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1999 Statewide Micro Surfacing Project

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This project introduced the use of micro surfacing as a pavement preventive maintenance surface treatment and tested different methods of using micro surfacing to correct or prevent defects in existing pavements.

Micro surfacing mixtures include polymer-modified emulsified asphalt cement, a well-graded 100 percent crushed mineral aggregate, and mineral filler, such as Portland cement or hydrated lime, with water and control additives added to control the speed of breaking and workability. Micro surfacing remains semi-liquid during mixing and placing phases and then cures chemically for a very durable asphalt surface treatment.

Application and testing revealed that the fast-moving micro surfacing process minimizes the amount of down time for traffic; does an excellent job of reestablishing cross sections; fills ruts; improves ride quality; increases friction numbers; and provides an excellent background for pavement markings. It does not seal reflective cracks, has generated some concerns about increased traffic noise, and does not work favorably for smoothing humps in pavement.

Overall, project selection played a key factor in the overall success of micro surfacing. A very thin surface treatment, micro surfacing cannot be expected to fix structural problems in existing pavements. Avoid using micro surfacing on roadways that are still rutting and repair potholes before placement of micro surfacing.

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1999 STATEWIDE MICRO SURFACING PROJECT

Final Report

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Chapter 1

Statewide Micro Surfacing Project

1.1 What is Micro Surfacing?

Micro Surfacing is a mixture of polymer-modified emulsified asphalt cement, a well-graded 100 percent crushed mineral aggregate, and mineral filler such as Portland cement or hydrated lime. Water and control additives are added to control the speed of breaking and workability. Micro Surfacing is a semi-liquid material during the mixing and placing phase of construction. It then cures chemically to provide a very durable asphalt surface treatment. The normal application thickness for a surfacing treatment is ⅜ to ½ inch thick. Micro Surfacing is also used to re-establish the cross-sections on rutted highways.

1.2 Objective

The objective of the statewide Micro Surfacing project was to introduce the use of Micro Surfacing as a pavement preventive maintenance surface treatment. It also allowed testing of different methods of using Micro Surfacing to correct or prevent defects in existing pavements.

1.3 Scope

The districts were surveyed to determine what projects were available to be included in a Micro Surfacing contract. It was decided to join the numerous projects into one contract to make it more attractive to contractors. District 3B in St. Cloud agreed to administer the contract and furnish the chief inspectors.

The original contract called for the following quantities of Micro Surfacing:

- 386,996 square meters of single pass Micro Surfacing.
- 348,093 square meters of single pass Micro Surfacing Special. This is the pay item for single pass surfacing with a 2-year warranty.
- 352 metric tons of Micro Surfacing Rut Fill Special. This is the pay item for rut filling with a 2-year warranty.

Additional projects were added to the contract and some of the work limits were changed during construction. All Micro Surfacing was done with an International Slurry Surfacing Association (ISSA) type II mix, except where a type III is noted **(Table 1)**. The contractor chose to use an Ortonville Stone Company's granite for all the project segments except in District 6. A Meridian Aggregate granite was used on the District 6 projects.

Sieve Size	Type II	Type III
9.5 mm (3/8")	100	100
4.75 mm (#4)	90 – 100	70 – 90
2.36 mm (#8)	65 – 90	45 – 70
1.18 mm (#16)	45 – 70	28 – 50
600 µm (#30)	30 – 50	19 – 34
300 µm (#50)	18 – 30	12 – 25
150 µm (#100)	10 – 21	7 – 18
75 µm (#200)	5 – 15	5 –15

Micro Surfacing Gradation

Table 1

1.4 Process

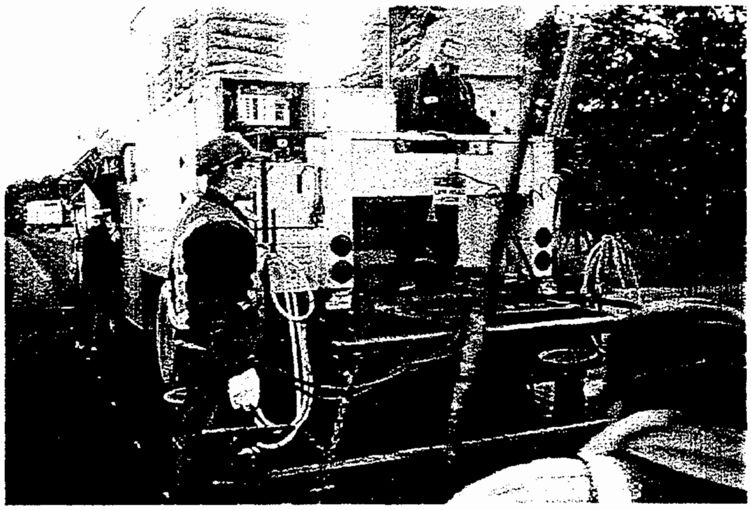
Micro Surfacing is made using a mobile mixing/paving machine hereafter referred to as a Micro Surfacing machine (**Photos 1 & 2**). MN/DOT's specification only allows use of a continuous Micro Surfacing machine; truck mounted Micro Surfacing machines are not allowed. This requirement is in place to limit the number of joints made in the surfacing project. The Micro Surfacing machine is supported by a fleet of supply trucks that carry aggregate, water, and emulsion to the Micro Surfacing machine (**Photo 3**). The Micro Surfacing machine is able to carry approximately 12 tons of aggregate, as well as all the other components. The supply trucks are located in front of the Micro Surfacing machine, which pushes the trucks along as materials are discharged into the Micro Surfacing machine. An experienced crew keeps the operation moving while supply trucks are unloading. Anytime the Micro Surfacing machine stops moving for as little as 15 seconds the crew must pick up the paving box and clean it. It can take up to 15 minutes to clean the paving box and square up the seam on the roadway.

1.5 Location and Planned type of Treatment

It is very important to understand the different treatments of Micro Surfacing described in Location Table found in Appendix A. These treatments are also described in more detail later in this report. The most cost-effective application of Micro Surfacing is as a preventive maintenance treatment to a structurally sound pavement, early in the pavement life. The limits of Micro Surfacing were stretched beyond a true preventive maintenance treatment as part of our research:

- Rut filling without a surface course. (The preferred method is to use a combination of filling the ruts and then applying a surface course).
- Micro Surfacing used as reactive maintenance. This may prove to be cost effective but should not be considered to be preventive maintenance.

When viewing these locations in the field, it is important to understand how the micro surfacing was used.

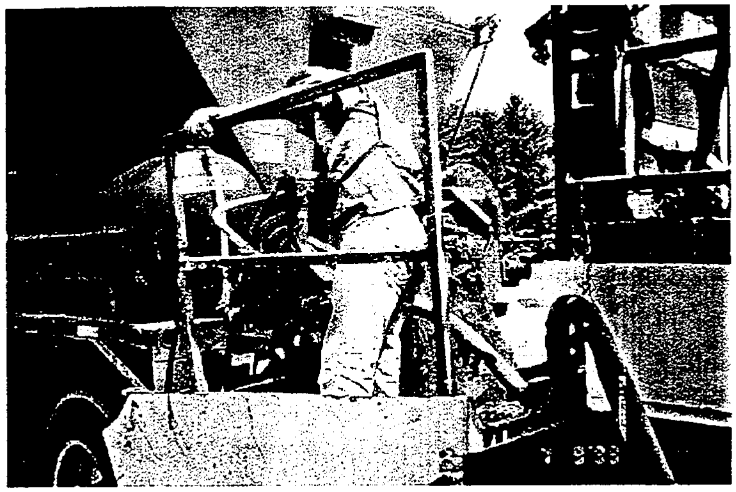


Rear view of continuous Micro Surfacing Machine

Photo 1

Front View of continuous Micro Surfacing Machine.

Photo 2



Truck off loading into the front of Micro Surfacing Machine.

Photo 3

CHAPTER 2

Project Summaries

2.1 District 2 - Bemidji

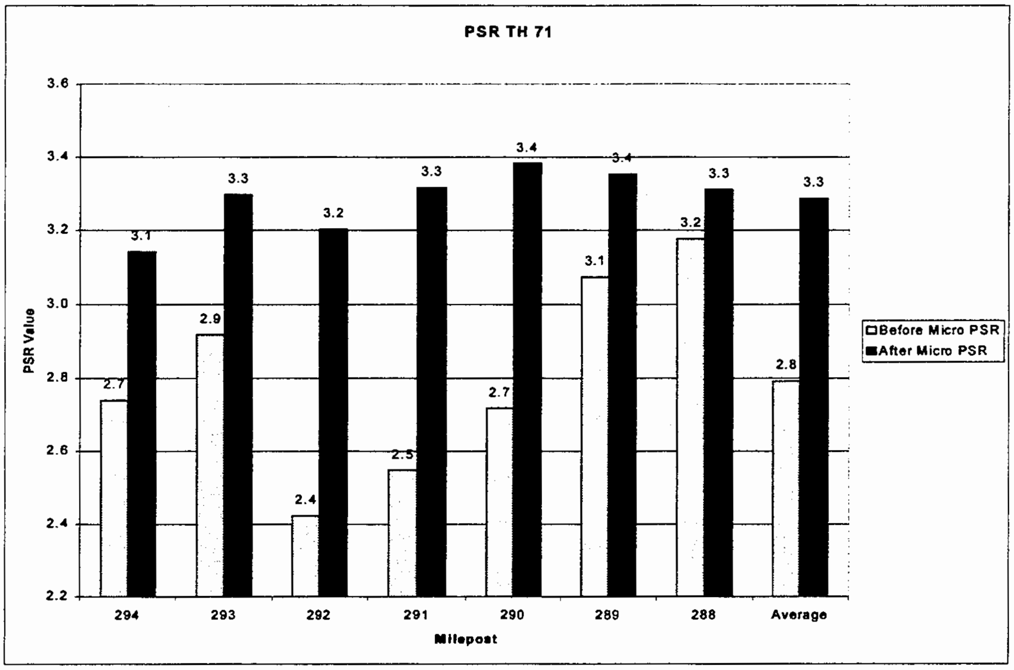
2.11 TH 2

This project was a single pass Micro Surfacing used as reactive maintenance. The district goals for Micro Surfacing this roadway were to improve the ride and slow down the formation of potholes for five years, at which time the next re-grading job is scheduled. TH 2 from milepost 163.800 to 168.800 just west of Deer River, Minnesota is a two-lane highway. It is the main east-west route across the upper part of the state. The Average Daily Traffic (ADT) count is 3,100 in rural areas and 7,400 in the city of Deer River. The route was last graded in 1939. It received its last overlay in 1984, which was 4.5 inches of hot mix asphalt over the concrete road. The roadway has deteriorated to the point where transverse cracks are starting to form small potholes.

2.12 TH 71

This project was a rut filling and surface course used as a preventive maintenance project. TH 71 from milepost 287.300 to 294.111 was added to the original contract. TH 71 is a two-lane highway that carries tourists to the headwaters of the Mississippi River. This roadway was last graded in 1985 and then paved with 5.5 to 6.5 inches of hot mix asphalt in 1985. The ADT is 2,300. The district was concerned about rutting that was up to ¾ inch deep. They decided to have the Contractor rut fill and then place a surface course of Micro Surfacing on the route. The rut filling operation uses a specially designed paving box that is five to six feet wide. It is equipped with two-spiral augers placed in a "V" shape to facilitate the movement of Micro Surfacing mix to the deepest point of the rut. The strike-off screed can be adjusted to place a crown into the material as it is placed. The crown is placed in the material to allow for consolidation as it cures.

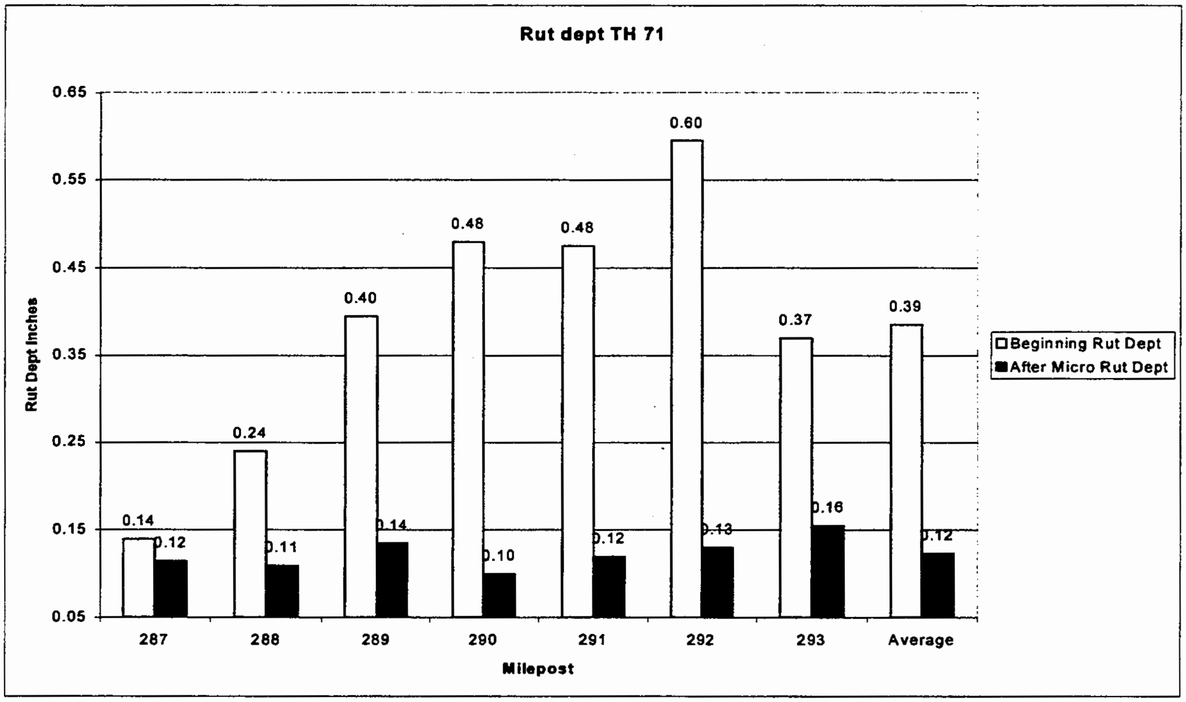
After the rut filling operation on the eastbound lane the Contractor suggested the method of operation be changed from using a traditional rut filling box on each wheel path to a 12 foot wide scratch course for the westbound lane. A scratch course is constructed using the normal paving box for applying the surface course with one change: The primary rubber screed is removed and replaced with a steel bar. This allows the paving box to ride on the high points of the road and place the material in the low areas. The use of the scratch course saved approximately 15 tons of material on the westbound lane compared to the eastbound lane. The ride data shows no difference between the two methods of rut filling used on this roadway (**Graph 1**).



Ride data for TH 71.

Graph 1

Note: The use of a scratch course should be limited to ruts under ½ inch. If the ruts have a greater depth, then the use of the rut box, or placing a double scratch course before the surfacing course should be considered **(Graph 2).**



Rut data for TH 71.

Graph 2

This roadway segment was scheduled to receive a mill and overlay in 2001. The estimated cost of the mill and overlay was $1,500,000. The Micro Surfacing at $400,000 cost less than 1/3 of the estimated cost of the mill and overlay. With an estimated life of seven to ten years, it is anticipated Micro Surfacing this project will have a greater cost benefit ratio.

2.2 District 3A, Baxter

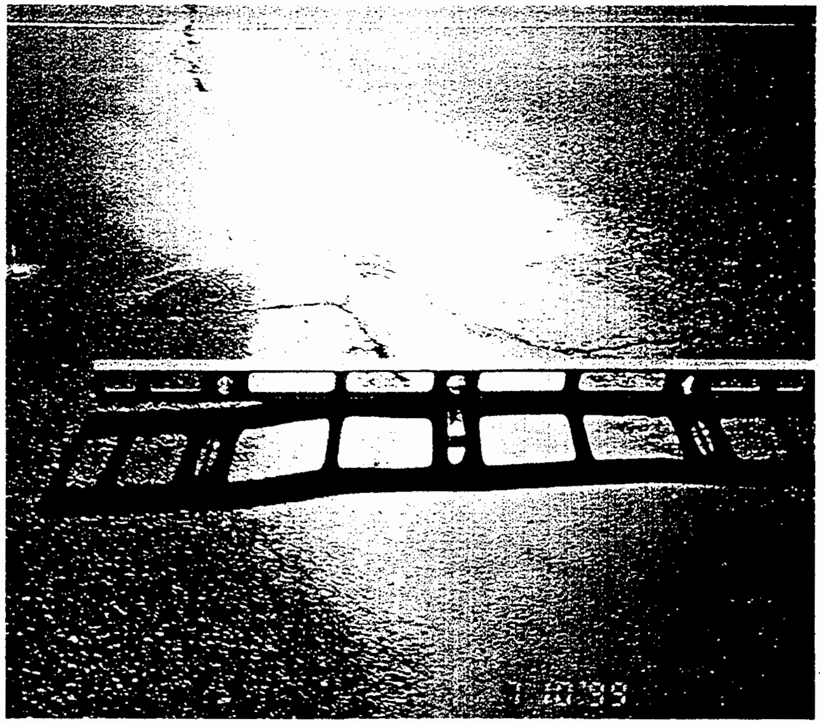
2.21 TH10 Staples

This project was a combination of preventive maintenance and reactionary maintenance to correct stripping and cupping in the right lane. TH 10 from milepost 105.048 to 96.746 is just west of Staples, Minnesota. This roadway is a four-lane divided highway with ADT of 7,000. The Micro Surfacing was placed only in the right westbound driving lane. The roadway was last paved in 1991 with 9 inches of hot mix asphalt. The upper layer of the right lane was experiencing stripping problems. The district decided to use Micro Surfacing to arrest the damage caused by the stripping. Micro Surfacing allows the material to be placed only where it was needed, due to the thin layers in which it is placed. If hot mix asphalt were used, both lanes and the shoulder would require paving or the right lane would be milled and filled.

The transverse cracks on this segment of roadway had been routed and sealed, and cupped up to ½ inch. The single pass of Micro Surfacing surface course removed approximately 60% of cupping. In order to restore a smooth surface with this type of cupping, two passes of Micro Surfacing are required.

2.22 TH 10 Rice

This project could best be characterized as ride restoration. TH 10 from milepost 170.091 to 162.091 is a four-lane divided highway with an ADT of 17,100. The Micro Surfacing was placed in the westbound lanes only. The eastbound lanes had a thin hot mix asphalt overlay placed with a motor grader. The roadway was graded in 1922 and last over laid in 1990 with 3 inches of hot mix asphalt. This section of roadway suffered from localized failures at the transverse cracks. Some of the cracks had developed potholes that district maintenance forces had filled with a blow patching system. Most of the patches were left high causing a slight hump



High patch on TH 10

Photo 4

Because of the characteristics of Micro Surfacing it does not level humps as well as it fills dips. If localized failures are to be patched before Micro Surfacing is placed, care must be taken not to leave any patches high. Early review of this roadway segment revealed that some of the patching materials are failing, causing the potholes to recur.

2.23 TH 10 at Big Lake

The Micro Surfacing was placed in the right lane of both directions to level and fill cupped transverse cracks. Only one course of Micro Surfacing was placed. TH 10 from milepost 203.568 to 204.000 is a four-lane undivided highway. With an ADT of 15,800. It was graded in 1947 and last overlaid in 1993 with 3.5 inches of hot mix asphalt.

2.24 TH 15

This project consisted of a single course of Micro Surfacing placed as a pavement preventive maintenance treatment. ADT of 11,500 from milepost 152.068 to 152.640, TH 15 is four-lane divided highway. This roadway was graded and paved in 1990 with 6 inches of hot mix asphalt.

2.25 TH 25

This project was a rut fill, accomplished in two passes of scratch course. TH 25 from milepost 67.706 to 68.722 is urban four-lane undivided highway located in the City of Monticello with a combination of head to head left turn lanes and center islands. This segment of roadway was last graded and paved in 1986 with 5 inches of hot mix asphalt. The ADT is 14,400. The hot mix asphalt was rutted from ½ inch to as much as1½ inches at the stop bars at the major intersections. In order to facilitate the re-establishment of cross section, this section was milled to remove the areas where the mix had pushed up along the curb line. The Micro

Surfacing was placed using a scratch course with the original plans calling for rut filling with no surface course. The contractor chose to place a second scratch course over the completed project to repair the damage caused by high traffic volumes driving on new Micro Surfacing immediately after placement. The second course also insured that the proper cross section had been re-established. Some of the head-to-head left turn lanes were not Micro Surfaced because no rutting existed. This lack of uniform coverage has caused slight water damming problems due to the lack of slope in the original pavement. The visual difference between the two types of pavement is pronounced and distracting.

2.26 I- 94 Bridges over County Road 75 and 19

Micro Surfacing was used on this project to increase the friction numbers to reduce accidents. The sections of interstate I-94 that were Micro Surfaced are from milepost 194.984 to 195.785 and milepost 199.600 to 200.321. These sections were graded and paved with concrete in 1973. The ADT is 40,400. The two areas which received Micro Surfacing on I-94 are two bridges and approaches to the bridges that have a high accident rate due to alignment and elevation changes. The International Slurry Surfacing Association (ISSA) Type III Micro Surfacing was placed on both lanes for a distance of 1,750 feet before the bridge to 1750 feet past the bridge. There have been comments about the increase in noise caused by using the ISSA Type III **(Table 1)**.

2.27 I-94 at Mn/Road site

The Mn/Road research staff decided to use Micro Surfacing on two cells to correct rutting of up to ¾ inch deep. Cells 20 and 23 are 500 feet long test sections on the MN/Road test sections on lanes to I-94 west of Albertville, Minnesota. The method of filling the ruts was to use a traditional rut fill box with ISSA Type II Micro Surfacing. This was followed by a single course Micro Surfacing of ISSA Type II on Cell 23 and ISSA Type III on Cell 20.

2.28 TH 169

This project used a single pass rut fill to correct rutting in the right driving lane from milepost 158.811 to 163.190. TH 169 is a divided four-lane highway graded in 1986 and overlaid in 1991 with 3 to 4 inches of hot mix asphalt. The ADT is 28,100. The Micro Surfacing was placed using a single course scratch course to fill the ruts and re-establish the cross section. The early review shows a successful re-establishment of the cross section. One negative observation made was that the wheel paths look like they are bleeding. This appearance is caused by using only a single course to fill ruts. This method allows the larger size stones to settle into the deepest part of the rut or depression. The normal method of rut filling is to place a surface course of Micro Surfacing over the rut-filling course. The second course gives the pavement surface a uniform look with greater friction numbers.

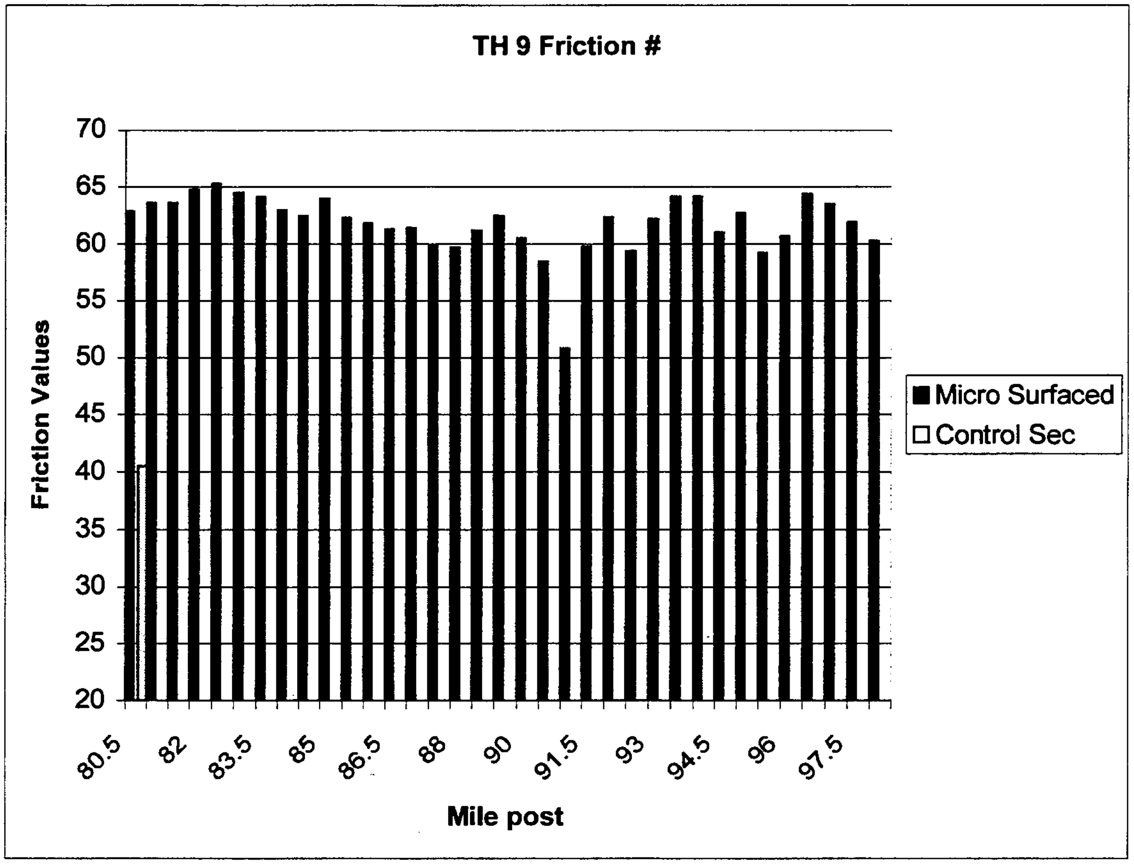
2.3 District 4 Detroit Lakes

2.31 TH 9

On this project, Micro Surfacing was used to correct severe raveling on TH 9 from milepost 79.791 to 98.050 from Herman, Minnesota to the junction of TH 55. This is a two-lane highway with an ADT of 700. The roadway was graded in 1950 and last overlaid in 1994 with 3.5 inches of hot mix asphalt. The paving was completed late in the season during a period of cold rainy weather, which caused a severe raveling problem; in some cases, the wearing coarse had raveled completely off at the centerline.

The transverse cracks had been routed and sealed. In some places the cracks were spaced as little as 5 feet apart. The plan was to place a single course of Micro Surfacing over 75 percent of the roadway with the worst 25 percent receiving two courses of Micro Surfacing. Due to the dryness in asphalt in the upper layer of the hot mix asphalt, it was decided to tack the surface before placement of the Micro Surfacing. The tack used was a CSS-1H diluted 50 percent with water. The application rate was .08 gallons per square yard.

Early review in the late fall of 1999 has shown very fine cracks appearing on both edges of the routed crack sealant. The Micro Surfacing appears to have a strong bond to the crack sealant. Friction test were run on this segment in the Fall of 1999 and shown that use of Micro Surfacing yielded a significant increase in the friction numbers **(Graph 3)**.



Friction numbers for TH 9

Graph 3

2.4 District 6 Rochester

2.41 TH 14

A project on TH 14 was added to the contract to correct rutting in the truck lane on a 6 percent uphill grade. TH 14 from milepost 251.2 to 252.9 has an ADT of 4,850 with 350 heavy trucks that use only the truck lane. The truck lane had ruts up to 1 inch deep. The ruts were filled with an ISSA Type III. This rut filling was followed by a surfacing course using ISSA Type II. The contractor chose to use Meridian Aggregate granite from the St. Cloud quarry on all of the Micro Surfacing work in District 6 due to production problems, which made delivery of material from Ortonville Stone impossible. Early review of this project shows that the Micro Surfacing is performing as expected. The re-establishment of the cross section has made this section of roadway safer to drive on especially during rain events.

2.42 TH 52

It was suggested to use Micro Surfacing on this project to test its ability to fix damage in hot mix asphalt caused by horseshoe cleats. A large Amish population uses the shoulder for travel in this area located on TH52 near Harmony MN. The center of the shoulder has an area approximately two feet wide showing a large amount of pocking caused by the striking of the horseshoes. The damage has caused pocks in the hot mix asphalt up to .75 inch deep. If this method of repair is successful, the technique could be tried to repair damage caused by studs on snowmobile tracks. Observations made one month after construction show new damage being caused by the horseshoes to the Micro Surfacing. Reviews of this section during the summer of 2000 reveals that the Micro Surfacing is performing satisfactorily. The area of the repairs is on TH 52 shoulders from milepost 0.000 to 9.257 in both directions.

2.5 Metro Division

2.51 I-35

This project was done as a true preventive maintenance treatment. I-35 from milepost 138.000 to 141.000 northbound and 137.000 to 140.000 southbound received a single course Micro Surfacing this segment is located north of Forest Lake, MN exit. The ADT is 36,500. The roadway was graded in 1968 and last overlaid with 4.75 inches of hot mix asphalt in 1986. After the contract was let, it was decided to test the effectiveness of using a scratch course to level slightly ($<\frac{3}{8}$ inch) cupped transverse cracks. The scratch course was placed in the right lane on the northbound side from milepost 139.500 to 141.000.

Chapter 3

Early Conclusions

The following is an early list of both positive and negative conclusions.

3.1 Quick construction

Micro Surfacing is a very fast moving process, which allows early return to traffic. The contractor averaged four lane miles per eight-hour day of construction. This average time include mobilization and set up of stockpile sites. The best day of construction was six lane miles for an eight-hour day. The general contractor was returning rolling traffic on the Micro Surfacing in less than 20 minutes after placement.

This rapid return to traffic is only possible with a chemical cure. One of the easiest methods to test for a true Micro Surfacing system, and not a polymer modified slurry system, is to require the construction of a test strip after dark. The test strip should be able to carry rolling traffic in less than one hour after construction without any visible signs of damage from vehicle tires.

3.2 Re-establishes cross-section

Micro Surfacing does an excellent job of reestablishing cross sections. The semi-liquid state of the mixture at application allows large particles to flow into the low areas. The high spots receive only the smaller particles and emulsion. If the cross section profile is greater than ¼ inch, it is recommend to use a scratch course. A scratch course is constructed using the normal paving box for applying a surface course with one change; the primary rubber screed is removed and replaced with a steel bar. Anytime a scratch course is applied, it should be covered with a surface course to give a more uniform surface texture.

3.3 Fills ruts

There are two methods of filling ruts; filling each wheel rut with a rut box or filling both wheels ruts with a scratch course. The depth and shape of the ruts will help to determine which method to use. If the ruts are less than ½ inch deep and vary in the location in the lane, use of a scratch course would probably be the most economic method to fill the ruts. For ruts with depths of greater than ½ inch, a traditional rut box should be used. The traditional rut box is 5-6 feet wide with a "V" shaped rubber screed. The screed allows a crowning to be placed for slight compaction on curing. The rut fill box also has two spiral augers that facilitate placement of the larger aggregate particles in the deepest part of the ruts. Using the traditional rut fill box requires making a pass over each wheel rut in each lane in order to fill it **(Graph 2)**.

3.4 Improves ride qualities

The semi-liquid state of Micro Surfacing at the time of placement allows it to be effective at leveling cupped transverse cracks, dips, and edge drop off. Two applications of Micro Surfacing are recommended if there are deformations greater then ¼ inch in depth. This will yield a much smoother ride for little additional cost. One example of the combination would be to first use a scratch course then follow with a surfacing course. If there are ruts greater then ½ inch, a rut fill might be used in place of the scratch course **(Graph 1)**.

3.5 Increases friction numbers

Minnesota Department of Transportation's (Mn/DOT) specification required the use of Class A aggregates for base material to make Micro Surfacing. Class A aggregates are Granite, Traprock, Basil, Quartzite, and Taconite tailings. This class of aggregates is the hardest, most durable stone available in the state. The angular nature of quarried (100% crushed) aggregates provide superior friction characteristics. The durability provided by Class A aggregates resists tire polishing and extends the life of the Micro Surfacing. The friction numbers on the ISSA Type II Micro Surfacing are surprisingly high, in the low to mid 60's (above a 35 being acceptable). On the I-94 project, two bridge decks and approaches were Micro Surfaced to increase friction and eliminate accidents caused by icing. ISSA Type III **(Table 1)** was chosen for this project because of its larger size. The early friction numbers on I-94 are in the low 40's. It appears that the macro texture furnished by this size aggregate is too rough to generate accurate friction numbers with Mn/DOT's testing equipment. Friction testing was only completed on TH 9 and I-94 in the fall of 1999. All of the sections will be tested on an annual basis to determine how wear from traffic affects the friction values **(Graph 3)**.

3.6 Provides an excellent background for pavement markings

Comments received from the traveling public noted that the new asphalt surface makes the traffic markings stand out. One observation was that due to the rougher surface supplied by the Micro Surfacing the marking paint had to be applied at a greater rate than on a normal hot mix asphalt surface.

3.7 Does not seal reflective cracks

Due to the thin application layer of Micro Surfacing and the brittle nature of the mixture after curing, the major working cracks will reflect through in a very short time. On the single course application, cracks reflected through after the first cold weather. It is recommended that all cracks are sealed before placement of the Micro Surfacing. Any top quality sealant meeting

Mn/DOT's specification for crack sealing can be used. It is recommended that the sealant be placed far enough ahead of the Micro Surfacing to allow it to completely cure. If the existing cracks are too numerous or large to seal, place the Micro Surfacing first and wait for the cracks to return. The cracks will be narrower and more manageable. The cracks can then be sealed using a clean and seal method of crack sealing.

3.8 Increased noise

There have been some concerns about noise created by traffic on the Micro surfaced roadways. Most of the comments are being generated by the work done on the I-94 project. This project used ISSA Type III for its surface course placed over a concrete pavement. Due to the uniformity of the concrete, the larger stones tended to stand prouder than is typical on a hot mix asphalt roadway that has some variability to its surface. Sound testing was completed summer of 2000 to determine if there is an increase in decibels or just a change in the pitch of the sound. The test results show very little increase in decibels. The ISSA Type III was louder then the Type II. A complete copy of the noise test is located in appendix B. MN/DOT will be testing a new gradation size to determine if high friction numbers can still be created without an increase in noise.

3.9 Projections in pavement

Micro Surfacing does not work favorably for smoothing humps in the pavement. The semi-liquid state of the mix at placement causes it to flow away from the hump. The recommended method would be to mill off any areas that are pushed up or have caused a hump. If potholes are being patched in preparation for Micro Surfacing, care must be taken to leave the patch level or slightly depressed.

3.10 Project Selection

Proper project selection is a key factor in the overall successes of the Micro Surfacing project. Micro Surfacing is a very thin surface treatment and it cannot be expected to fix structural problems in existing pavements. If the roadway is still rutting Micro Surfacing should not be placed. Micro Surfacing should only be used for rut filling on pavements that are done rutting. Potholes should be repaired before placement of Micro Surfacing. If the pavement has a large number of potholes or is badly alligator cracked, may be a better candidate for a hot mix asphalt overlay.

Chapter 4

Project Review

All of the sections of the statewide Micro Surfacing project were review during summer of 2000. They all are performing satisfactorily. In appendix C is a set of graphs that give the Present Service Rating for each of the original sections of the project.

Appendix A
Location Table

Route #	Limits	Direction	Location	Planned Type of Treatment
TH 2	163.800-168.800	Both	West of Deer River	Reactive maintenance[1]
TH 9	79.791-98.050	Both	North of Herman	Correct Raveling[2]
TH 10	96.746-105.048	West Rt. Lane	West of Staples	Stripping of Asphalt in right lane
TH 10	162.900-170.091	North	North of St. Cloud	Ride Restoration Treatment[3]
TH 10	203.568 – 204.00	Both Right Lane only	Big Lake	Restore ride
TH 14	251.2-252.9	East Truck Lane	East of Stockton	Rut Filling
TH 15	152.068-152.640	North	In St. Cloud	Preventive Maintenance
TH 25	67.706 – 68.722	Both	In Monticello	Rut Fill
I-35	137 – 141	Both[4]	Stacy	Preventive Maintenance
TH 52	0.00-9.257	Both Shoulders	North of Iowa Border	Repair of damage[5]
TH 71	287.300–294.111	Both	Lake George	Rut Fill & Surface Course
I-94	194.984-195.785	Both	East of Monticello	Safety[6]
I-94	199.600-200.321	Both	East of Monticello	Safety[7]
I-94	196-198	Westbound	Mn/Road Site	Test Rut filling and Surface Course[8]
TH 169	158-160.3	Both Right Lanes only	North of Elk River	Rut Fill without Surface Course

Location Table

[1] To retard disintegration of the road surface for five years until total re-construct. This section had numerous small potholes at the transverse cracks.

[2] This segment of roadway was paved during cold wet weather and was raveling severely.

[3] This segment of roadway at the time of construction was probably too badly deteriorated to be called a true preventive maintenance treatment. It better classified as ride restoration treatment.

[4] The mile post are off set one mile north bound versus south bound even through the micro surface is across from each other on the roadway.

[5] To repair damage to three-year-old shoulder caused by hooves of horses that pull Amish buggies.

[6] Micro Surfacing was used to increase friction of roadway to reduce number of accident on bridges and approaches.

[7] Micro Surfacing was used to increase friction of roadway to reduce number of accident on bridges and approaches.

[8] Two 500 foot cells were Micro Surfaced at Mn/Road. Cell 20 & 23.

Appendix B

Draft Noise Study

By Mn/DOT's Office of Environmental Services

The authors want to thanks Melvin Roseen from Mn/DOT's Office of Environmental Services Sound Unit for the draft report on noise.

Following is a summary of tire noise testing done on several pavement surfaces during the summer of 2000. For those unfamiliar with the acoustical or statistical terminology used, there is a glossary at the end of the section. Testing was done at the roadside, 50 ft. from the near lane center line, and inside the test vehicle. All testing was done at a speed of 65mph. The results from the roadside testing could be summed up by saying that the loudness differences between the various surfaces were relatively small. While there were statistically significant differences there was only one difference that tested as "substantial" at a statistical significance level of 5%. This was the A-weighted level (AL) difference between the Nova Chip on I-35 near Stacy, MN. and the Micro Surfacing on I-94 near Monticello, MN. Testing was done inside the test car to determine interior noise levels on the various surfaces. The differences inside the test vehicle were again relatively small. The largest difference based on interior measurements was 3 dBA between the 35Nova Chip and the 94 Micro Surfacing.

Two separate test scenarios were carried out in order to compare the tire noise on the various surfaces. A test was run at the roadside for each surface and a test of the vehicle's interior noise levels was run on each surface. The data taken at the roadside were used to quantify the loudness of the tire noise on each surface. Two descriptors were used. The A-weighted Level (AL), denoted by dBA, is considered to give a fairly good representation of perceived loudness. A couple of critical approximations concerning AL's are as follows. When comparing the loudness of different sources a 10 dBA change in noise level is roughly perceived as a doubling or halving of the loudness, depending on whether the change is plus or minus. A 3 dBA change in noise level represents a change in loudness that is just barely perceivable. MN/DOT has defined a level change of 5 dBA, or more, as a substantial change. It is this change of 5 dBA to which particular attention was paid, rather than the barely perceived change of 3 dBA.

For the roadside testing we also used an alternative descriptor of loudness that uses a comparison of sound levels at different frequencies with a 40 dB tone at a frequency of 1000 cycles/second. This descriptor is denoted by a linear unit called a "sone". Some professionals working in acoustics feel that a sone value calculated using Zwicker's Method (ZM) gives a more accurate quantification of perceived loudness than that associated with the AL approach. For the roadside testing we used both approaches in order to have a check on the two methods. The comparison of the loudness of two different sources using ZM is done by forming a ratio of the two sone values. If the ratio equals one the two sources are equal in perceived loudness. If the ratio is one half or two, the loudness of one source is considered as halved or doubled depending on how the ratio was formed.

To compare the vehicle's interior noise levels on different surfaces just AL's were used. AL's were collected inside the vehicle as it drove at constant speed over the various pads. All controllable noise sources inside the vehicle (radio, fans, vents, cracked windows, etc.) were silenced as best we could. The same information and characteristics of AL's, as descriptors of perceived loudness, as given above apply.

Two assumptions were tested in order to determine if tire noise differences existed between the different surfaces and whether or not they were substantial (>= 5 dBA). In the absence of excellent evidence to the contrary, it's assumed that there is no tire noise difference between the various surfaces. Secondly, if there is excellent evidence that a true difference different from zero, or one in the case of sone ratios, exists than it was assumed that, in the absence of excellent evidence to the contrary, the tire noise difference between surfaces was not substantial.

Test Vehicle: 1992 Plymouth Grand Voyager Van equipped with all season Goodyear Regatta Touring mts p205/70R15 tires with moderate wear.

> The test vehicle was tested on a quiet bit pavement to ascertain if the tire/pavement noise component could be considered dominant. Based on the results it was determined that the vehicle's peak pass-by level at 50 ft., at a speed of 65mph, was dominated by the tire noise component. This meant that test results would pertain to the tire noise component exclusively.
>
> The test vehicle wasn't as well suited to testing interior noise levels on the various surfaces as it was for measuring roadside noise levels. Noise components such as engine noise, airflow noise and other miscellaneous components tended to mask the tire noise component on the interior of the vehicle to some extent.

The surfaces tested were as follows:

> Micro Surfacing overlay on I-35W near Stacy MN. This surface is labeled 35 Micro Surface.
>
> Nova Chip overlay on I-35W near Stacy MN. This surface is labeled 35 Nova Chip.

Asphalt Concrete on I-35W near Stacy MN. This surface was used as a control surface and is labeled 35 Control.

Micro Surfacing overlay on I-94 near Monticello MN. This surface is labeled 94 Micro Surface.

Burlap drag Concrete surface on I-94 near Monticello MN. This surface was used as a control surface and is labeled 94Control.

Comparison of surfaces: Following is a list of the tested surfaces ranked on the basis of the average of tire noise measurements at the roadside. This list gives the average AL of the tire noise on each pad, accurate to the nearest ½ dBA. The list also contains the average Sone value of the tire noise on each pad, accurate to the nearest ½ Sone. The FHWA's average automobile emission level at 50 ft., at 65 mph on an average pavement surface is 77 dBA.

Surface	AL	Sone
94 Control	77-1/2 dBA	40 Sones
94 Micro Surface	77 dBA	38 Sones
35 Micro Surfacing	74-1/2 dBA	32-1/2 Sones
35 Control	73 dBA	30-1/2 Sones
35 Nova Chip	73 dBA	28-1/2 Sones

The following roadside comparison is based on the average differences between the AL's of the tire noise, accurate to the nearest ½ dBA. As can be seen, with statistical considerations included, the differences of some surfaces that had different means could not be discounted as having the same tire noise level.

Surface	Comparison	Ranking
94 Micro Surface & 94 Control	Same	Noisiest
35 Micro Surface		On average 3dBA quieter than the above
35 Nova Chip & 35 Control	Same	Quietest and on average 2dBA quieter than the above

Following is a list of the tested surfaces based on noise measurements made in the interior of the test vehicle. The ranking is based on the average AL, accurate to the nearest ½ dBA.

Surface	Average Level
94 Micro Surface	71-½ dBA
94 Control	71 dBA
35 Micro Surface	70 dBA
35 Control	69 dBA
35 Nova Chip	68-½ dBA

Following is a comparison of the tested surfaces based on noise measurements in the interior of the test vehicle. The comparison is based on the sampled differences between the interior AL's, accurate to the nearest ½ dBA.

Surface	Ranking
94 Micro Surfacing	Noisiest
94 Control	On average 0.5 dBA quieter than the above.
35 Micro Surfacing	On average 1 dBA quieter than the above
35 Control	On average 1 dBA quieter than the above
35 Nova Chip	Quietest and on average 0.5 dBA quieter than the above

Detailed
Pavement Comparisons:

The comparisons were done as requested by Materials.
35 Micro Surfacing and 35 Control
35 Nova Chip and 35 Control
35 Micro Surfacing and 35Nova Chip
94 Micro Surfacing and 94 Control
94 Micro Surfacing and 35 Micro Surfacing
94 Micro Surfacing and 35 Nova Chip

Based on Roadside Noise

AL differences and Sone ratios were used to check the comparative loudness of the various pavement surfaces. Generally changes or differences in noise level are easier to quantify and describe than absolute levels are.

35 Micro Surfacing and 35 Control
Based on AL sampling the tire-noise on the 35 Micro Surfacing increased relative to that on the 35 Control pad. The increase averaged 1.35 dBA and is statistically significant at a significance level of 5%. The possibility that the true increase is substantial is rejected at a significance level of 5%.
Based on sampling of ZM sone values the tire-noise on the 35 Micro Surfacing increased over that on the 35 Control pad. The average ratio of the 35 Micro Surfacing sone values to the 35 Control pad sone values was 1.07 and is statistically significant at a significance level of 5%. The possibility that the true increase is substantial is rejected at a significance level of 5%.

35 Nova Chip and 35 Control
Based on AL sampling the tire-noise on the 35 Nova Chip remained the same relative to that on the 35 Control pad. The possibility that there is a true change different from zero is rejected at a significance level of 5%. The possibility that the true change is substantial is rejected at a significance level of 5%.
Based on sampling of ZM sone values the tire-noise on the 35 Nova Chip remained the same as that on the 35 Control pad. The possibility that the true ratio is different than 1 is rejected at a significance level of 5%. The possibility that the true ratio would indicate a substantial change is rejected at a significance level of 5%.

35 Micro Surfacing and 35 Nova Chip
Based on AL sampling the tire-noise on the 35 Micro Surfacing increased relative to that on the 35 Nova Chip. The increase averaged 1.7 dab and is statistically significant at a significance level of 5%. The possibility that the true increase is substantial is rejected at a significance level of 5%.
Based on sampling of ZM sone values the tire-noise on the 35 Micro Surfacing increased relative to that on the 35 Nova Chip. The average ratio of the 35 Micro Surfacing sone values to the 35 Nova Chip sone values was 1.14 and is statistically significant at a significance level of 5%. The possibility that the true increase is substantial is rejected at a significance level of 5%.

94 Micro Surfacing and 94 Control
Based on AL sampling the tire-noise on the 94 Micro Surfacing remained the same relative to that on the 94 Control pad. The possibility that there is a true change different from zero is rejected

at a significance level of 5%. The possibility that the true change is substantial is rejected at a significance level of 5%.
Based on sampling of ZM sone values the tire-noise on the 94 Micro Surfacing remained the same as that on the 94 Control pad. The possibility that the true ratio is different than 1 is rejected at a significance level of 5%. The possibility that the true ratio would indicate a substantial change is rejected at a significance level of 5%.

94 Micro Surfacing and 35 Micro Surfacing
Based on AL sampling the tire-noise on the 94 Micro Surfacing increased relative to that on the 35 Micro Surfacing. The increase averaged 2.7 dBA and is statistically significant at a significance level of 5%. The possibility that the true increase is substantial is rejected at a significance level of 5%.
Based on sampling of ZM sone values the tire-noise on the 94 Micro Surfacing increased relative to that on the 35 Micro Surfacing. The average ratio of the 94 Micro Surfacing sone values to the 35 Micro Surfacing sone values is 1.17 and is statistically significant at a significance level of 5%. The possibility that the true increase is substantial is rejected at a significance level of 5%.

94 Micro Surfacing and 35 Nova Chip
Based on AL sampling the tire-noise on the 94 Micro Surfacing increased relative to that on the 35 Nova Chip. The increase averaged 4.5 dBA and is statistically significant at a significance level of 5%. The possibility that the true increase is substantial cannot be rejected at a significance level of 5%.
Based on sampling of ZM sone values the tire-noise on the 94 Micro Surfacing increased relative to that on the 35 Nova Chip. The average ratio of the 94 Micro Surfacing sone values to the 35 Nova Chip sone values was 1.32 and is statistically significant at a significance level of 5%. The possibility that the true increase is substantial is rejected at a significance level of 5%. The fact that the AL results can't reject the possibility of a substantial change, while the sone values can, may be due to a slightly greater precision of the ZM sone values.

A caution concerning
Masking: In conclusion, I think it is important for the person responsible for making decisions concerning which pavement surfaces are to be used, under different circumstances, must be aware of how the masking of one noise source or component by another can seriously limit the overall noise benefits that might be derived. The crux of the problem stems from the fact that not all vehicles on the highway are dominated by tire noise at highway speeds. Especially in urban or suburban situations the noise of most trucks and buses

are dominated by exhaust and engine noise. This fact, along with the fact that trucks and buses are noisier (louder) than automobiles at comparable speeds can severely limit the benefits of quieting tire noise.

By way of an example the effect of masking might be demonstrated. Consider two noise components of a noise source. Let both, produce a noise level of 80 dBA each. The total noise from both sources considered together is 83 dBA. Assume the one of the components can be quieted by 10 dBA. This is a significant reduction by anybody's standards. However, the total noise level will be 80 dBA, just 3 dBA lower then the unreduced level. One has to be aware that while tire noise reduction may look very significant when just the tire noise is considered, such as is generally the case for automobiles, that the over all reduction often depends on other sources or components that are less affected by the choice of pavement. To invest a lot in a large reduction in one noise component while not reducing the other, possibly noisier components, can in the long run appear to have been an investment in very little.

GLOSSARY:

A-weighted Level (AL): A frequency filtered sound level, which under defined conditions approximates the frequency response of the human ear. Usually indicated as dBA. A 10 dBA change in AL is considered indicative of an approximate doubling or halving of a noise sources perceived loudness.

Dominant noise component: A noise source component that is at a noise level that is more than 6dBA greater than the noise level due to all other components combined.

Sone ratio: To compare loudness levels calculated by ZM for two noise sources, the ratio of the two sone values is formed. If the ratio equals one, then the loudness of the two sources is judged equal. If the ratio equals two than the source represented by the numerator of the ratio is twice as loud as the source represented in the denominator. A doubling of the loudness as determined by ZM is approximately equivalent to an AL increase of 10 dBA.

Zwicker's Method (ZM): A method for quantifying loudness that is considered by some Acousticians to be more accurate than the A-weighted level (AL). The method is standardized in: ISO 532-B, "Method for Calculating Loudness Level". Loudness calculated by this method is expressed in linear units called Sones.

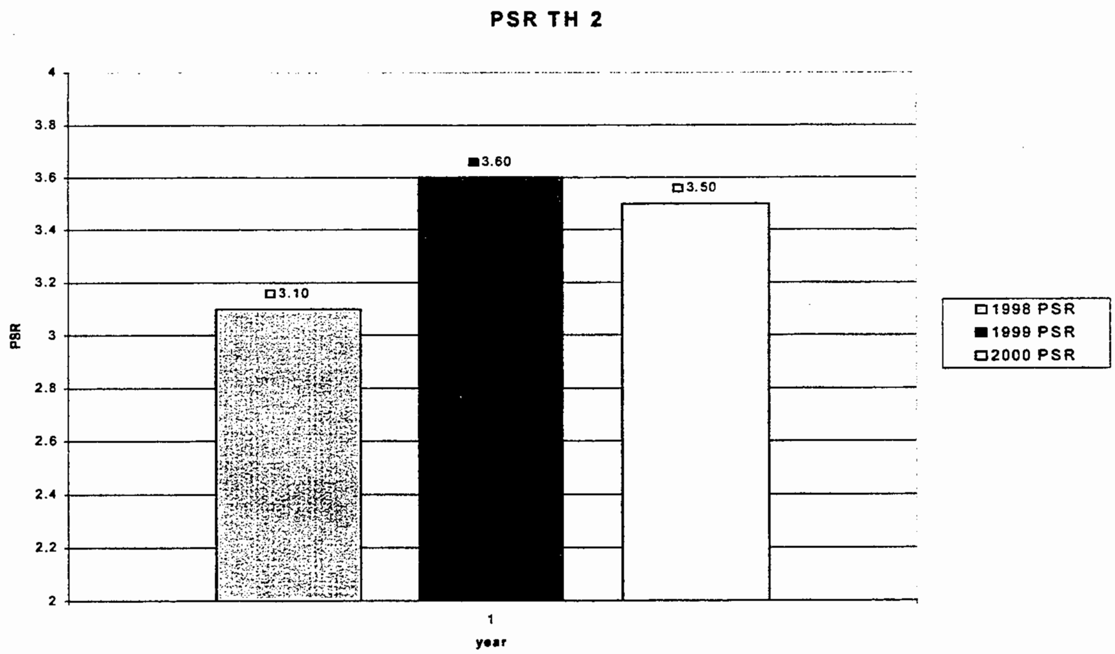
Statistically Significant: In this report Statistical Significance is based on a significance level of 5%. Essentially this means that by taking a sampled difference into account, the probability of a difference of zero, in the case of AL's, or a ratio of one in the case of sone value ratios, is less than 5%.
Put another way this means that the probability that the true AL difference between test surfaces is zero is less than 5%. Used with the ZM sone ratio comparison between surfaces it means that the probability that the true ratio is one is less than 5%.

Substantial change (difference): As per 23CFR etc. MN/DOT has defined a substantial change in noise level as a change of 5 dBA or more. In this report, unless there is a greater than 5% chance that the difference between tire noise levels is equal to or greater than 5 dBA, it is assumed that the difference is not substantial.

Masking: In this report masking will refer to a situation where a dominant, or nearly dominant, sound or noise component of a noise source reduces or eliminates the audibility of other sound (or noise)components of a noise source.

Appendix C

Present Service Ratings (PSR) from Mn/DOT's Pavement Management Office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3.2
3
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year
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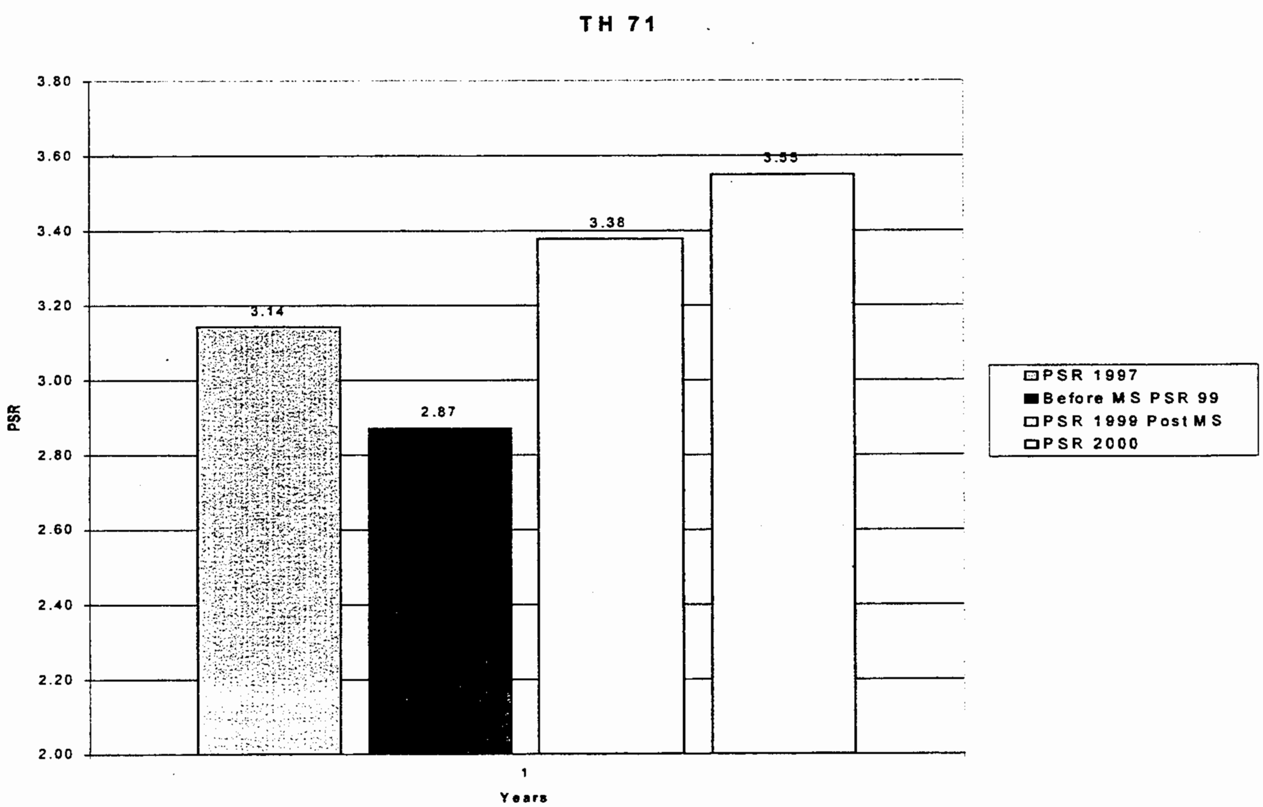
1999 PSR
2000 PSR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2.40
2.20
2.00
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Years
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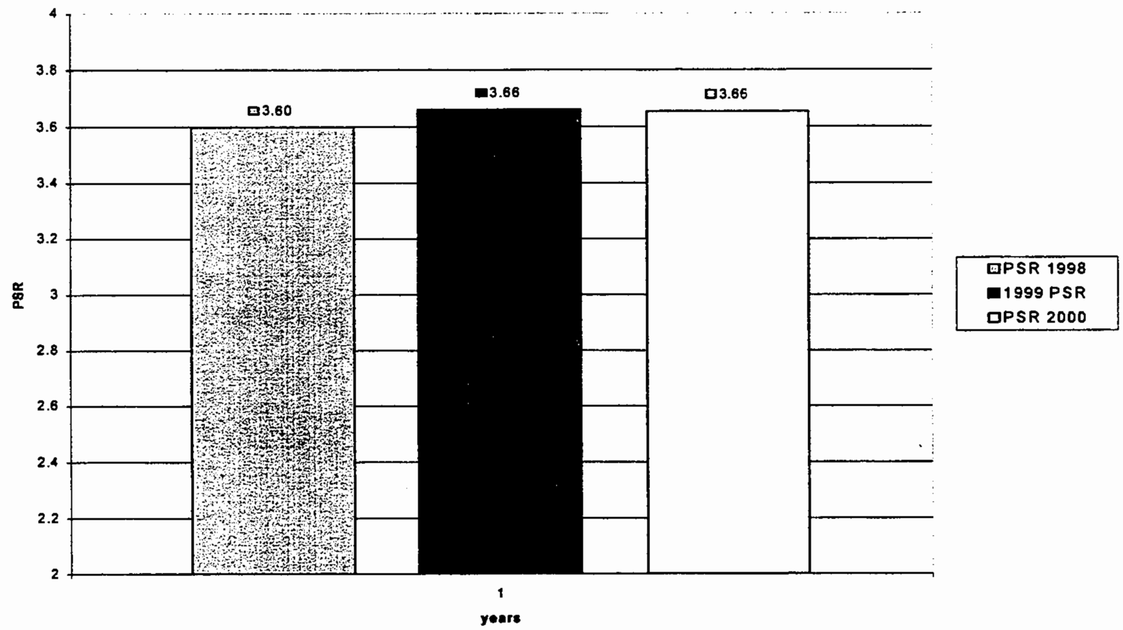
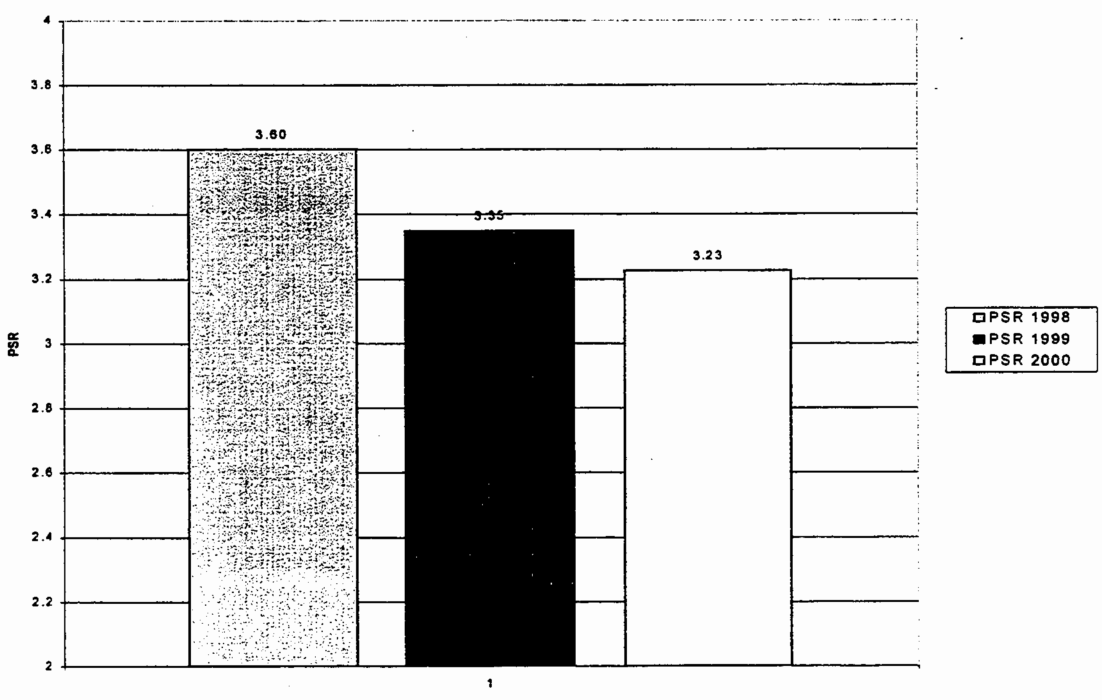
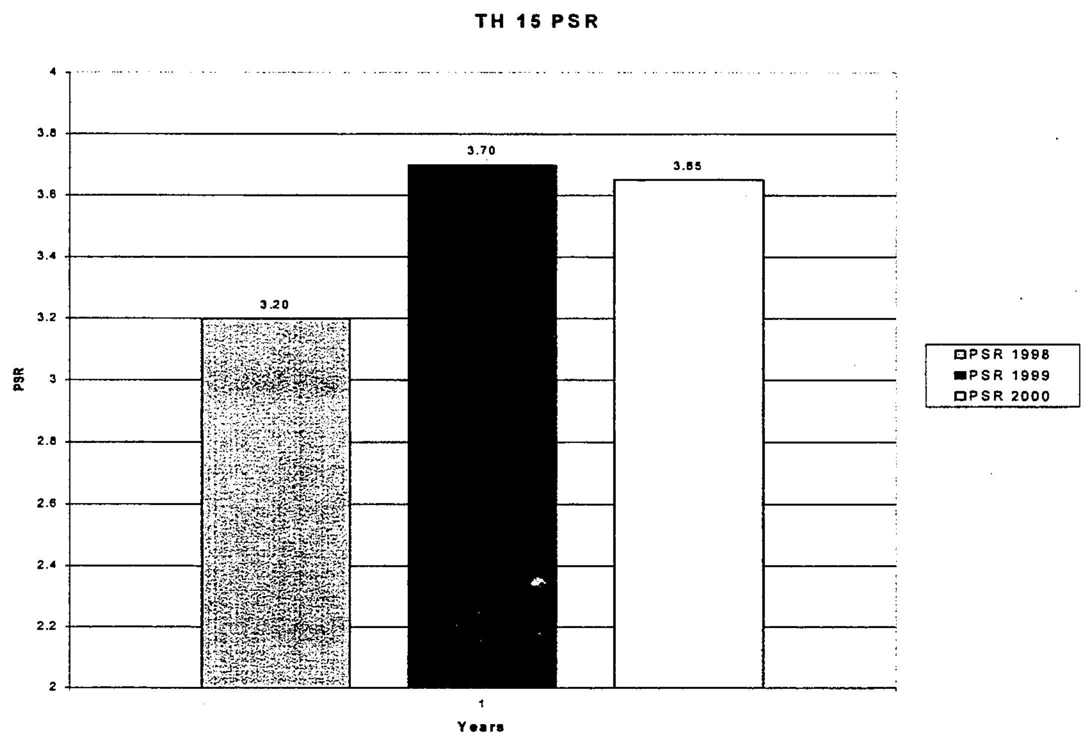
Before MS PSR 99
PSR 1999 Post MS
PSR 2000

PSR TH 10 Rice



I-94

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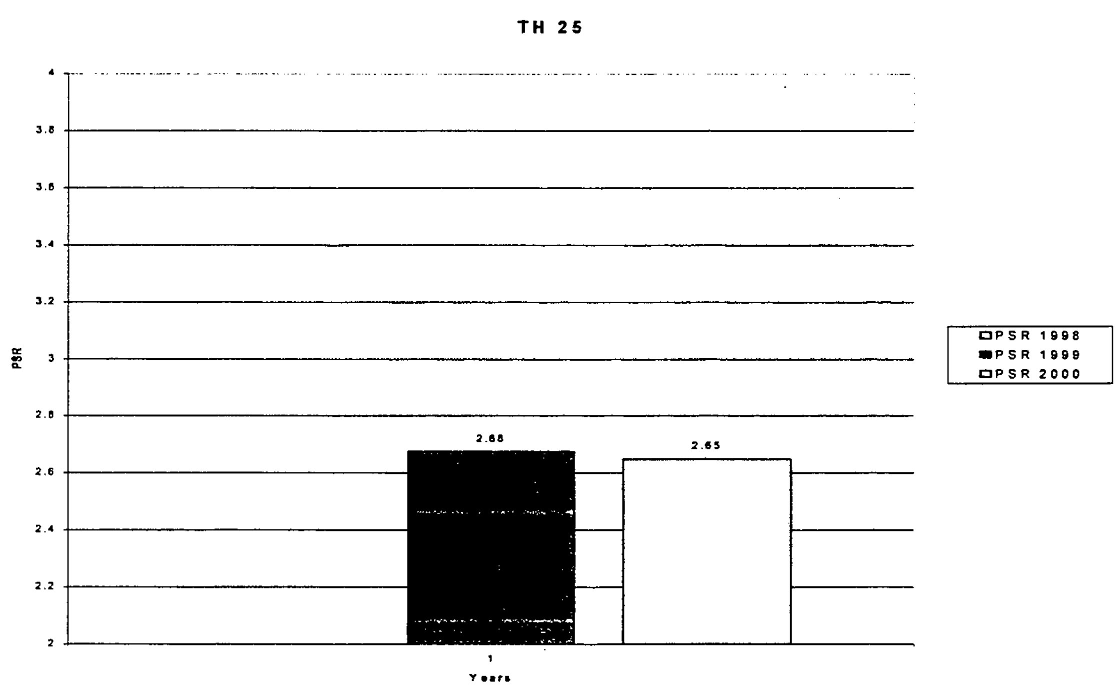
1
Years
PSR 1998
PSR 1999
PSR 2000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1
Years
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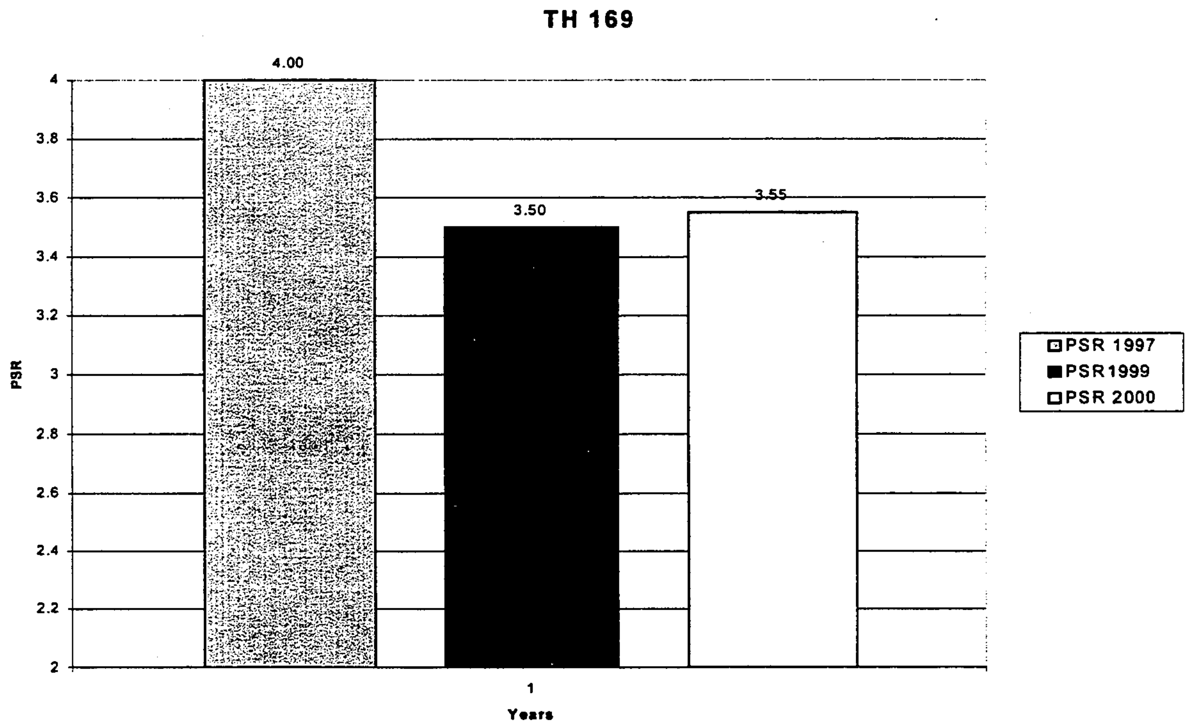
PSR 1998
PSR 1999
PSR 2000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2
PSR
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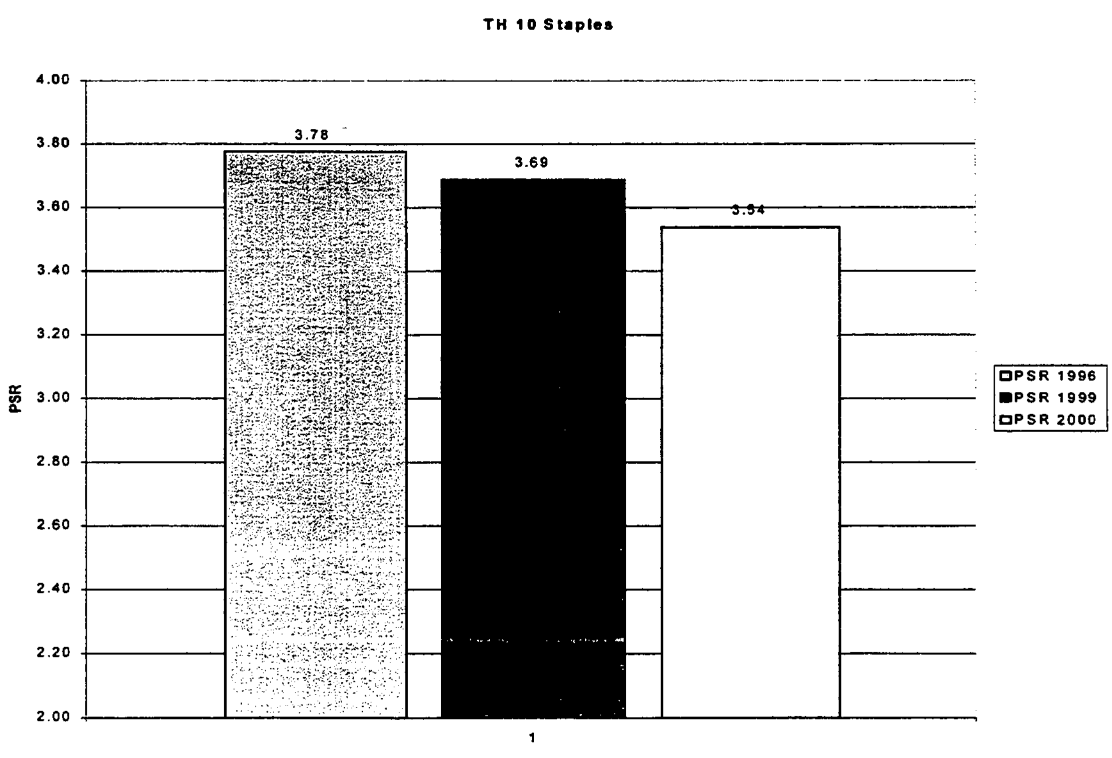
Years
PSR 1997
PSR1999
PSR 2000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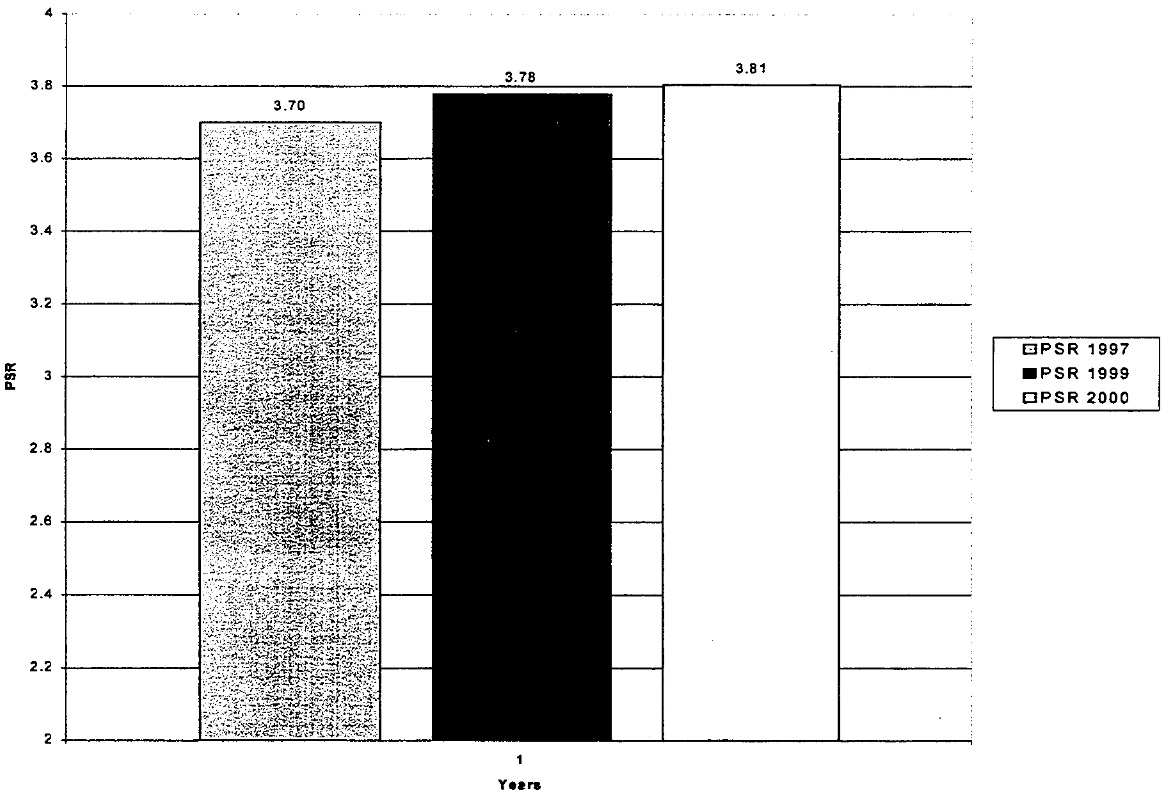
2.00
PSR
1
Years
PSR 1996
PSR 1999
PSR 2000

TH 9



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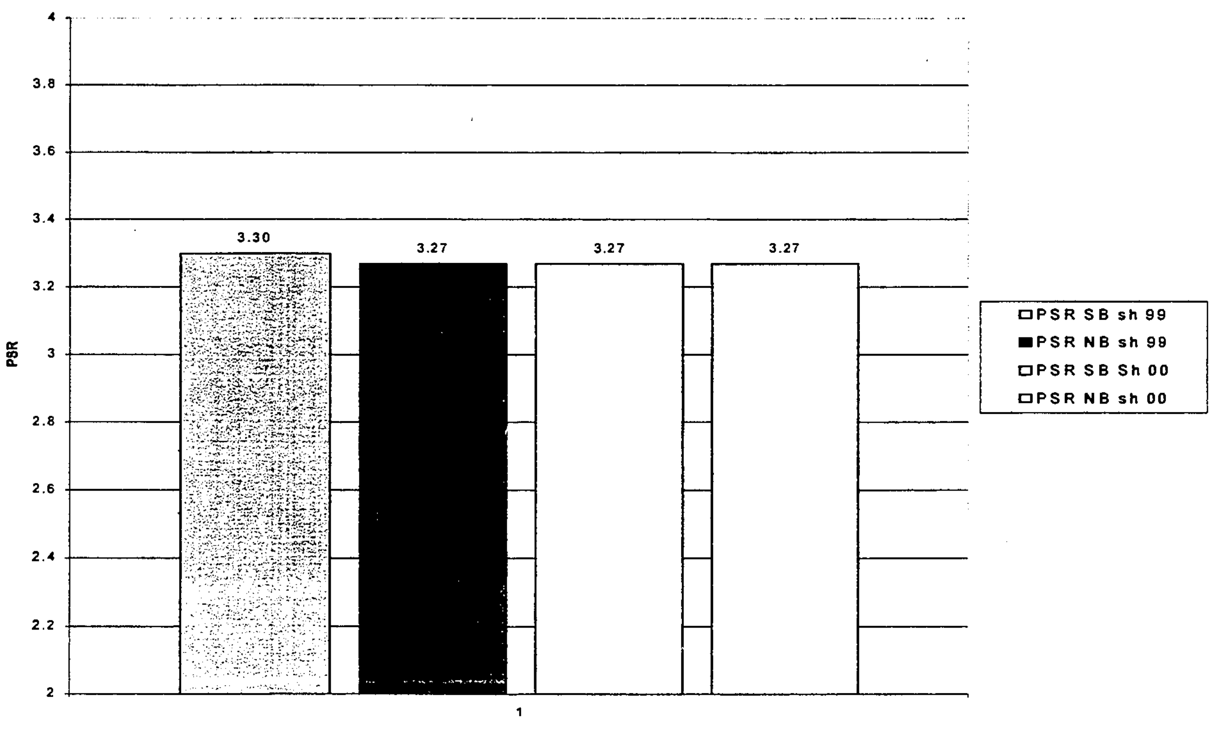
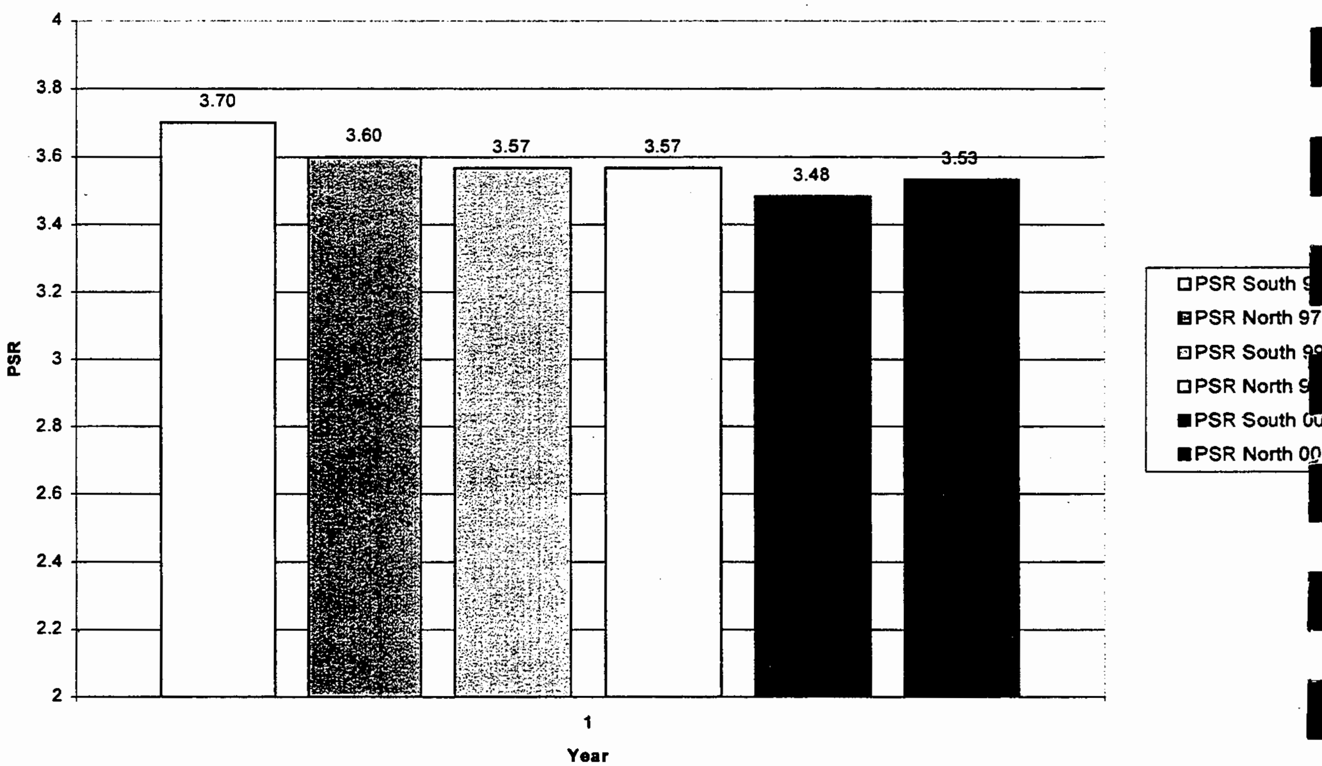


I 35



4
3.8
3.6
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3
2.8
2.6
2.4
2.2
2
PSR
3.70
3.60
3.57
3.57
3.48
3.53
1
Year
PSR North 97