFACE DIELECTRIC RESULTS

APPENDIX D

SURFACE DIELECTRIC RESULTS



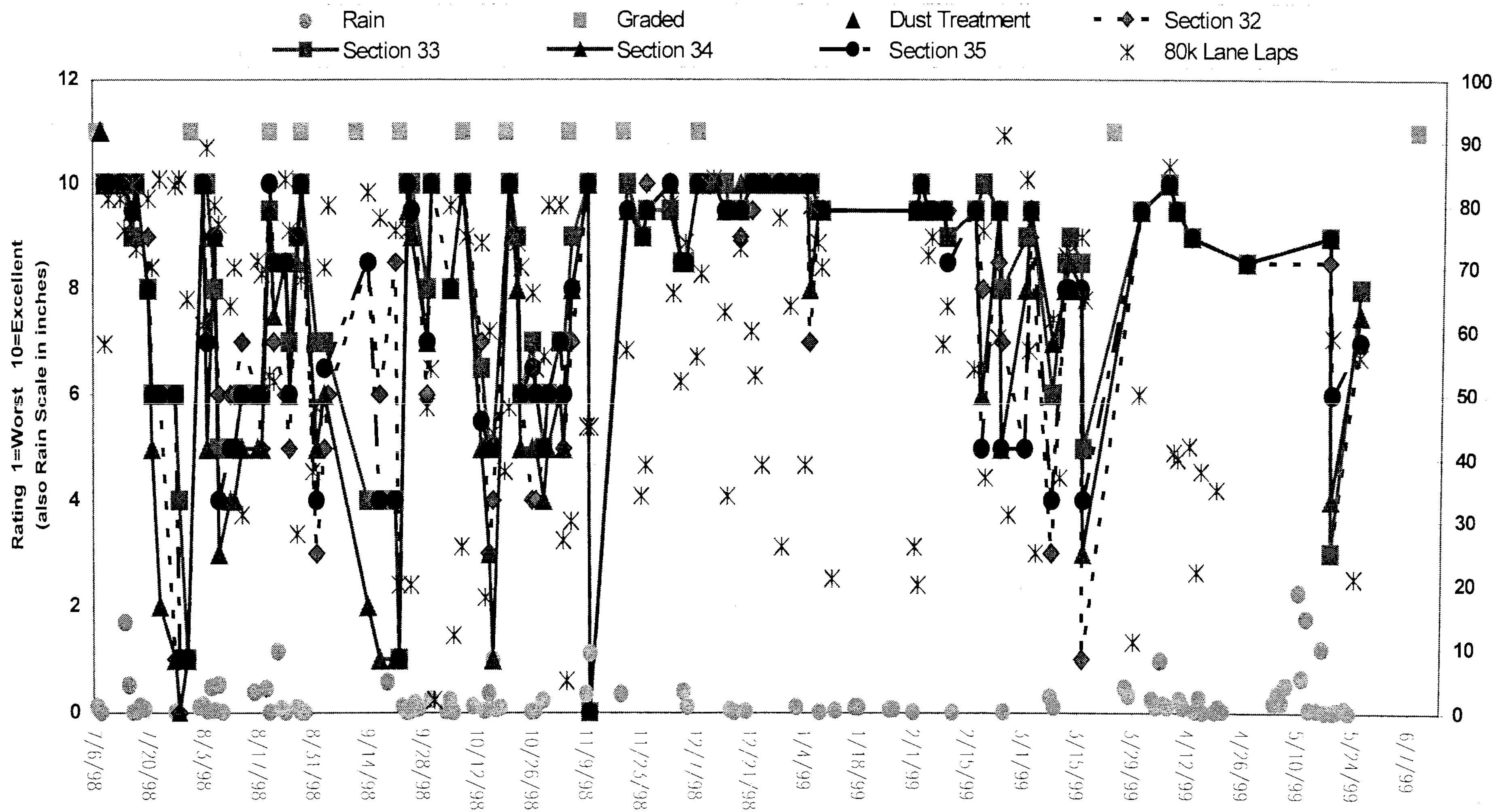


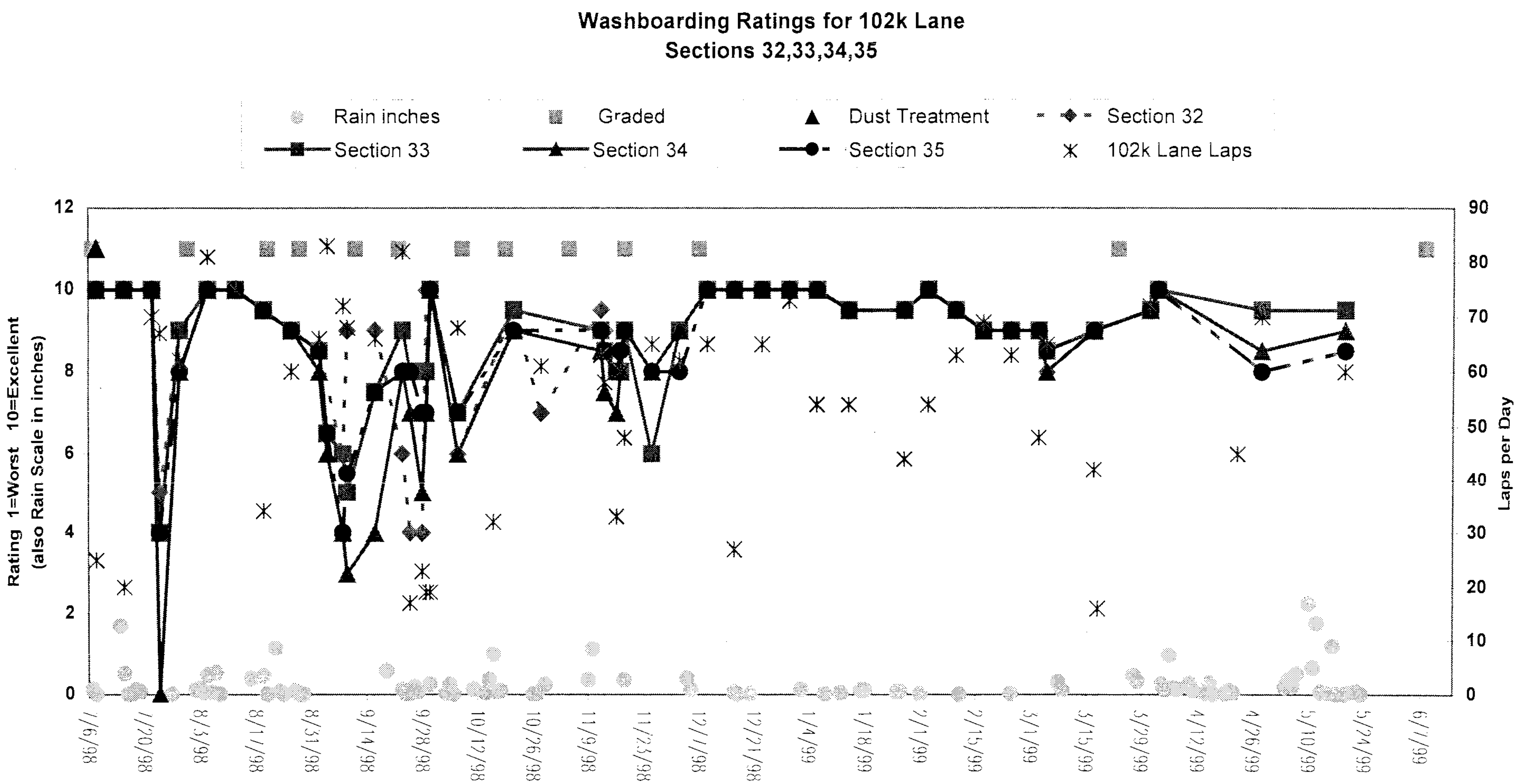

Surface Dielectric Test Results (Surfacing Gravel)
Proctor Compaction Method
Elmore Cl.5 (Section 34)
Upper Limit for Marginal Material
Upper Limit for Good Material
Sample #1
Sample #2
Sample #4
Sample #3
Dielectric
Hours
0
48
96
144
192
240
0
2
4
6
8
10
12
14
16
18

APPENDIX E

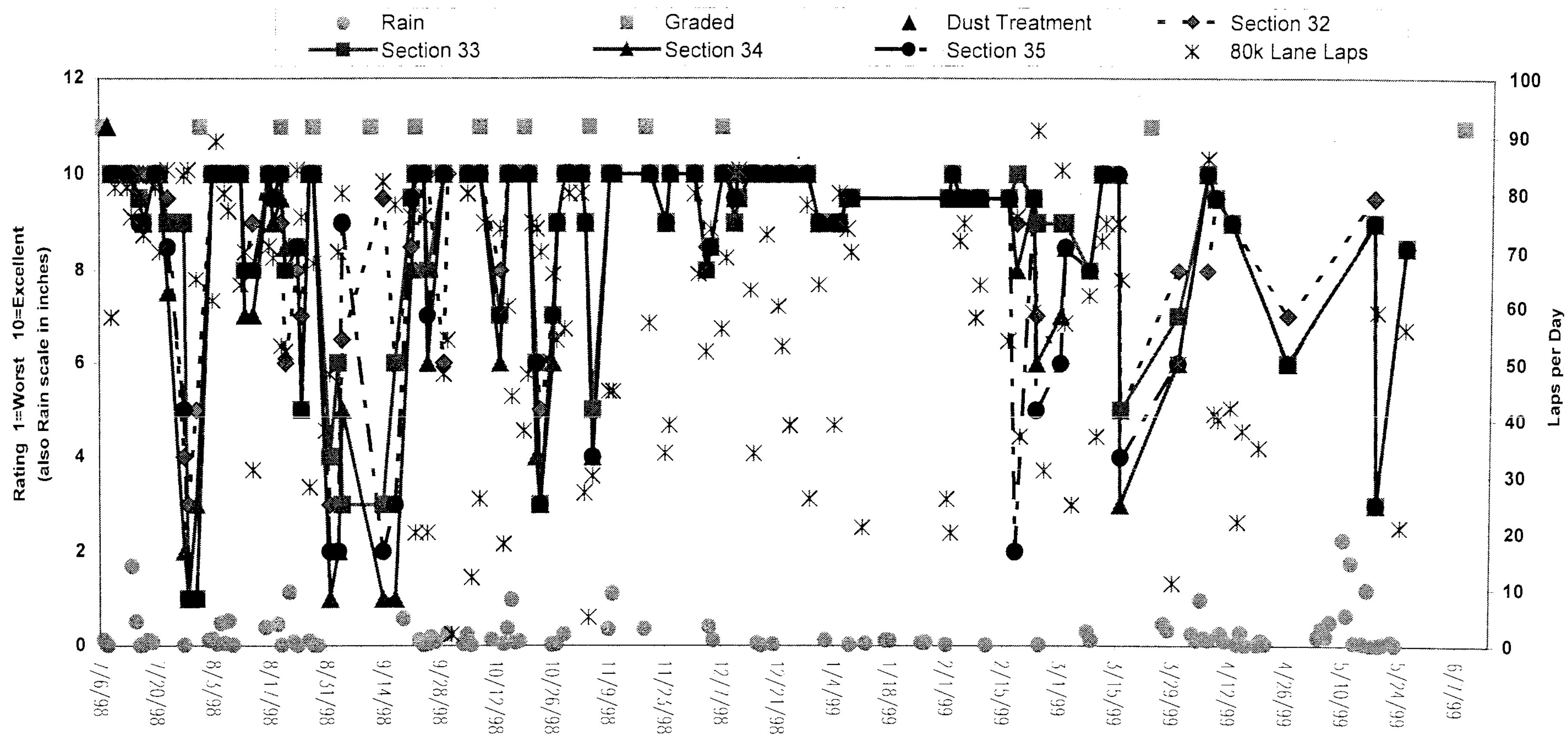
DRIVER RATINGS

Washboarding Ratings for 80k Lane
Sections 32,33,34 and 35

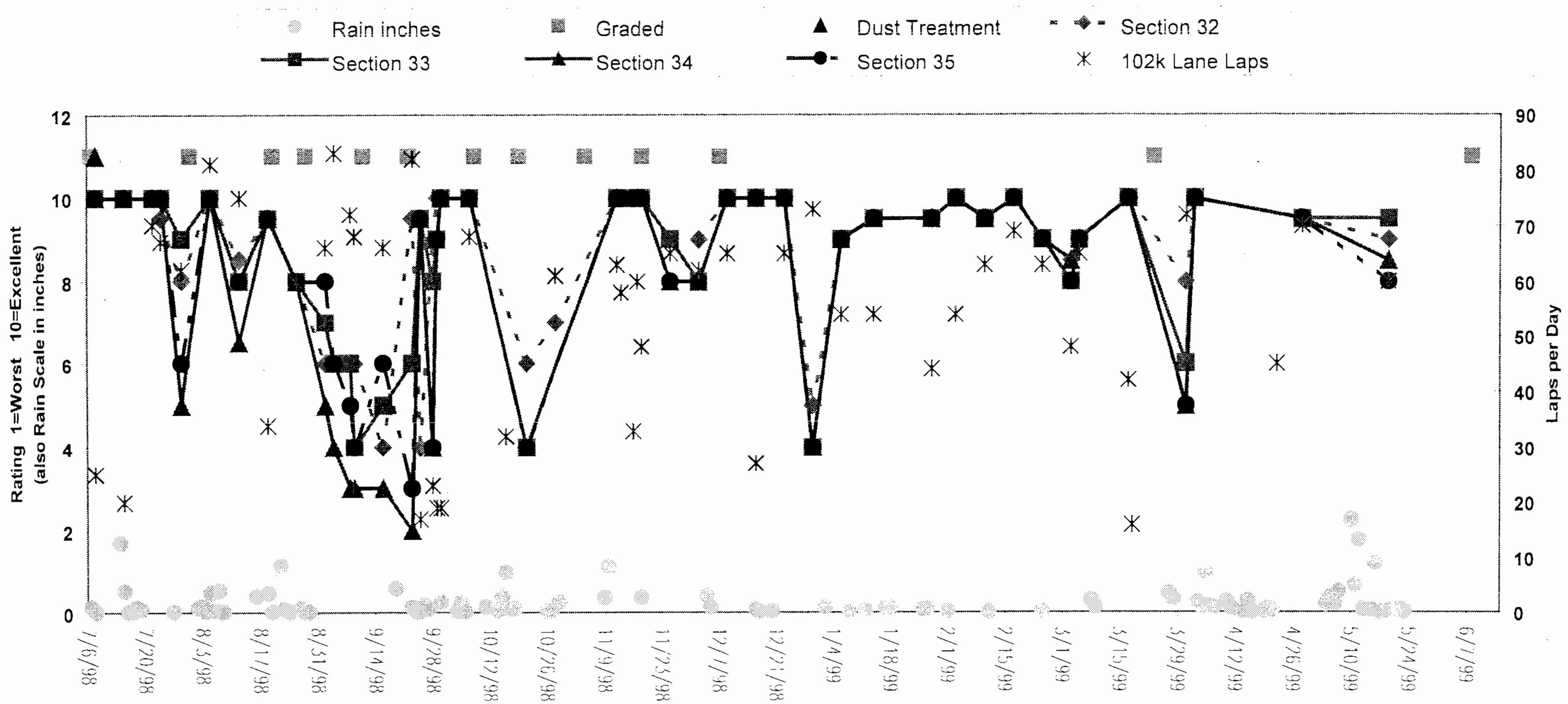



Washboarding Ratings for 102k Lane
Sections 32,33,34,35
Rain inches
Graded
Dust Treatment
Section 32
Section 33
Section 34
Section 35
102k Lane Laps
Rating 1=Worst 10=Excellent
(also Rain Scale in inches)
Laps per Day
12
10
8
6
4
2
0
90
80
70
60
50
40
30
20
10
0
7/6/98
7/20/98
8/3/98
8/17/98
8/31/98
9/14/98
9/28/98
10/12/98
10/26/98
11/9/98
11/23/98
12/7/98
12/21/98
1/4/99
1/18/99
2/1/99
2/15/99
3/1/99
3/15/99
3/29/99
4/12/99
4/26/99
5/10/99
5/24/99
6/7/99

Dust Ratings for 80k Lane
Sections 32,33,34 and 35



Dust Ratings for 102k Lane
Sections 32,33,34,35



Office of Research Services
395 John Ireland Blvd., Mail Stop 330
St. Paul, MN 55155-1899

(651) 282-2274