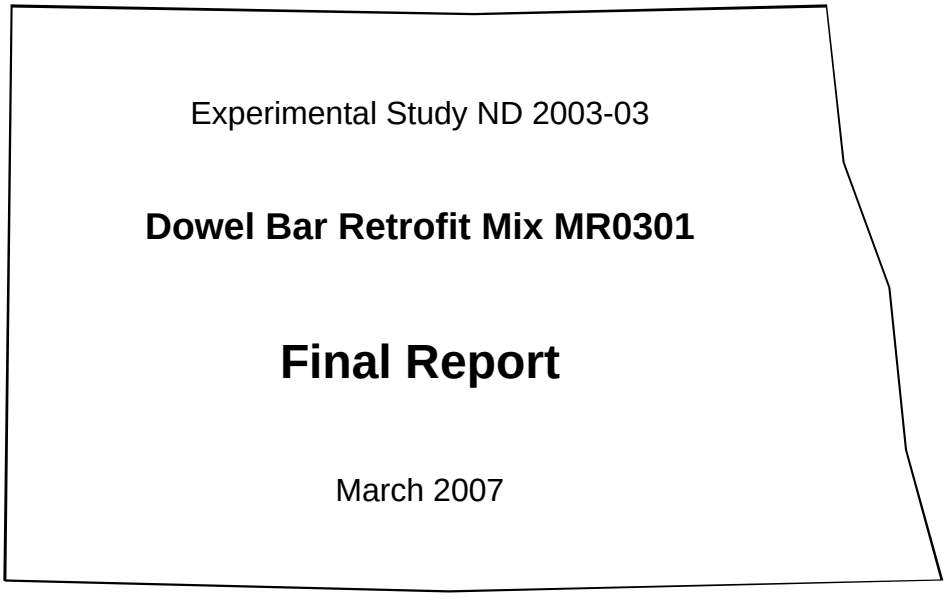
NORTH DAKOTA

DEPARTMENT OF TRANSPORTATION

MATERIALS AND RESEARCH DIVISION



Experimental Study ND 2003-03

Dowel Bar Retrofit Mix MR0301

Final Report

March 2007

Prepared by

NORTH DAKOTA DEPARTMENT OF TRANSPORTATION
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U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

EXPERIMENTAL PROJECT REPORT

EXPERIMENTAL PROJECT

EXPERIMENTAL PROJECT NO. (1)

STATE	YEAR		NUMBER	SURF
ND	2003	-	03	

CONSTRUCTION PROJ NO (8): AC-IM-8-094(041)342

LOCATION (28): Cass County

EVALUATION FUNDING (48)

1 X HP&R — 3 DEMONSTRATION
2 CONSTRUCTION — 4 IMPLEMENTATION

NEEP NO. (49):

PROPRIETARY FEATURE? (51): Yes / X No

SHORT TITLE

TITLE (52): Dowel Bar Retrofit Mix MR0301

THIS FORM

DATE (140): MO. 03 -- YR. 2007

REPORTING: 1 INITIAL — 2 ANNUAL — 3 X FINAL

KEY WORDS

KEY WORD 1 (145)	KEY WORD 2 (167)
Joints	Load Transfer
KEY WORD 3 (189)	**KEY WORD 4 (211)**
Dowels	Rehabilitation
UNIQUE WORD (233)	**PROPRIETARY FEATURE NAME (255)**

CHRONOLOGY

Date Work Plan Approved (277)	Date Feature Constructed: (281)	Evaluation Scheduled Until: (285)	Evaluation Extended Until: (289)	Date Evaluation Terminated: (293)
08-2003	08-2003	08-2008		04-2006

QUANTITY AND COST

QUANTITY OF UNITS (ROUNDED TO WHOLE NUMBERS) (297)	UNITS (305)		UNIT COST (*Dollars, Cents*) (306)
432	1 LIN. FT 2 SY 3 SY-IN 4 CY	5 TON 6 LBS 7 X EACH 8 LUMP SUM	39.60

AVAILABLE EVALUATION REPORTS

CONSTRUCTION (315)	PERFORMANCE	FINAL
X	X	X

EVALUATION

CONSTRUCTION PROBLEMS (318)

1 X NONE
2 SLIGHT
3 MODERATE
4 SIGNIFICANT
5 SEVERE

PERFORMANCE (319)

1 EXCELLENT
2 GOOD
3 SATISFACTORY
4 X MARGINAL
5 UNSATISFACTORY

APPLICATION (320)

1 ADOPTED AS PRIMARY STD.
2 PERMITTED ALTERNATIVE
3 ADOPTED CONDITIONALLY
4 PENDING
5 X REJECTED
6 NOT CONSTRUCTED

(Explain in remarks if 3, 4, 5, or 6 is checked)

REMARKS (321)

It is recommended that the NDDOT continue using the proprietary mixes currently allowed in the standard specifications due to higher costs and poor performance of the experimental mix. It is also recommended that special attention is given to the location of coreboards after the dowel bar mix is placed. Coreboard failures can be reduced or eliminated if the coreboard remains in the joint and not allowed to move into the dowel bar slot.

700

Form FHWA 1461

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Experimental Study ND 2003-03

Dowel Bar Retrofit Mix MR0301

FINAL REPORT

Project AC-IM-8-094(041)342

March 2007

Written by

Bryon Fuchs

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Disclaimer

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TABLE OF CONTENTS

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Dowel Bar Retrofit Mix MR0301
ND 2003-03

Purpose and Need

The North Dakota Department of Transportation (NDDOT) has been constructing dowel bar retrofit projects since 1995 to restore load transfer across transverse joints in plain jointed concrete pavements. While this rehabilitation has worked to restore load transfer, the patch mix material previously used has had caused durability problems.

There are several commercially available patch mixes on the market and the NDDOT had used a number of them. The mixes were considered expensive and suffered from durability problems such as; raveling, shrinkage cracks, and spalling. The mixes set up very quickly. This can lead to little or no mix under the dowel bar which has led to the patch mix material breaking loose in the slot and losing load transfer.

There was a need for a low cost patch mix material using locally available materials. North Dakota State University (NDSU), Civil Engineering Department, had developed a patch mix designed specifically for this purpose.

Objective

The objective of this applied research was to evaluate the patch mix developed at NDSU.

Location

NDDOT project number AC-IM-8-094(041)342 (westbound lane) near exit 342 was selected to incorporate this applied research. The project was located on Interstate 94 between the West Fargo Interchange and the Red River. Please refer to Figure 1 on the next page.

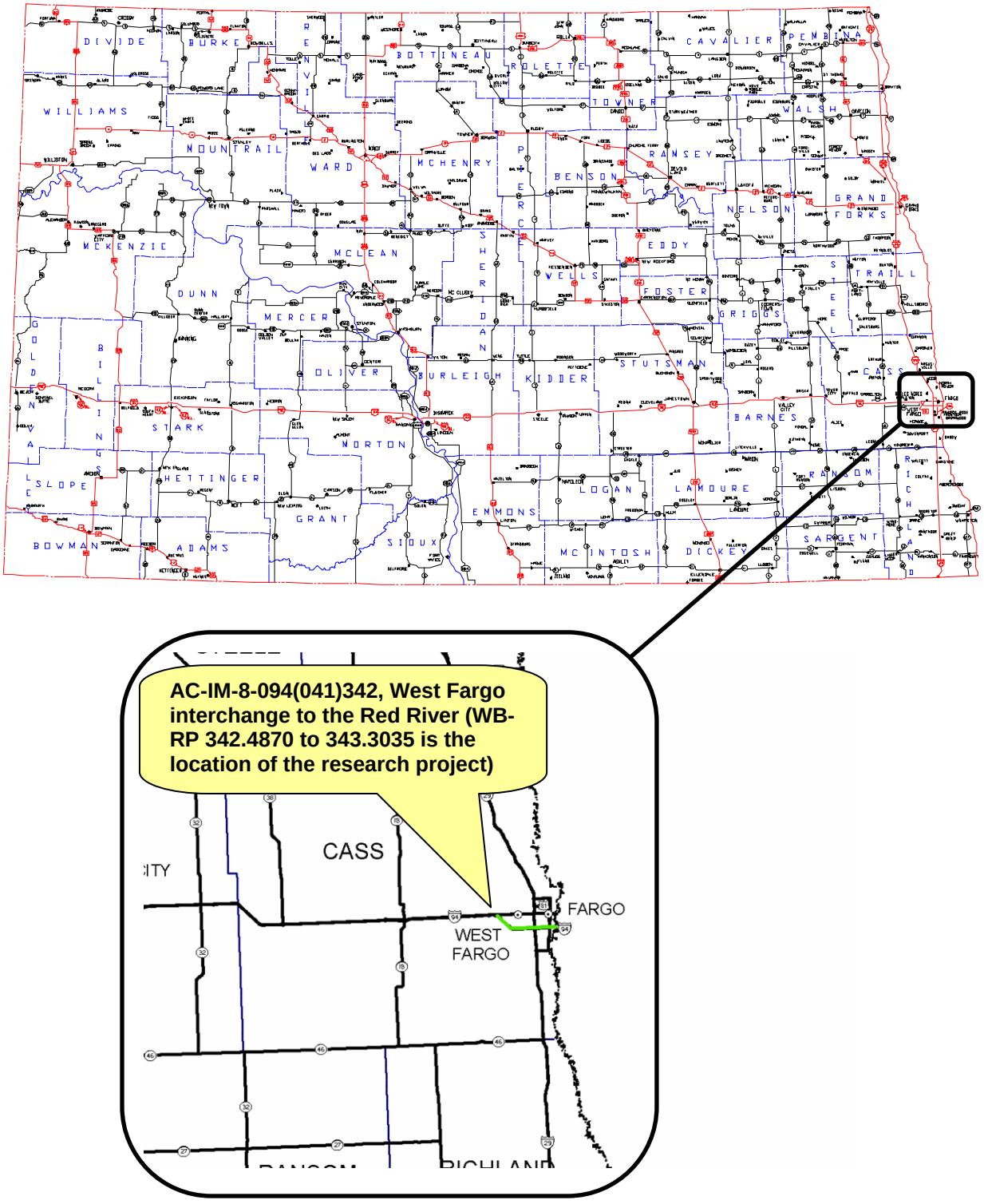

Figure 1 - Project Location.

Traffic

Two-way traffic is provided in the following table from RP 342.803 to 343.800.

Year	Passenger	Trucks	Total	30th Max Hour	Two-way Rigid ESALs
2002	10,550	2,050	12,600	1,260	2,870
2004	12,300	1,800	14,100	1,410	2,520
2006	13,325	2,275	16,600	1,560	2,685

Design

The design of the patch mix material was conducted by NDSU. Provided below is a summary of the information that was presented to the contractor in order to incorporate this experimental patch mix material onto the project. Refer to Appendix A for the entire submittal package.

Description

This work shall consist of retrofitting approximately one-half lane mile of epoxy-coated dowel bars into existing concrete pavement using an experimental concrete mix. Section 570 of the 2002 edition of the NDDOT *Standard Specifications for Road and Bridge Construction* shall govern except where noted below.

Material

1. Patching Material**.** "Concrete Patch Mix " shall be a mix prepared using the following mix design:

Material	Per CY Quantities
Cement (*Type III – Lehigh*)	850 lbs
Water	255 lbs
Fine Aggregate (*Section 816.01*)	1079 lbs
Coarse Aggregate (*Section 816.02 – Granite*)	1526 lbs
Air-entraining Admixture (*Master Builders – Pave Air*)	2.975 fl-oz
Accelerating Admixture (*Master Builders – Pozzolith NC 534*)	340 fl-oz
Water Reducer (Super Plasticizer) (*Master Builders – Rheobuild 3000FC*)	102 fl-oz

- The Dowel Bar Retrofit Mix shall have the following properties:

Maximum Water to Cement (W/C) Ratio	0.30
Slump	9” ± 1”
Air	6% ± 1%

Construction

The primary contractor for project number AC-IM-8-094(041)342 was Wanzek Construction, Inc located in Fargo, ND. The work related to the dowel bar retrofit was subcontracted to Highway Services / Penhall Company (Penhall) located in Rogers, MN.

The project engineer on this project was Joe Peyerl of the Fargo District, NDDOT. The inspectors on this project were Robin Bellmore and Larry Ostenson from the Fargo District.

The following personnel from Materials and Research Division were present on site for the construction of the experimental dowel bar mix; Bryon Fuchs, Mike Marquart, Steven Henrichs, Kyle Evert, and Tony Gross.

The experimental mix was change ordered onto this project at a cost of $39.60 per dowel bar. The bid price using “Five Star” patch mix was $25.00 per dowel bar. The bid price was for approximately 1,056 bars.

The construction of the experimental mix occurred on August 14, 2003. The contractor started placing the experimental mix in the dowel bar slots at 9:15 am. The weather on this day during construction had an average temperature of 86°F, average wind speed of 20 mph (gusts – 20 to 30 mph), 48% relative humidity and sunshine.

Testing

Throughout construction of the experimental mix, tests were conducted. The tests were completed at the start of construction (set A), when approximately 25% (set B), 50% (set C) and 75% (set D) of the mix was placed.

The following table lists the averages for the four sets of tests conducted:

Test	Set A	Set B	Set C	Set D
Air (%)	5.1	5.5	4.3	5.1
Slump (in)	9.00	8.75	8.50	7.50
6-hr Comp Strength (psi)	5,060	5,610	5,390	5,110
7-day Comp Strength (psi)	8,820	9,180	9,990	9,280
28-day Comp Strength (psi)	10,260	10,370	11,370	11,280
28-day Flex Strength (psi)	980	1,100	1,090	1,190
Freeze/Thaw Durability-300 cycles (Factor)	93.1	89.8	98.9	96.9

Post Construction Analysis

The experimental project site was visited on September 24, 2003 and again on October 8, 2003. Using an FWD, the load transfer across the transverse joints were tested on October 14, 2003.

Three different sections were evaluated for visual distresses and load transfer. Each section contains 72 transverse joints or 432 dowel bar slots. The following table identifies the differences in each section.

Section	Location	Description
Control Section 1	RP 343.2082 to 343.3035	Five Star Mix used on majority of project
Experimental Section	RP 343.1111 to 343.2067	MR0301 Mix
Control Section 2	RP 342.4870 to 343.0546	Five Star Mix using granite aggregate as used in the MR0301 Mix

Visual distresses were noted in each of the sections. The primary distress in each section was longitudinal shrinkage cracks between the patch mix and existing concrete. However, the experimental section had more longitudinal shrinkage cracks than the other two sections evaluated. The depth of the shrinkage cracks was unknown as cores were not taken.

Provided in the following table is a summary of the sections evaluated.

	Control Section 1	Experimental Section	Control Section 2
Date of Construction	6-27-03	8-14-03	8-15-03
Average (high) Temp (°F)	58 (68)	86 (90)	86 (91)
Average Wind Speed (gusts) (mph)	9 (N/A)	20 (23-30)	11 (N/A)
Humidity	78%	48%	64%
6-hour Comp Breaks (psi)	7,080	5,290	4,850
Load Transfer	97.1%	88.6%	84.6%
Production Rate	143 slots/hr	54 slots/hr	156 slots/hr
Percentage of slots distressed			
Percentage of slots distressed	1.4%	32.4%	3.5%

Based on the above table, there were several items that stood out and they are as follows:

- Environmental conditions
- Load transfer efficiency
- Production rate
- Longitudinal shrinkage cracks

Several of these items may have been caused by the same thing. The one item that is not tied to the others is the production rate. The production rates in the control sections were nearly three times the production rate than in the experimental section. This was attributed to the mixing time requirements. Fifteen minutes of mix time was substantially longer than the mixing time required for the current proprietary mixes (two – three minutes.) The use of admixtures required more mixing time in order for them to work as intended which slows production.

The increase in longitudinal shrinkage cracks in the experimental section may be the result of either the environmental conditions, the use of a water reducing admixture or both. The Portland Cement Association (PCA) publishes a book titled *Design and Control of Concrete Mixtures, 14th Edition* states that water reducing admixtures may cause an increase in drying shrinkage. The same publication also states that when using high-range water reducers (this project used a high-range water reducer), the drying shrinkage is comparable to concretes without high-range water reducers when

the water to cement ratios remains the same. Another publication, *Properties of Concrete, Fourth Edition* written by A. M. Neville states lignosulfonate-based water reducing admixtures (not used on this project) increase shrinkage, but other water reducing admixtures do not affect shrinkage. This same publication also states that super plasticizers (used on this project) do not influence shrinkage. Based on these two sources, the water reducing admixture used should not have caused an increase in longitudinal shrinkage in the experimental mix.

Based on the above information, environmental effects appear to have played a major role in the longitudinal shrinkage cracks. Based on Figure 13-8 in the publication *Design and Control of Concrete Mixtures, 14th Edition*, the rate of evaporation was calculated for the mixes on the day they were placed. The exact concrete temperature during placement was unknown in the two control sections and a reasonable temperature was assumed. Provided in the following table was the rate of evaporation calculated along with the input data.

Section	Air Temperature	Humidity	Concrete Temperature	Wind Speed	Rate of Evaporation
Control #1	58° F	78%	*60° F	9 mph	0.035 lb (ft^2/hr)
Control #2	86° F	64%	*78° F	11 mph	0.04 lb (ft^2/hr)
Experimental	86° F	48%	78° F	20 mph	0.18 lb (ft^2/hr)

*Assumed concrete temperature

As seen in the table above, the rate of evaporation in the experimental section far exceeded those in the control sections. The wind speed was the major factor in this. Even though curing compound was applied immediately, the wind will dry the pre-wetted slot prior to the placement of the grout and the experimental mix. The other factor that is not seen here is the temperature of the surrounding PCC Pavement. During summer months, when the air temperature is around 90°F, the PCC pavement can reach temperatures of 110°F plus. At these temperatures, the heat from the pavement may also have contributed to the evaporation of water.

Local PCC pavement temperature data (RWIS site at Red River Bridge, I-94) is not available for the immediate area on August 14 & 15, 2003, however data was available for June 27, 2003. The PCC pavement temperature stated on the previous page is from another site with very similar environmental conditions (sun, wind, etc) on these days (RWIS site west of Jamestown, ND, I-94).

Using RWIS data, the difference in pavement temperature ranged from approximately 20°F to 42°F lower in June compared to August. This temperature difference was important as it may indicate that the Experimental mix and Control Section #2 mix set up quicker than Control Section #1 mix, which may result in a slightly poorer bond to the existing concrete. The difference in the average ambient air temperature was 28°F lower in June compared to August.

Evaluations

Materials and Research conducted the first evaluation of the dowel bar slots on September 28, 2004. The final evaluation was conducted on October 26, 2005. Control section 1, control section 2, and the experimental section were evaluated visually for distresses. Load transfers across the joints were performed on these sections with a FWD.

Control Section 1

Photo 1 shows an overall view of control section 1.

Photo 1 - Overall view of control section 1.

Overall, control section 1 looks good. The number of visible distresses identified has nearly doubled but the load transfer efficiency has remained the same. Control section #1 is outperforming the other sections with lower visible distresses and higher load transfer efficiency.

Provided in the following table is the percent of slots (there is a total of 432 slots) with distresses in control section 1 and average load transfer efficiency within this section. The percentage of transverse cracks is slightly lower than one year ago but the amount of coreboard failures are up. The location of some transverse cracks suggests that they may be the initial stages of coreboard failures. Coreboard failures are a result of misalignment of the coreboard within the slot (coreboard does not remain in the joint).

Control Section 1				
Date	Distress / Load Transfer			
	Visible Long. Cracks	Transverse Crack	Coreboard Failure	Load Transfer
October 2003	1.4%	0.0%	0.0%	97.1%
September 2004	9.3%	2.1%	0.5%	93.9%
October 2005	16.9%	1.9%	1.9%	93.6%

Photo 2 - Typical joint in control section 1.

Photo 3 - Spalling at joint and dowel bar slot.

Photo 4 - Coreboard failure in control section 1.

Control Section 2

Photo 5 shows an overall view of control section 2.

Photo 5 - Overall view of control section 2.

Overall, control section 2 looks OK. There has been a substantial increase in the number of visible distresses identified in the period of a year and load transfer efficiency has dropped. As the number and severity of the distresses increase, it is anticipated that the load transfer will continue to drop in this section.

Provided in the following table is the percent of slots (there is a total of 432 slots) with distresses in control section 2 and average load transfer efficiency within this

section. The location of some transverse cracks suggests that they may be the initial stages of coreboard failures. Coreboard failures are a result of misalignment of the coreboard within the slot (coreboard does not remain in the joint).

Control Section 2				
Date	**Distress / Load Transfer**			
	Visible Long. Cracks	**Transverse Crack**	**Coreboard Failure**	**Load Transfer**
October 2003	3.5%	0.2%	0.2%	84.6%
September 2004	18.3%	2.1%	0.2%	84.1%
October 2005	51.6%	33.3%	6.3%	80.5%

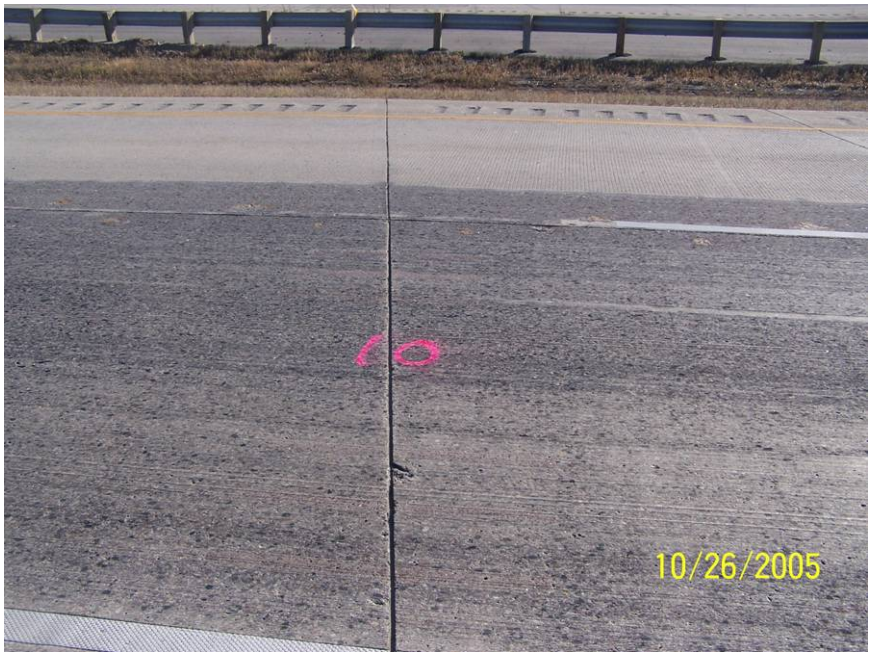

Photo 6 - Typical joint in control section 2 - spall area is in the original PCC pavement.

Experimental Section

Photo 7 shows an overall view of the experimental section.

Photo 7 - Overall view of the experimental section.

Overall, the experimental section is experiencing the most visible distresses of the three sections evaluated. There has been an increase in the number of visible distresses identified with a decrease in load transfer efficiency. As the number and severity of the distresses increase, it is anticipated that the load transfer will continue to drop in this section.

Provided in the following table is the percent of slots (there is a total of 432 slots) with distresses in the experimental section and average load transfer efficiency within this section. The location of some transverse cracks suggests that they may be the initial stages of coreboard failures. Coreboard failures are a result of misalignment of the coreboard within the slot (coreboard does not remain in the joint).

Experimental Section				
Date	**Distress / Load Transfer**			
	Visible Long. Cracks	**Transverse Crack**	**Coreboard Failure**	**Load Transfer**
October 2003	32.4%	0.0%	0.7%	88.6%
September 2004	50.9%	1.2%	3.0%	83.1%
October 2005	79.6%	5.3%	4.6%	78.5%

Photo 8 - Typical joint in experimental section.

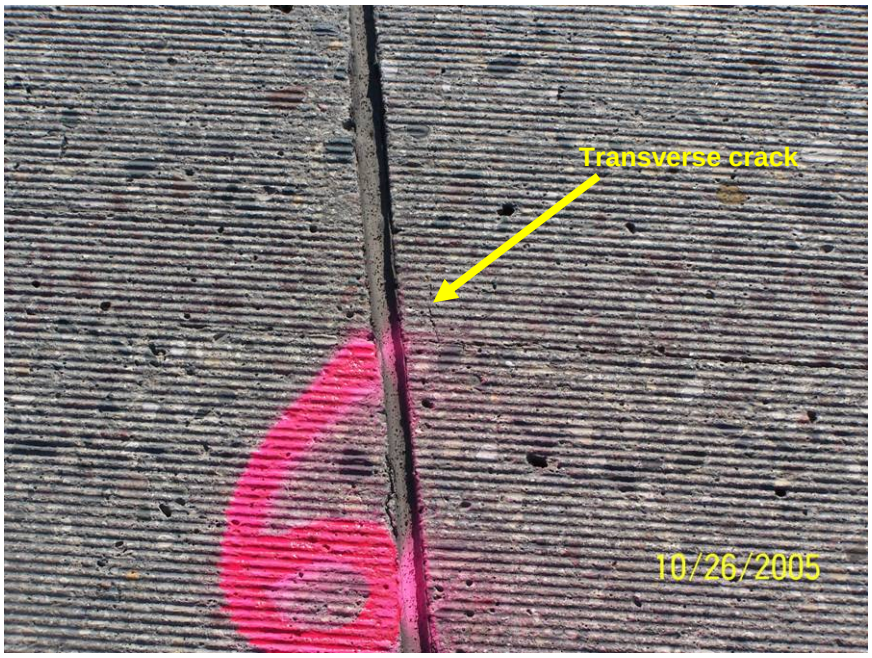

Photo 9 - Transverse crack location is likely the early signs of a coreboard failure.

Summary

The production rates achieved during construction with the experimental mix will not allow the experimental mix to be competitive on a construction cost basis with other proprietary mixes currently used.

The long-term performance and continued load transfer of dowel bar retrofits relies on the performance of the concrete patch mix and dowel bar itself. Over the evaluation period, all sections experienced an increase in visible distresses. However, the experimental mix has also shown more distresses than control section 1 or control section 2. The load transfer efficiency is significantly lower in the experimental section and control section 2 compared with control section 1. Provided in the following table is a summary of the distress (in terms of percentage of slots) and load transfer efficiency observed or measured to date.

Distress	Control Section 1			Experimental Section			Control Section 2		
	Oct-03	Sep-04	Oct-05	Oct-03	Sep-04	Oct-05	Oct-03	Sep-04	Oct-05
Visible crack-long.	1.4%	9.3%	16.9%	32.4%	50.9%	79.6%	3.5%	18.3%	51.6%
Transverse crack	0.0%	2.1%	1.9%	0.0%	1.2%	5.3%	0.2%	2.1%	33.3%
Coreboard	0.0%	0.5%	1.9%	0.7%	3.0%	4.6%	0.2%	0.2%	6.3%
Load Transfer	97.1%	93.9%	93.6%	88.6%	83.1%	78.5%	84.6%	84.1%	80.5%

Where as the load transfer and distress in control section 1 is relatively stable, distress continues to increase and load transfer continues to decrease in the experimental section and control section 2.

It is believed that the environmental conditions at the time of construction are, in part, responsible for the distress noted initially and in subsequent evaluations. The ambient air temperature, wind speed, and temperature of the surrounding concrete have a dramatic affect on the rate of evaporation and rate of hydration of the concrete patch mix.

The decline in load transfer efficiency in the experimental section and in control section 2 appears to be related to the increased distress in the concrete patch mix for these sections. Distress in control section 1 although increasing, is relatively low and stable, and the load transfer efficiency for this section remains in the 90% plus range.

Recommendations

It is recommended that the NDDOT continue using the proprietary mixes currently allowed in the standard specifications due to higher costs and poor performance of the experimental mix.

It is recommended that special attention is given to the location of coreboards after the dowel bar mix is placed. Coreboard failures can be reduced or eliminated if the coreboard remains in the joint and not allowed to move into the dowel bar slot when placing the concrete patch mix.

It is also recommended that tighter controls be placed on the allowable environmental conditions at the time that concrete patch mix is being placed. The effects of temperature, humidity, and wind speed can dramatically affect the rate of cure and final condition of the concrete patch mix. These factors have been shown to contribute to the formation of shrinkage cracks; as well as the development of bonding problems with the side walls of the existing concrete. Ambient air temperatures must be, at a minimum, within the manufacturer's recommendations at the time of placing the concrete patch mix. These concerns should be addressed in the Special Provisions for future Dowel Bar Retrofit projects.

Appendix A: Mix Design

North Dakota Department of Transportation
Dowel Bar Retrofit Mix "MR0301"

Description

This work shall consist of retrofitting approximately one-half lane mile of epoxy-coated dowel bars into existing concrete pavement using an experimental concrete mix. Section 570 of the 2002 edition of the NDDOT *Standard Specifications for Road and Bridge Construction* shall govern except where noted below.

Material

1. Patching Material**.** "Concrete Patch Mix " shall be a mix prepared using the following mix design:

Material	Per CY Quantities
Cement	850 lbs
Water	255 lbs
Fine Aggregate	1079 lbs
Coarse Aggregate	1526 lbs
Air-entraining Admixture	2.975 fl-oz
Accelerating Admixture	340 fl-oz
Water Reducer (Super Plasticizer)	102 fl-oz

- The cement shall be a Type III (Lehigh) meeting the requirements of Section 804.01.

- The fine aggregate shall meet the requirements of Section 816.01 and have the following gradation:

Sieve Size	% Passing
3/8"	100
#4	95-100
#8	45-65
#50	10-30
#100	0-10
#200 (Max)	3

- The coarse aggregate shall be granite obtained from Ortonville, MN. The owner of the pit is Aggregate Industries. The coarse aggregate shall meet the requirements of Section 816.02 and have the following gradation:

Sieve Size	% Passing
3/8"	100
#4	25-30
#8	10-20
#200 (Max)	1

- The concrete admixtures shall be the following:

Air-entraining	Master Builders – Pave-Air
Accelerator	Master Builders – Pozzolith NC534
Water Reducer (Super plasticizer)	Master Builders – Rheobuild 3000FC

- The Dowel Bar Retrofit Mix shall have the following properties:

Maximum Water to Cement (W/C) Ratio	0.30
Slump	9" ± 1"
Air	6% ± 1%

Construction Requirements

1. A trial batch shall be conducted prior to placement in the slots in order to test the material properties. Minor adjustments may be required in order to meet the mix requirements as stated in Section 570 of the specifications and the changes indicated above.
2. A grout mix shall be applied to the dowel bar slot after pre-wetting the dowel bar slot and prior to placement of the MR0301 patch mix in the slot. The patch mix shall be placed in the slot prior to the grout mix drying. Drying of the grout mix will be considered when the grout mix starts to turn white. If the grout mix starts to dry, the grout shall be removed and cleaned according to Section 570.04 C.2.c.
3. The recommended mixing procedure is as follows:
    a. Place the coarse aggregate into the mixer.
    b. Combine the super plasticizer and water.
    c. Add half the quantity of water with super plasticizer to the coarse aggregate and mix for two minutes before adding other components.
    d. Add the fine aggregate (the air entraining admixture shall be added to the fine aggregate as it is being added to the mix).
    e. Add the cement.
    f. Add the remaining quantity of water with super plasticizer.
    g. Add the accelerating admixture.
    h. After the last component is added, mixing shall continue for additional five minutes and then stop the mixer for three minutes and then resume mixing for an additional two minutes.
4. The curing compound shall be applied immediately after the patch mix is finished.

Method of measurement and basis of Payment

Installation of the Dowel Bars will be measured and paid for as "Dowel Bar Retrofit Type A" for each dowel installed and accepted by the Engineer. Payment shall be full compensation for all labor, equipment, and materials necessary to complete the work as specified.

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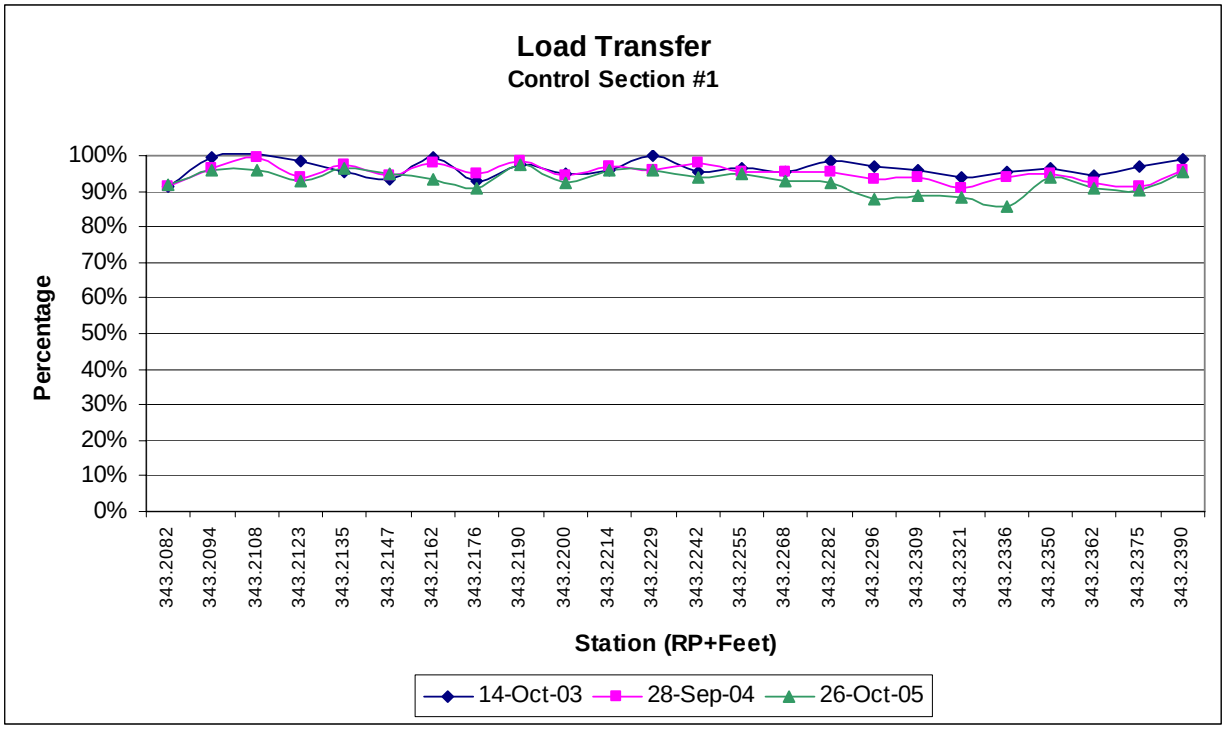
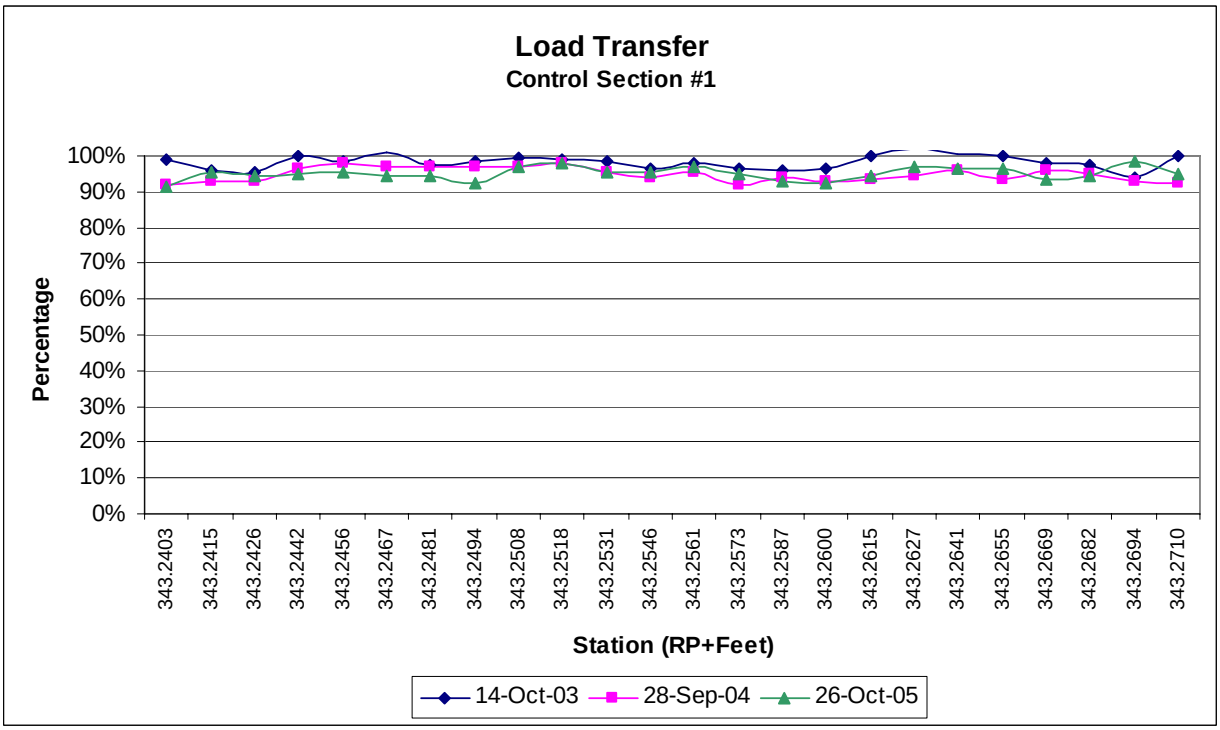
Appendix B: Load Transfer

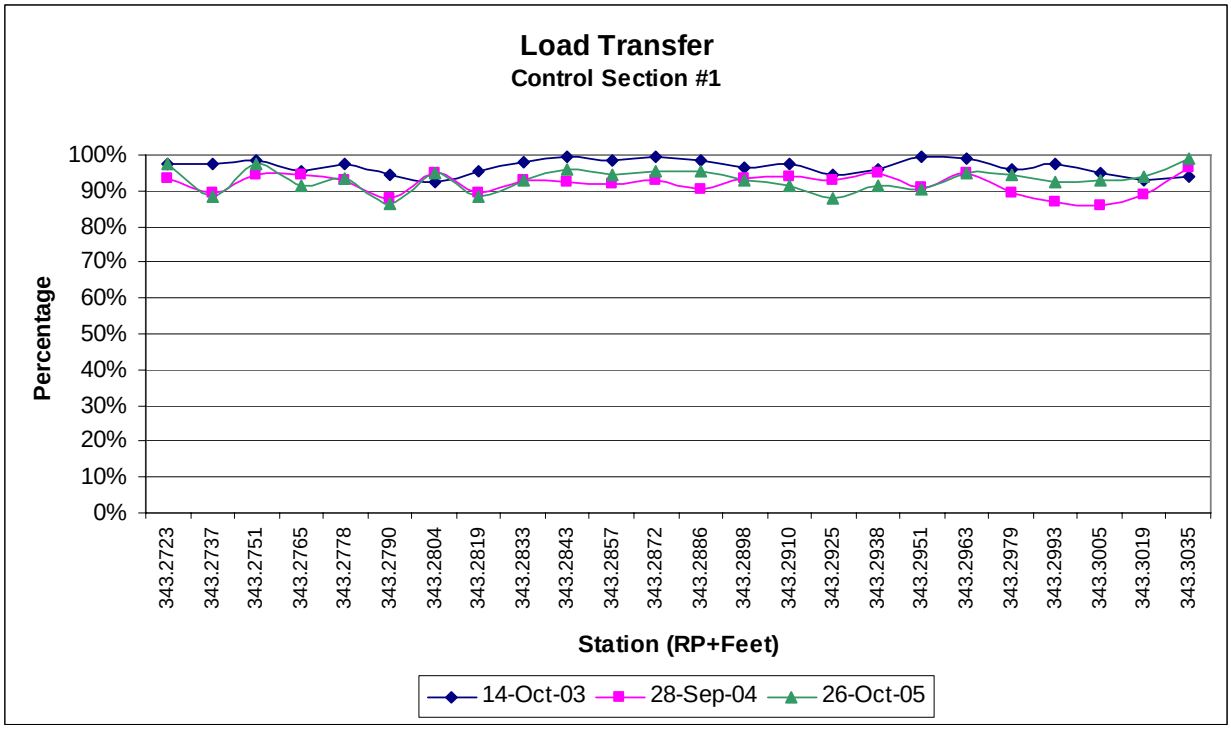
Control Section #1

Station (mile.feet)	2003 Load Transfer	2004 Load Transfer	2005 Load Transfer
343.2082	91.4%	91.2%	91.9%
343.2094	99.6%	96.5%	95.9%
343.2107	100.3%	99.7%	95.8%
343.2123	98.6%	93.8%	92.7%
343.2136	95.6%	97.3%	96.2%
343.2148	93.5%	94.6%	94.8%
343.2162	99.4%	98.1%	93.2%
343.2176	92.8%	94.6%	90.9%
343.2190	97.2%	98.5%	97.2%
343.2201	94.9%	94.6%	92.6%
343.2214	96.1%	97.0%	95.8%
343.2229	99.8%	96.0%	95.8%
343.2243	95.3%	98.1%	93.8%
343.2254	96.3%	95.6%	95.0%
343.2268	95.6%	95.2%	92.9%
343.2282	98.4%	95.6%	92.5%
343.2297	96.7%	93.2%	87.8%
343.2308	95.7%	93.8%	88.7%
343.2321	93.6%	90.9%	88.1%
343.2337	95.4%	93.9%	85.8%
343.2350	96.3%	95.1%	93.9%
343.2362	94.6%	92.5%	90.6%
343.2375	96.8%	91.2%	90.2%
343.2390	98.9%	96.0%	95.5%
343.2403	99.1%	91.7%	91.5%
343.2415	96.2%	93.1%	95.3%
343.2426	95.4%	92.7%	94.2%
343.2442	99.8%	96.2%	94.9%
343.2456	98.7%	98.2%	95.5%
343.2467	100.9%	97.0%	94.4%
343.2481	97.5%	96.9%	94.5%
343.2494	98.7%	97.1%	92.6%
343.2508	99.7%	97.1%	96.8%
343.2521	99.1%	98.0%	98.0%
343.2533	98.7%	95.7%	95.6%
343.2547	96.7%	93.8%	95.7%
343.2561	97.9%	95.6%	96.7%
343.2573	96.4%	91.9%	94.8%
343.2587	95.8%	94.1%	93.0%
343.2601	96.6%	93.1%	92.4%
343.2615	100.2%	93.6%	94.3%
343.2628	102.1%	94.3%	96.8%

Station (mile.feet)	2003 Load Transfer	2004 Load Transfer	2005 Load Transfer
343.2641	100.6%	96.0%	96.4%
343.2655	99.8%	93.4%	96.5%
343.2670	98.2%	95.9%	93.4%
343.2681	97.3%	94.9%	94.5%
343.2695	94.1%	92.8%	98.5%
343.2710	100.2%	92.3%	94.9%
343.2723	97.7%	93.2%	97.7%
343.2736	97.5%	89.4%	88.4%
343.2750	98.6%	94.5%	97.3%
343.2765	95.3%	94.5%	91.6%
343.2779	97.4%	93.0%	93.3%
343.2791	94.2%	87.9%	86.5%
343.2804	92.6%	95.0%	95.1%
343.2819	95.5%	89.3%	88.4%
343.2833	97.9%	92.8%	92.7%
343.2845	99.4%	92.2%	95.8%
343.2858	98.3%	92.0%	94.2%
343.2873	99.5%	93.1%	95.2%
343.2887	98.6%	90.6%	95.4%
343.2898	96.6%	93.2%	92.7%
343.2910	97.4%	93.8%	91.6%
343.2926	94.7%	92.7%	88.0%
343.2939	96.1%	95.0%	91.2%
343.2952	99.3%	90.7%	90.3%
343.2964	99.0%	95.0%	95.0%
343.2979	96.1%	89.5%	94.7%
343.2995	97.4%	86.8%	92.2%
343.3005	95.1%	85.9%	93.0%
343.3019	93.1%	88.9%	94.0%
343.3035	94.1%	96.6%	98.8%


Load Transfer
Control Section #1
Percentage
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
343.2082
343.2094
343.2108
343.2123
343.2135
343.2147
343.2162
343.2176
343.2190
343.2200
343.2214
343.2229
343.2242
343.2255
343.2268
343.2282
343.2296
343.2309
343.2321
343.2336
343.2350
343.2362
343.2375
343.2390
Station (RP+Feet)
14-Oct-03
28-Sep-04
26-Oct-05

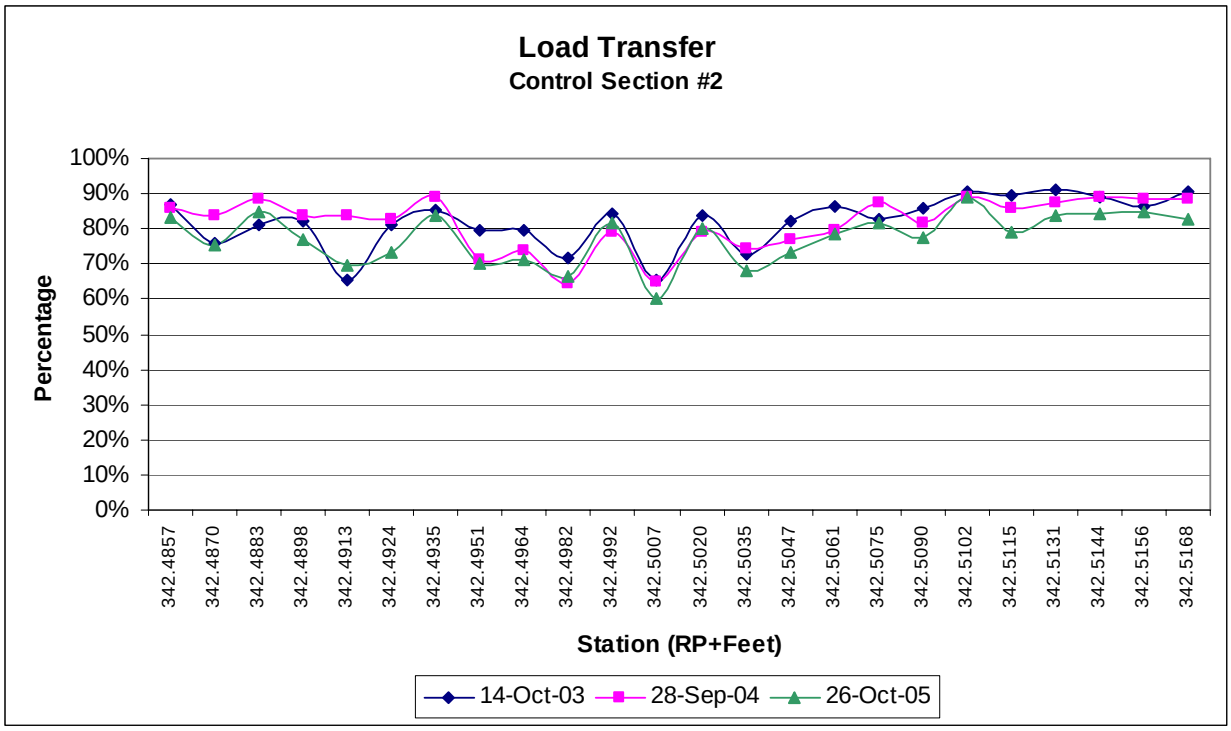

Load Transfer
Control Section #1
Percentage
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
343.2403
343.2415
343.2426
343.2442
343.2456
343.2467
343.2481
343.2494
343.2508
343.2518
343.2531
343.2546
343.2561
343.2573
343.2587
343.2600
343.2615
343.2627
343.2641
343.2655
343.2669
343.2682
343.2694
343.2710
Station (RP+Feet)
14-Oct-03
28-Sep-04
26-Oct-05

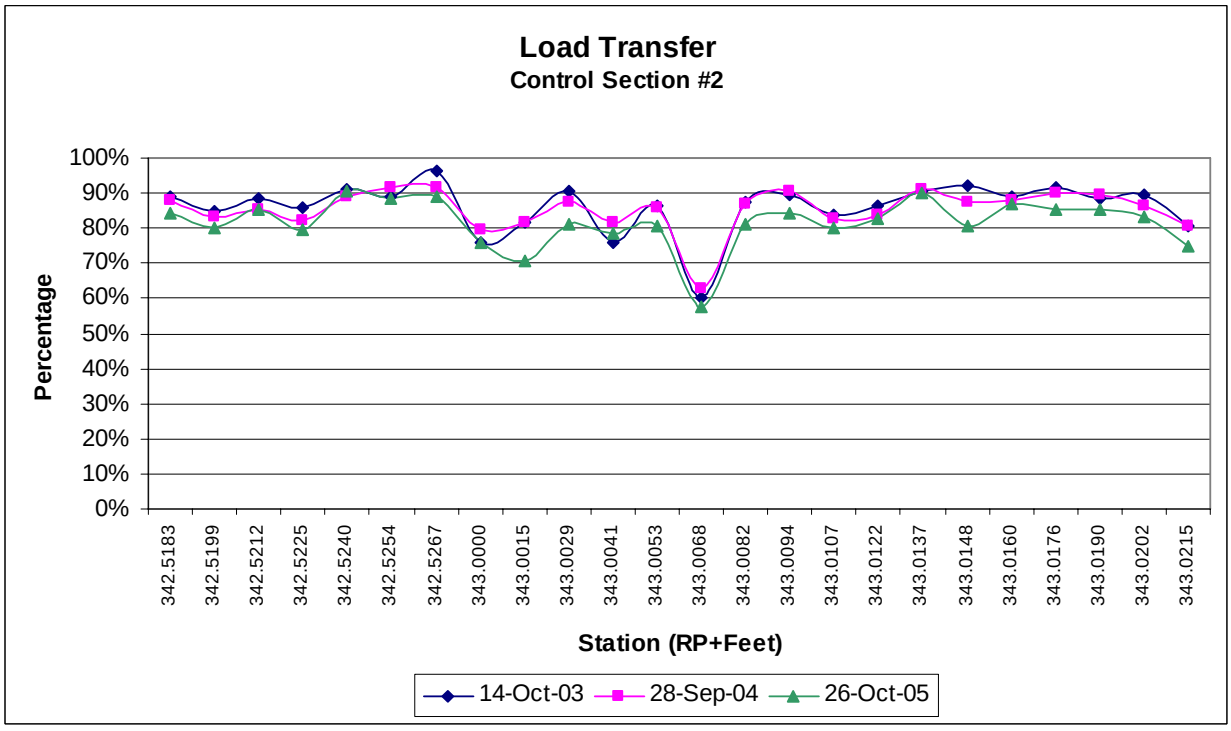

Load Transfer
Control Section #1
Percentage
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
343.2723
343.2737
343.2751
343.2765
343.2778
343.2790
343.2804
343.2819
343.2833
343.2843
343.2857
343.2872
343.2886
343.2898
343.2910
343.2925
343.2938
343.2951
343.2963
343.2979
343.2993
343.3005
343.3019
343.3035
Station (RP+Feet)
14-Oct-03
28-Sep-04
26-Oct-05

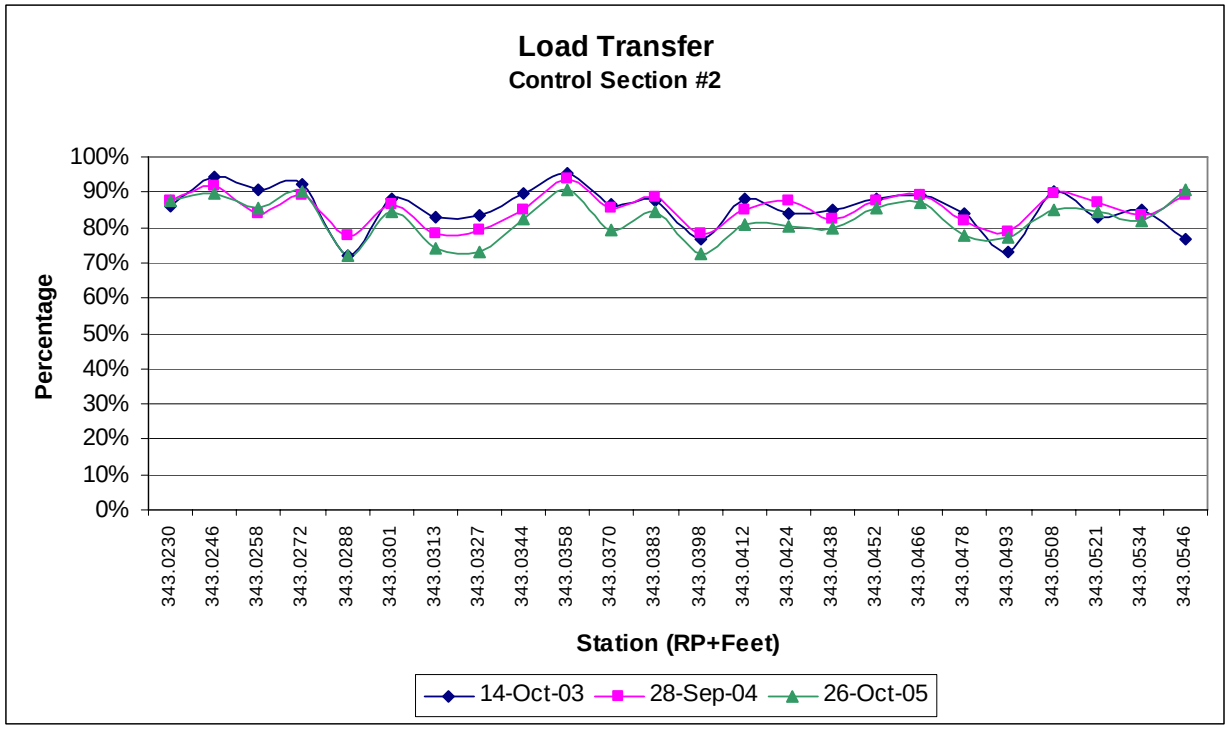
Control Section #2

Station (mile.feet)	2003 Load Transfer	2004 Load Transfer	2005 Load Transfer
342.4857	87.0%	86.0%	83.4%
342.4870	76.1%	83.6%	75.6%
342.4883	81.3%	88.3%	85.1%
342.4898	82.4%	83.6%	77.2%
342.4913	65.5%	83.6%	69.6%
342.4924	80.9%	82.6%	73.4%
342.4935	85.2%	88.8%	84.0%
342.4951	79.8%	71.2%	70.1%
342.4964	79.5%	73.6%	71.4%
342.4982	71.8%	64.6%	66.7%
342.4993	84.1%	78.8%	81.6%
342.5007	65.3%	65.2%	60.0%
342.5021	83.7%	79.0%	79.9%
342.5035	72.9%	74.5%	67.9%
342.5048	82.4%	76.8%	73.1%
342.5061	86.6%	79.8%	78.5%
342.5075	82.6%	87.6%	81.9%
342.5090	86.1%	81.5%	77.7%
342.5102	90.5%	89.1%	88.8%
342.5115	89.3%	85.8%	79.0%
342.5131	91.1%	87.7%	84.0%
342.5144	88.9%	89.2%	84.2%
342.5157	86.3%	88.2%	84.7%
342.5169	90.4%	88.2%	82.9%
342.5183	89.2%	87.9%	84.3%
342.5199	84.9%	83.4%	80.3%
342.5211	88.7%	85.4%	85.4%
342.5225	86.1%	82.3%	79.8%
342.5240	91.2%	88.9%	90.7%
342.5253	89.2%	91.8%	88.4%
342.5267	96.3%	91.5%	89.2%
343.0000	76.0%	79.4%	75.9%
343.0015	81.9%	81.7%	70.9%
343.0029	90.4%	87.7%	81.0%
343.0041	75.8%	81.8%	78.4%
343.0055	86.2%	86.0%	80.8%
343.0069	60.5%	62.8%	57.7%
343.0082	87.3%	87.1%	81.4%
343.0095	89.8%	90.5%	84.4%
343.0108	83.7%	82.8%	80.2%
343.0122	86.6%	84.0%	82.6%
343.0137	90.3%	91.3%	89.8%

Station (mile.feet)	2003 Load Transfer	2004 Load Transfer	2005 Load Transfer
343.0149	92.1%	87.4%	80.9%
343.0162	89.3%	88.2%	87.1%
343.0177	91.4%	90.3%	85.4%
343.0190	88.2%	89.5%	85.4%
343.0203	89.7%	86.2%	83.0%
343.0216	80.8%	80.5%	74.7%
343.0230	86.0%	87.8%	87.6%
343.0246	94.1%	91.9%	89.7%
343.0258	90.5%	83.8%	85.5%
343.0272	92.1%	89.2%	90.3%
343.0287	72.0%	77.6%	71.8%
343.0301	88.2%	86.4%	84.4%
343.0314	82.7%	78.1%	74.3%
343.0327	83.2%	79.3%	73.2%
343.0342	89.8%	85.0%	82.6%
343.0357	95.6%	93.7%	90.9%
343.0370	86.5%	85.5%	79.1%
343.0383	87.6%	88.8%	84.4%
343.0398	76.9%	78.5%	72.5%
343.0411	88.1%	84.8%	80.9%
343.0424	84.2%	87.7%	80.5%
343.0437	85.0%	82.6%	79.7%
343.0453	88.3%	87.4%	85.3%
343.0467	89.2%	89.4%	87.0%
343.0478	83.7%	81.6%	77.9%
343.0493	73.2%	78.9%	77.2%
343.0507	90.3%	89.7%	85.1%
343.0520	83.0%	86.9%	84.5%
343.0534	85.2%	83.5%	82.0%
343.0546	76.9%	89.3%	90.7%


Load Transfer
Control Section #2
Percentage
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
342.4857
342.4870
342.4883
342.4898
342.4913
342.4924
342.4935
342.4951
342.4964
342.4982
342.4992
342.5007
342.5020
342.5035
342.5047
342.5061
342.5075
342.5090
342.5102
342.5115
342.5131
342.5144
342.5156
342.5168
Station (RP+Feet)
14-Oct-03
28-Sep-04
26-Oct-05

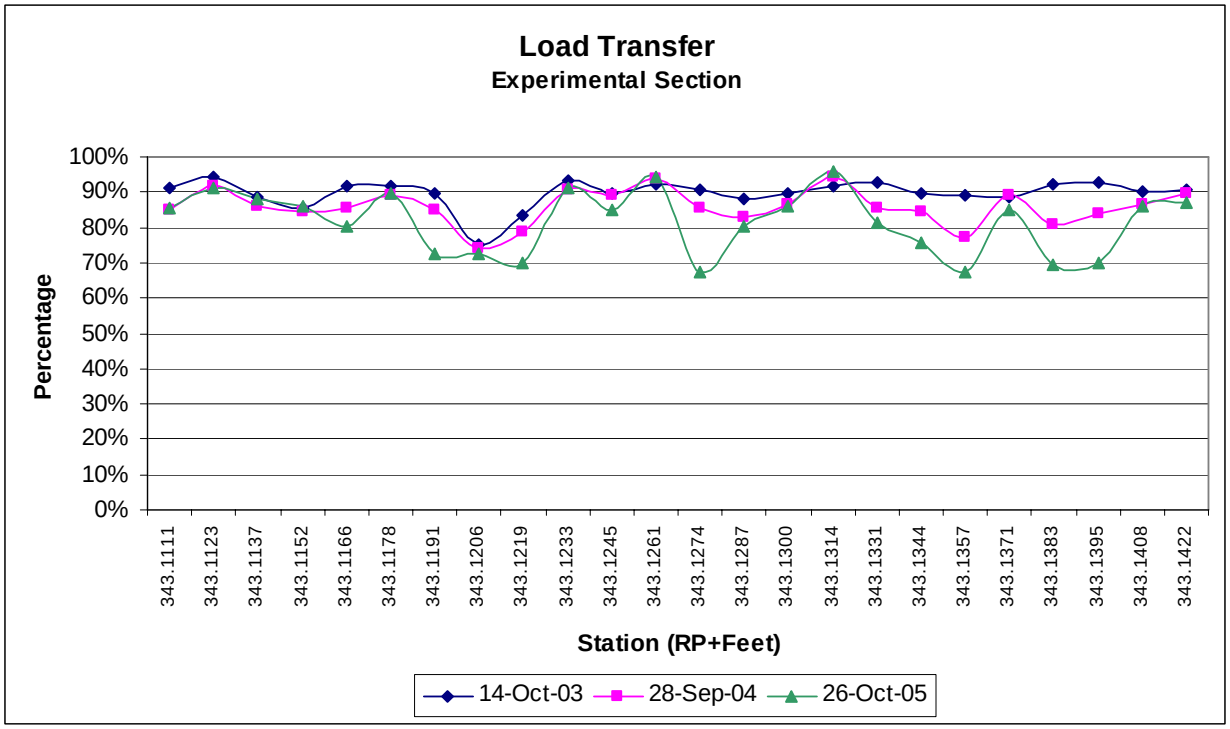

Load Transfer
Control Section #2
Percentage
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
342.5183
342.5199
342.5212
342.5225
342.5240
342.5254
342.5267
343.0000
343.0015
343.0029
343.0041
343.0053
343.0068
343.0082
343.0094
343.0107
343.0122
343.0137
343.0148
343.0160
343.0176
343.0190
343.0202
343.0215
Station (RP+Feet)
14-Oct-03
28-Sep-04
26-Oct-05

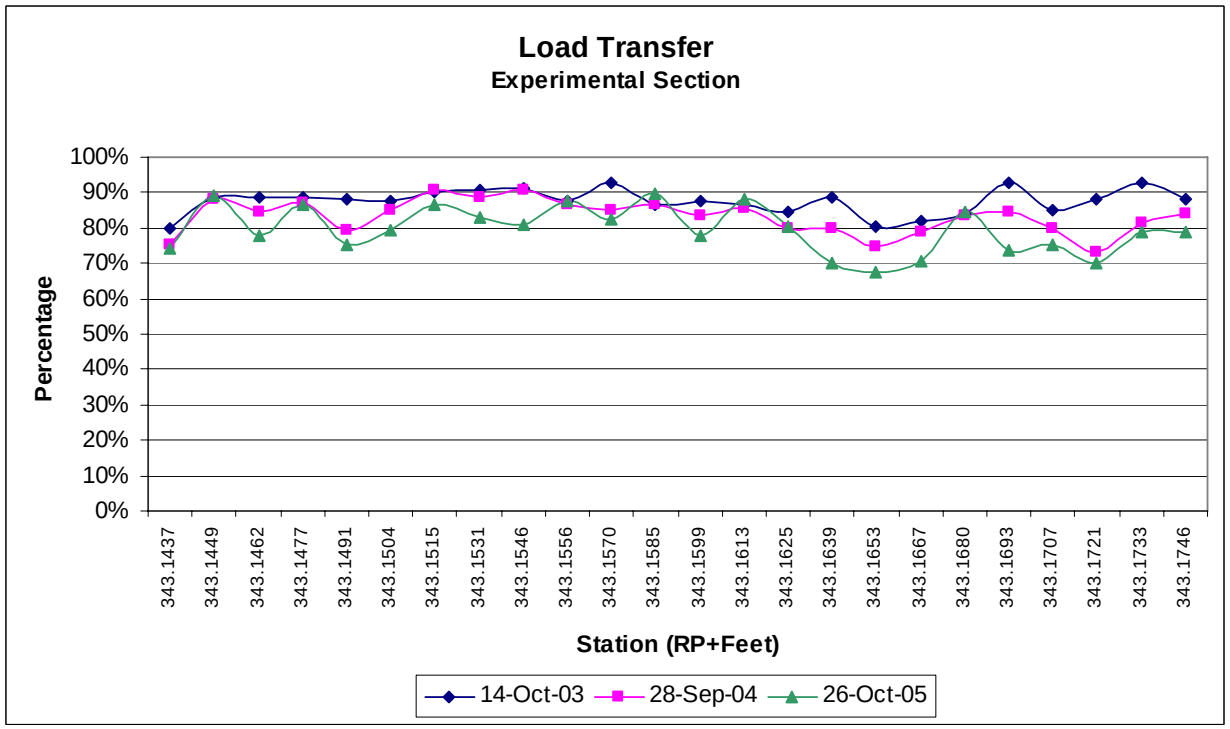

Load Transfer
Control Section #2
Percentage
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
343.0230
343.0246
343.0258
343.0272
343.0288
343.0301
343.0313
343.0327
343.0344
343.0358
343.0370
343.0383
343.0398
343.0412
343.0424
343.0438
343.0452
343.0466
343.0478
343.0493
343.0508
343.0521
343.0534
343.0546
Station (RP+Feet)
14-Oct-03
28-Sep-04
26-Oct-05

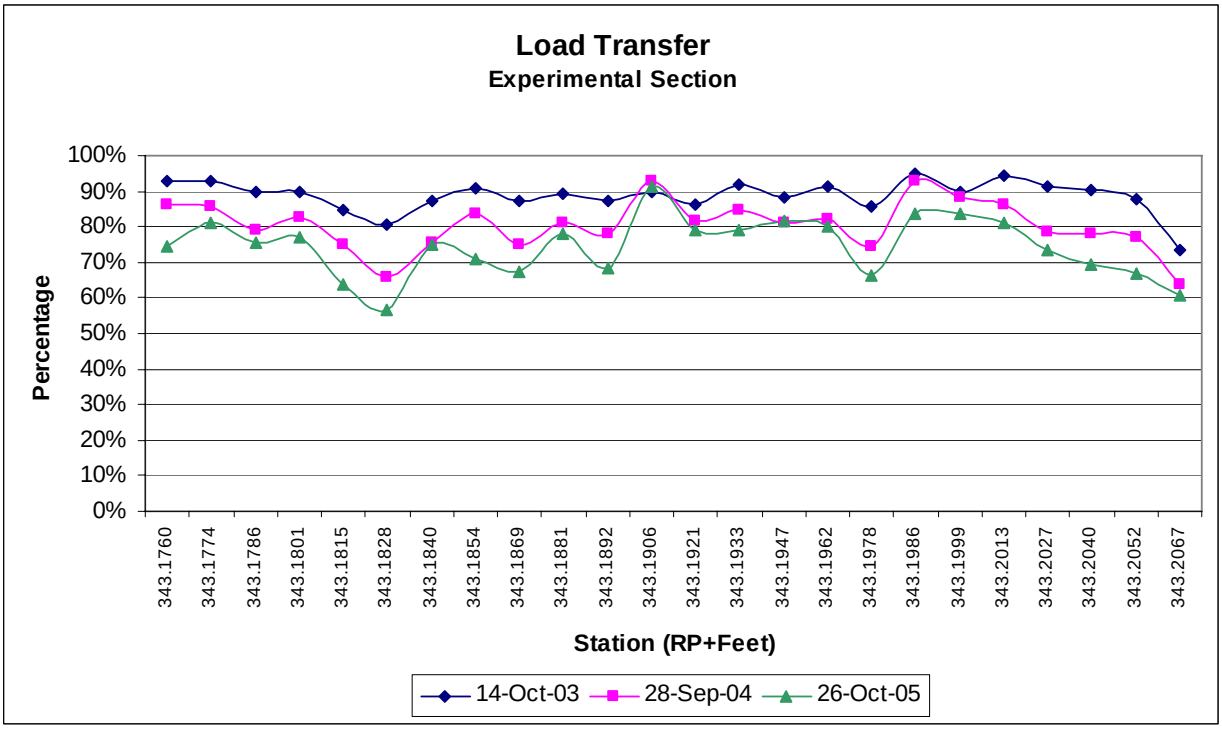
Experimental Section

Station (mile.feet)	2003 Load Transfer	2004 Load Transfer	2005 Load Transfer
343.1111	91.1%	85.1%	85.6%
343.1123	94.1%	91.8%	91.3%
343.1136	88.5%	86.1%	88.2%
343.1152	85.5%	84.3%	86.0%
343.1165	91.8%	85.6%	80.5%
343.1178	91.8%	88.9%	89.4%
343.1191	89.6%	84.9%	72.8%
343.1205	75.2%	74.0%	72.5%
343.1220	83.4%	78.5%	69.8%
343.1232	93.3%	90.4%	91.2%
343.1245	89.6%	89.1%	84.9%
343.1260	92.3%	93.6%	94.1%
343.1273	90.6%	85.7%	67.5%
343.1287	87.8%	83.0%	80.3%
343.1300	89.6%	86.8%	86.0%
343.1314	91.5%	94.3%	95.7%
343.1330	92.5%	85.4%	81.5%
343.1343	89.6%	84.5%	75.7%
343.1357	89.4%	77.1%	67.6%
343.1371	88.8%	89.2%	85.2%
343.1384	92.1%	81.0%	69.4%
343.1396	92.5%	83.9%	70.0%
343.1408	90.3%	86.5%	86.0%
343.1422	90.6%	89.5%	87.3%
343.1437	80.0%	75.3%	74.0%
343.1449	88.9%	88.0%	89.1%
343.1462	88.5%	84.6%	77.9%
343.1477	88.5%	86.9%	86.7%
343.1491	87.9%	79.6%	75.1%
343.1504	87.4%	84.9%	79.4%
343.1517	90.1%	90.9%	86.8%
343.1531	90.8%	88.6%	83.1%
343.1546	91.3%	90.6%	81.0%
343.1557	87.6%	86.5%	87.8%
343.1570	92.9%	84.8%	82.5%
343.1585	86.6%	86.6%	89.6%
343.1599	87.7%	83.6%	77.7%
343.1613	86.8%	85.7%	88.4%
343.1625	84.3%	80.0%	80.4%
343.1640	88.7%	80.2%	70.3%
343.1654	80.3%	74.6%	67.5%
343.1666	82.1%	78.7%	70.5%

Station (mile.feet)	2003 Load Transfer	2004 Load Transfer	2005 Load Transfer
343.1679	84.1%	83.2%	84.5%
343.1694	92.9%	84.5%	73.8%
343.1707	85.2%	80.1%	75.3%
343.1720	88.1%	73.4%	69.9%
343.1733	93.0%	81.3%	78.8%
343.1747	88.1%	84.3%	78.8%
343.1762	93.0%	86.0%	74.6%
343.1774	93.0%	85.9%	81.3%
343.1785	89.6%	79.2%	75.4%
343.1801	89.8%	82.6%	77.0%
343.1815	84.5%	74.8%	63.9%
343.1828	80.5%	65.7%	56.7%
343.1839	87.1%	75.7%	75.2%
343.1854	90.9%	83.8%	71.0%
343.1869	87.3%	75.1%	67.6%
343.1881	89.3%	81.3%	78.0%
343.1893	87.4%	77.9%	68.3%
343.1908	89.6%	92.7%	91.2%
343.1922	86.0%	81.8%	78.9%
343.1934	91.7%	84.8%	79.0%
343.1948	88.2%	81.3%	81.8%
343.1963	91.4%	82.0%	80.0%
343.1978	86.0%	74.4%	66.1%
343.1987	94.7%	92.7%	83.4%
343.1999	89.9%	88.5%	83.9%
343.2014	94.2%	86.1%	81.1%
343.2028	91.4%	78.4%	73.5%
343.2040	90.4%	78.1%	69.6%
343.2053	87.8%	76.9%	66.9%
343.2067	73.4%	63.9%	60.7%


Load Transfer
Experimental Section
Percentage
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
343.1111
343.1123
343.1137
343.1152
343.1166
343.1178
343.1191
343.1206
343.1219
343.1233
343.1245
343.1261
343.1274
343.1287
343.1300
343.1314
343.1331
343.1344
343.1357
343.1371
343.1383
343.1395
343.1408
343.1422
Station (RP+Feet)
14-Oct-03
28-Sep-04
26-Oct-05


Load Transfer
Experimental Section
Percentage
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
343.1437
343.1449
343.1462
343.1477
343.1491
343.1504
343.1515
343.1531
343.1546
343.1556
343.1570
343.1585
343.1599
343.1613
343.1625
343.1639
343.1653
343.1667
343.1680
343.1693
343.1707
343.1721
343.1733
343.1746
Station (RP+Feet)
14-Oct-03
28-Sep-04
26-Oct-05


Load Transfer
Experimental Section
Percentage
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
343.1760
343.1774
343.1786
343.1801
343.1815
343.1828
343.1840
343.1854
343.1869
343.1881
343.1892
343.1906
343.1921
343.1933
343.1947
343.1962
343.1978
343.1986
343.1999
343.2013
343.2027
343.2040
343.2052
343.2067
Station (RP+Feet)
14-Oct-03
28-Sep-04
26-Oct-05

Appendix C: Compressive Strength

6-Hour Compressive Break – Five Star

5011

PROJECT: ACIM-8-094 (041) 342 **DATE:** 6/30/3

REPORT TO ND DEPARTTMENT OF TRANSPORTATION **COPIES** WILLIE SHACHER
300 AIRPORT ROAD JOE PEYERL
BISMARCK, NORTH DAKOTA
ATTN: DENNIS BLASL

PROJECT # 03-3039.06

FIELD DATA:

TIME OF PLASTIC TEST:	12:10	CONCRETE T	N.T.
TICKET NUMBER:	N.P.	SLUMP (inche	N.T.
COUNTY:	CASS	AIR CONTEN	N.T.
DISTRICT:	FARGO	UNIT WEIGH	N.T.
CONTRACTOR:	HIGHWAY SERVICES		
PAVING STATION/	STA 1543+10 LT		
PART OF STRUCTURE:	WB CLOSURE DRIVE LANE SEG. A		

FRACTURE

	A - CONE
	B - CONE AN
	C - CONE ANI
	D - SHEAR
	E- COLUMNAI

SPECIFIED STRENGTH @ 28 DAYS:

MIX DESIGN NUMBER:

Mix Used Per Sack of Cement	N.P.
Water / Sack of Cement (gals)	N.P.
TTL Water / Sack of Cement (	N.P.
Sacks per Cu Yd:	N.P.
Source of Gravel:	1-139-46
Source of Sand:	1-139-46
Class of Concrete:	5 STAR

CONCRETE FURNISHED BY:

COMPRESSIVE STRENGTH:

SET NUMBER:	**5011-A**	**5011-B**
DATE CAST:	6/27/3	
DATE RECEIVED:	6/27/3	
DATE OF TEST:	**6/27/3**	**6/27/3**
LABORATORY #:	**2715A**	**2715B**
METHOD OF CURING:		
Days on Job & Enroute:	0	0
Days Lab Cured-ASTM C193:	0	0
AGE AT TEST (days):	0	0
LOAD AT FAILURE (lbs):	195,210	205,090
DIAMETER OF CYLINDER (ir	6.0	6.0
AREA OF CYLINDER (inches	28.3	28.3
STRENGTH (psi):	**6900**	**7250**
TYPE OF FRACTURE:	**D**	**D**

Cast

REMARKS: Field data prepared by: NDDOT

BY: Keith Fraase

10/15/2003 13:36 701-239-7109 NDDOT PAGE 02

6-Hour Compressive Break – Five Star with Granite Aggregate

NORTHERN TECHNOLOGIES, INC.
2942 Fischer Drive, Fargo, ND 58103 701-232-1422 701-232-1864 Fax

COMPRESSION TESTS OF CONCRETE CYLINDERS

PROJECT: ACIM-8-094 (041) 342 **DATE:** 8/18/2003

REPORT TO: ND DEPARTTMENT OF TRANSPORTATION
300 AIRPORT ROAD
BISMARCK, NORTH DAKOTA
ATTN; DENNIS BLASL

COPIES TO: WILLIE SHACHER
JOE PEYERL

PROJECT #: 03-3039.08

FIELD DATA:

TIME OF PLASTIC TEST:	11:00	CONCRETE TEMP:	N.T.
TICKET NUMBER:	N.P.	SLUMP (inches):	N.T.
COUNTY:	CASS	AIR CONTENT (%):	N.T.
DISTRICT:	FARGO	UNIT WEIGHT (pcf)	N.T.
CONTRACTOR:	HIGHWAY SERVICES		
PAVING STATION/	WB I-94 DRIVING LANE		
PART OF STRUCTURE:	SEG. A STA 1488+00 LT		

TYPE OF FRACTURE

- [ ] A - CONE
- [ ] B - CONE AND SPLIT
- [ ] C - CONE AND SHEAR
- [ ] D - SHEAR
- [ ] E- COLUMNAR

SPECIFIED STRENGTH @ 28 DAYS:

MIX DESIGN NUMBER:

Mi[illegible]d Per Sack of Cement:	N.P.
W[illegible] Sack of Cement (gals):	N.P.
TTL Water / Sack of Cement (gals):	N.P.
Sacks per Cu Yd:	N.P.
Source of Gravel:	1-139-46
Source of Sand:	1-139-46
Class of Concrete:	5 STAR

CONCRETE FURNISHED BY:

COMPRESSIVE STRENGTH:

SET NUMBER:	5040-A	5040-B
DATE CAST:	8/15/2003	
DATE RECEIVED:	8/15/2003	
DATE OF TEST:	8/15/2003	8/15/2003
LABORATORY #:	3184A	3184B
METHOD OF CURING:		
Days on Job & Enroute:	0	0
Days Lab Cured-ASTM C193:	0	0
AGE AT TEST (days):	0	0
LOAD AT FAILURE (lbs):	140,000	134,320
DIAMETER OF CYLINDER (inches)	6.0	6.0
AREA OF CYLINDER (inches)	28.3	28.3
STRENGTH (psi):	4950	4750
TYPE OF FRACTURE:		

REMARKS: Field data prepared by: NDDOT

BY: Keith Frease

6-Hour Compressive Break – Mix MR0301-Set A

A

PROJECT:	**ACIM-8-094 (041) 342**	**DATE:**	**8/18/3**
REPORT TO:	**ND DEPARTTMENT OF TRANSPORTATION**	**COPIES TO:**	**WILLIE SH**
	300 AIRPORT ROAD		**JOE PEYE**
	BISMARCK, NORTH DAKOTA		
	ATTN: DENNIS BLASL		

PROJECT #: 03-3039.08

FIELD DATA:

TIME OF PLASTIC TEST:	10:30	CONCRETE TEMP:	N.T.
TICKET NUMBER:	N.P.	SLUMP (inches):	N.T.
COUNTY:	CASS	AIR CONTENT (%):	N.T.
DISTRICT:	FARGO	UNIT WEIGHT (pcf)	N.T.
CONTRACTOR:	HIGHWAY SERVICES		
PAVING STATION/	I-94 WB W OF WEST FARGO		
PART OF STRUCTURE:	INTERCHANGE DOWEL BAR RETROFIT		

SPECIFIED STRENGTH @ 28 DAYS:

MIX DESIGN NUMBER:

Mix Used Per Sack of Cement:	N.P.
Water / Sack of Cement (gals):	N.P.
TTL Water / Sack of Cement (gals):	N.P.
Sacks per Cu Yd:	N.P.
Source of Gravel:	N.P.
Source of Sand:	N.P.
Class of Concrete:	TRIAL MIX

CONCRETE FURNISHED BY:

TYPE OF FRACT

	A - CONE
	B - CONE
	C - CONE
	D - SHEAF
	E- COLUM

COMPRESSIVE STRENGTH:

SET NUMBER:	**A-A**	**A-B**
DATE CAST:	8/14/3	
DATE RECEIVED:	8/14/3	
DATE OF TEST:	**8/14/3**	**8/14/3**
LABORATORY #:	**3164A**	**3164B**
METHOD OF CURING:		
Days on Job & Enroute:	0	0
Days Lab Cured-ASTM C193:	0	0
AGE AT TEST (days):	0	0
LOAD AT FAILURE (lbs):	140,870	145,080
DIAMETER OF CYLINDER (in.)	6.0	6.0
AREA OF CYLINDER (In.)	28.3	28.3
STRENGTH (psi):	**4980**	**5130**
TYPE OF FRACTURE:	D	D

REMARKS: Field data prepared by: NDDOT

BY: Keith Fraase

6-Hour Compressive Break – Mix MR0301-Set B

B

PROJECT:	**ACIM-8-094 (041) 342**	**DATE:**	**8/18/3**
REPORT TO:	**ND DEPARTTMENT OF TRANSPORTATION** **300 AIRPORT ROAD** **BISMARCK, NORTH DAKOTA** **ATTN: DENNIS BLASL**	**COPIES TO:**	**WILLIE SI** **JOE PEYE**

PROJECT #: **03-3039.08**

FIELD DATA:

TIME OF PLASTIC TEST:	12:30	CONCRETE TEMP:	N.T.
TICKET NUMBER:	N.P.	SLUMP (inches):	N.T.
COUNTY:	CASS	AIR CONTENT (%):	N.T.
DISTRICT:	FARGO	UNIT WEIGHT (pcf)	N.T.
CONTRACTOR:	HIGHWAY SERVICES		
PAVING STATION/	I-94 WB W OF WEST FARGO		
PART OF STRUCTURE:	INTERCHANGE DOWEL BAR RETROFIT		

SPECIFIED STRENGTH @ 28 DAYS:

MIX DESIGN NUMBER:

Mix Used Per Sack of Cement:	N.P.
Water / Sack of Cement (gals):	N.P.
TTL Water / Sack of Cement (gals):	N.P.
Sacks per Cu Yd:	N.P.
Source of Gravel:	N.P.
Source of Sand:	N.P.
Class of Concrete:	TRIAL MIX

CONCRETE FURNISHED BY:

TYPE OF FRACT

	A - CONE
	B - CONE
	C - CONE
	D - SHEAF
	E- COLUM

COMPRESSIVE STRENGTH:

SET NUMBER:	**B-A**	**B-B**
DATE CAST:	8/14/3	
DATE RECEIVED:	8/14/3	
DATE OF TEST:	**8/14/3**	**8/14/3**
LABORATORY #:	**3170A**	**3170B**
METHOD OF CURING:		
Days on Job & Enroute:	0	0
Days Lab Cured-ASTM C193:	0	0
AGE AT TEST (days):	0	0
LOAD AT FAILURE (lbs):	160,930	156,340
DIAMETER OF CYLINDER (In.)	6.0	6.0
AREA OF CYLINDER (In.)	28.3	28.3
STRENGTH (psi):	**5690**	**5530**
TYPE OF FRACTURE:	**D**	**D**

REMARKS: Field data prepared by. NDDOT

BY: Keith Fraase

6-Hour Compressive Break – Mix MR0301-Set C

C

PROJECT:	**ACIM-8-094 (041) 342**	**DATE:**	**8/18/3**
REPORT TO:	**ND DEPARTTMENT OF TRANSPORTATION**	**COPIES TO:**	**WILLIE SI**
	300 AIRPORT ROAD		**JOE PEYE**
	BISMARCK, NORTH DAKOTA		
	ATTN: DENNIS BLASL		

PROJECT #: **03-3039.08**

FIELD DATA:

TIME OF PLASTIC TEST:	3:30	CONCRETE TEMP:	N.T.
TICKET NUMBER:	N.P.	SLUMP (inches):	N.T.
COUNTY:	CASS	AIR CONTENT (%):	N.T.
DISTRICT:	FARGO	UNIT WEIGHT (pcf)	N.T.
CONTRACTOR:	HIGHWAY SERVICES		

PAVING STATION/
PART OF STRUCTURE: I-94 WB W OF WEST FARGO INTERCHANGE DOWEL BAR RETROFIT

SPECIFIED STRENGTH @ 28 DAYS:

MIX DESIGN NUMBER:

Mix Used Per Sack of Cement:	N.P.
Water / Sack of Cement (gals):	N.P.
TTL Water / Sack of Cement (gals):	N.P.
Sacks per Cu Yd:	N.P.
Source of Gravel:	N.P.
Source of Sand:	N.P.
Class of Concrete:	TRIAL MIX

CONCRETE FURNISHED BY:

TYPE OF FRACT

	A - CONE
	B - CONE
	C - CONE
	D - SHEAF
	E- COLUM

COMPRESSIVE STRENGTH:

SET NUMBER:	**C-A**	**C-B**
DATE CAST:	8/14/3	
DATE RECEIVED:	8/14/3	
DATE OF TEST:	**8/14/3**	**8/14/3**
LABORATORY #:	**3175A**	**3175B**
METHOD OF CURING:		
Days on Job & Enroute:	0	0
Days Lab Cured-ASTM C193:	0	0
AGE AT TEST (days):	0	0
LOAD AT FAILURE (lbs):	150,150	154,560
DIAMETER OF CYLINDER (in.)	6.0	6.0
AREA OF CYLINDER (in.)	28.3	28.3
STRENGTH (psi):	**5310**	**5470**
TYPE OF FRACTURE:	**D**	**D**

REMARKS: Field data prepared by: NDDOT

BY: Keith Fraase

6-Hour Compressive Break – Mix MR0301-Set D

D

PROJECT: ACIM-8-094 (041) 342 **DATE:** 8/18/3

REPORT TO: ND DEPARTTMENT OF TRANSPORTATION **COPIES TO:** WILLIE SI
300 AIRPORT ROAD JOE PEYE
BISMARCK, NORTH DAKOTA
ATTN: DENNIS BLASL

PROJECT #: 03-3039.08

FIELD DATA:

TIME OF PLASTIC TEST:	4:30	CONCRETE TEMP:	N.T.
TICKET NUMBER:	N.P.	SLUMP (inches):	N.T.
COUNTY:	CASS	AIR CONTENT (%):	N.T.
DISTRICT:	FARGO	UNIT WEIGHT (pcf)	N.T.
CONTRACTOR:	HIGHWAY SERVICES		
PAVING STATION/ PART OF STRUCTURE:	I-94 WB W OF WEST FARGO INTERCHANGE DOWEL BAR RETROFIT		

TYPE OF FRACT

	A - CONE
	B - CONE
	C - CONE
	D - SHEAF
	E- COLUM

SPECIFIED STRENGTH @ 28 DAYS:

MIX DESIGN NUMBER:

Mix Used Per Sack of Cement:	N.P.
Water / Sack of Cement (gals):	N.P.
TTL Water / Sack of Cement (gals):	N.P.
Sacks per Cu Yd:	N.P.
Source of Gravel:	N.P.
Source of Sand:	N.P.
Class of Concrete:	TRIAL MIX

CONCRETE FURNISHED BY:

COMPRESSIVE STRENGTH:

SET NUMBER:	D-A	D-B
DATE CAST:	8/14/3	
DATE RECEIVED:	8/14/3	
DATE OF TEST:	8/14/3	8/14/3
LABORATORY #:	3176A	3176B
METHOD OF CURING:		
Days on Job & Enroute:	0	0
Days Lab Cured-ASTM C193:	0	0
AGE AT TEST (days):	0	0
LOAD AT FAILURE (lbs):	145,690	143,370
DIAMETER OF CYLINDER (in.)	6.0	6.0
AREA OF CYLINDER (in.)	28.3	28.3
STRENGTH (psi):	5150	5070
TYPE OF FRACTURE:	D	D

REMARKS: Field data prepared by: NDDOT

BY: Keith Fraase

7-Day Compressive Break – Mix MR0301-Set A

AUG 22 2003

GEOSERV, INC. *Testing - Exploration - Engineering*

Construction Materials Testing, Geotechnical, Geosynthetics, Geoenvironmental, Drilling

TO: Mr. Dennis Blasl
NDDOT
Materials & Research Division
300 Airport Road
Bismarck, ND 58504-6005

DATE: 8-21-03
PROJECT NO: GEO-080319

COPY TO:

PROJECT: PSPR 001 0025 01 02
Cass County

COMPRESSION TESTS OF CYLINDERS

FIELD DATA:

* Job Identification	A7 - 335	A7 - 336
* Date Cast	8-14-03	8-14-03
* Age to be Tested, Days	7	7
* Slump (inches)	N/A	N/A
* Air Content (%)	N/A	N/A
* Location of Placement	N/A	
* Specified Strength @ 28 Days	N/A	
* Mix Proportions		
Cement	850#	
Fine Aggregate	1079#	
Coarse Aggregate	1526#.	
Water	255#	
Admixture	Air 2.975 oz.	
	W/R 102.0 oz.	
	Accelerator 340.0 oz.	
* Concrete Furnished by	N/A	

COMPRESSIVE STRENGTH: Test Method-ASTM:C39, 6"x12" Cylinder, Area 28.26 Sq. In.

* Laboratory Number	ND27947-1	ND27947-2
* Date Received	8-21-03	8-21-03
* Method of Curing:		
Days on Job & Enroute	7	7
Days Lab. Cured-ASTM:C192	0	0
* Age at Test, days	7	7
* Load at Failure, pounds	251,000	247,250
* Strength, psi	8,880	8,750
* Typical Failure	Shear (Long Plane)	Shear (Long Plane)

GEOSERV, INC.

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geoservinc@quest.net

7-Day Compressive Break – Mix MR0301-Set B

GEOSERV, INC. *Testing - Exploration - Engineering*

Construction Materials Testing, Geotechnical, Geosynthetics, Geoenvironmental, Drilling

TO: Mr. Dennis Blasl
NDDOT
Materials & Research Division
300 Airport Road
Bismarck, ND 58504-6005

DATE: 8-21-03
PROJECT NO: GEO-080319

COPY TO:

PROJECT: PSPR 001 0025 01 02
Cass County

COMPRESSION TESTS OF CYLINDERS

FIELD DATA:

* Job Identification	B7 - 337	B7 - 338
* Date Cast	8-14-03	8-14-03
* Age to be Tested, Days	7	7
* Slump (inches)	N/A	N/A
* Air Content (%)	N/A	N/A
* Location of Placement	N/A	
* Specified Strength @ 28 Days	N/A	
* Mix Proportions		
Cement	850#	
Fine Aggregate	1079#	
Coarse Aggregate	1526#.	
Water	255#	
Admixture	Air 2.975 oz.	
	W/R 102.0 oz.	
	Accelerator 340.0 oz.	
* Concrete Furnished by	N/A	

COMPRESSIVE STRENGTH: Test Method-ASTM:C39, 6"x12" Cylinder, Area 28.26 Sq. In.

* Laboratory Number	ND27948-1	ND27948-2
* Date Received	8-21-03	8-21-03
* Method of Curing:		
Days on Job & Enroute	7	7
Days Lab. Cured-ASTM:C192	0	0
* Age at Test, days	7	7
* Load at Failure, pounds	256,750	261,750
* Strength, psi	9,090	9,260
* Typical Failure	Shear (Long Plane)	Shear (Long Plane)

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7-Day Compressive Break – Mix MR0301-Set C

GEOSERV, INC. *Testing - Exploration - Engineering*

Construction Materials Testing, Geotechnical, Geosynthetics, Geoenvironmental, Drilling

TO: Mr. Dennis Blasl
NDDOT
Materials & Research Division
300 Airport Road
Bismarck, ND 58504-6005

DATE: 8-21-03
PROJECT NO: GEO-080319

COPY TO:

PROJECT: PSPR 001 0025 01 02
Cass County

COMPRESSION TESTS OF CYLINDERS

FIELD DATA:

* Job Identification	C7 - 339	C7 - 340
* Date Cast	8-14-03	8-14-03
* Age to be Tested, Days	7	7
* Slump (inches)	N/A	N/A
* Air Content (%)	N/A	N/A
* Location of Placement	N/A	
* Specified Strength @ 28 Days	N/A	
* Mix Proportions		
Cement	850#	
Fine Aggregate	1079#	
Coarse Aggregate	1526#.	
Water	255#	
Admixture	Air 2.975 oz.	
	W/R 102.0 oz.	
	Accelerator 340.0 oz.	
* Concrete Furnished by	N/A	

COMPRESSIVE STRENGTH: Test Method-ASTM:C39, 6"x12" Cylinder, Area 28.26 Sq. In.

* Laboratory Number	ND27949-1	ND27949-2
* Date Received	8-21-03	8-21-03
* Method of Curing:		
Days on Job & Enroute	7	7
Days Lab. Cured-ASTM:C192	0	0
* Age at Test, days	7	7
* Load at Failure, pounds	277,750	287,000
* Strength, psi	9,830	10,155
* Typical Failure	Shear (Long Plane)	Shear (Long Plane)

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7-Day Compressive Break – Mix MR0301-Set D

GEOSERV, INC. *Testing - Exploration - Engineering*

Construction Materials Testing, Geotechnical, Geosynthetics, Geoenvironmental, Drilling

TO: Mr. Dennis Blasl
NDDOT
Materials & Research Division
300 Airport Road
Bismarck, ND 58504-6005

DATE: 8-21-03
PROJECT NO: GEO-080319

COPY TO:

PROJECT: PSPR 001 0025 01 02
Cass County

COMPRESSION TESTS OF CYLINDERS

FIELD DATA:

* Job Identification	D7 - 341	D7 - 342
* Date Cast	8-14-03	8-14-03
* Age to be Tested, Days	7	7
* Slump (inches)	N/A	N/A
* Air Content (%)	N/A	N/A
* Location of Placement	N/A	
* Specified Strength @ 28 Days	N/A	
* Mix Proportions		
Cement	850#	
Fine Aggregate	1079#	
Coarse Aggregate	1526#.	
Water	255#	
Admixture	Air 2.975 oz.	
	W/R 102.0 oz.	
	Accelerator 340.0 oz.	
* Concrete Furnished by	N/A	

COMPRESSIVE STRENGTH: Test Method-ASTM:C39, 6"x12" Cylinder, Area 28.26 Sq. In.

* Laboratory Number	ND27950-1	ND27950-2
* Date Received	8-21-03	8-21-03
* Method of Curing:		
Days on Job & Enroute	7	7
Days Lab. Cured-ASTM:C192	0	0
* Age at Test, days	7	7
* Load at Failure, pounds	260,500	263,750
* Strength, psi	9,220	9,330
* Typical Failure	Shear (Long Plane)	Shear (Long Plane)

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28-Day Compressive Break – Mix MR0301-Set A

GEOSERV, INC. *Testing - Exploration - Engineering*

Construction Materials Testing, Geotechnical, Geosynthetics, Geoenvironmental, Drilling

TO: Mr. Dennis Blasl
NDDOT
Materials & Research Division
300 Airport Road
Bismarck, ND 58504-6005

DATE: 9-11-03
PROJECT NO: GEO-080319

COPY TO:

SEP 16 2003

PROJECT: PSPR 001 0025 01 02
Cass County

COMPRESSION TESTS OF CYLINDERS

FIELD DATA:

* Job Identification	A28 - 343	A28 - 344
* Date Cast	8-14-03	8-14-03
* Age to be Tested, Days	28	28
* Slump (inches)	N/A	N/A
* Air Content (%)	N/A	N/A
* Location of Placement	N/A	
* Specified Strength @ 28 Days	N/A	
* Mix Proportions		
Cement	850#	
Fine Aggregate	1079#	
Coarse Aggregate	1526#.	
Water	255#	
Admixture	Air 2.975 oz.	
	W/R 102.0 oz.	
	Accelerator 340.0 oz.	
* Concrete Furnished by	N/A	

COMPRESSIVE STRENGTH: Test Method-ASTM:C39, 6"x12" Cylinder, Area 28.26 Sq. In.

* Laboratory Number	ND27967-1	ND27967-2
* Date Received	9-11-03	9-11-03
* Method of Curing:		
Days on Job & Enroute	28	28
Days Lab. Cured-ASTM:C192	0	0
* Age at Test, days	28	28
* Load at Failure, pounds	298,250	281,750
* Strength, psi	10,555	9,970
* Typical Failure	Shear (Long Plane)	Shear (Long Plane)

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geoservinc@quest.net

28-Day Compressive Break – Mix MR0301-Set B

GEOSERV, INC. *Testing - Exploration - Engineering*

Construction Materials Testing, Geotechnical, Geosynthetics, Geoenvironmental, Drilling

TO: Mr. Dennis Blasl
NDDOT
Materials & Research Division
300 Airport Road
Bismarck, ND 58504-6005

DATE: 9-11-03
PROJECT NO: GEO-080319

COPY TO:

PROJECT: PSPR 001 0025 01 02
Cass County

COMPRESSION TESTS OF CYLINDERS

FIELD DATA:

* Job Identification	B28 - 345	B28 - 346
* Date Cast	8-14-03	8-14-03
* Age to be Tested, Days	28	28
* Slump (inches)	N/A	N/A
* Air Content (%)	N/A	N/A
* Location of Placement	N/A	
* Specified Strength @ 28 Days	N/A	
* Mix Proportions		
Cement	850#	
Fine Aggregate	1079#	
Coarse Aggregate	1526#.	
Water	255#	
Admixture	Air 2.975 oz.	
	W/R 102.0 oz.	
	Accelerator 340.0 oz.	
* Concrete Furnished by	N/A	

COMPRESSIVE STRENGTH: Test Method-ASTM:C39, 6"x12" Cylinder, Area 28.26 Sq. In.

* Laboratory Number	ND27968-1	ND27968-2
* Date Received	9-11-03	9-11-03
* Method of Curing:		
Days on Job & Enroute	28	28
Days Lab. Cured-ASTM:C192	0	0
* Age at Test, days	28	28
* Load at Failure, pounds	295,000	291,250
* Strength, psi	10,440	10,305
* Typical Failure	Shear (Long Plane)	Shear (Long Plane)

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PHONE 701-223-6149
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geoservinc@quest.net

28-Day Compressive Break – Mix MR0301-Set C

GEOSERV, INC. *Testing - Exploration - Engineering*

Construction Materials Testing, Geotechnical, Geosynthetics, Geoenvironmental, Drilling

TO: Mr. Dennis Blasl
NDDOT
Materials & Research Division
300 Airport Road
Bismarck, ND 58504-6005

DATE: 9-11-03
PROJECT NO: GEO-080319

COPY TO:

PROJECT: PSPR 001 0025 01 02
Cass County

COMPRESSION TESTS OF CYLINDERS

FIELD DATA:

* Job Identification	C28 - 347	C28 - 348
* Date Cast	8-14-03	8-14-03
* Age to be Tested, Days	28	28
* Slump (inches)	N/A	N/A
* Air Content (%)	N/A	N/A
* Location of Placement	N/A	
* Specified Strength @ 28 Days	N/A	
* Mix Proportions		
Cement	850#	
Fine Aggregate	1079#	
Coarse Aggregate	1526#.	
Water	255#	
Admixture	Air 2.975 oz.	
	W/R 102.0 oz.	
	Accelerator 340.0 oz.	
* Concrete Furnished by	N/A	

COMPRESSIVE STRENGTH: Test Method-ASTM:C39, 6"x12" Cylinder, Area 28.26 Sq. In.

* Laboratory Number	ND27969-1	ND27969-2
* Date Received	9-11-03	9-11-03
* Method of Curing:		
Days on Job & Enroute	28	28
Days Lab. Cured-ASTM:C192	0	0
* Age at Test, days	28	28
* Load at Failure, pounds	322,750	320,000
* Strength, psi	11,420	11,325
* Typical Failure	Shear (Long Plane)	Shear (Long Plane)

GEOSERV, INC.

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28-Day Compressive Break – Mix MR0301-Set D

GEOSERV, INC. *Testing - Exploration - Engineering*

Construction Materials Testing, Geotechnical, Geosynthetics, Geoenvironmental, Drilling

TO: Mr. Dennis Blasl
NDDOT
Materials & Research Division
300 Airport Road
Bismarck, ND 58504-6005

DATE: 9-11-03
PROJECT NO: GEO-080319

COPY TO:

PROJECT: PSPR 001 0025 01 02
Cass County

COMPRESSION TESTS OF CYLINDERS

FIELD DATA:

* Job Identification	D28 - 349	D28 - 350
* Date Cast	8-14-03	8-14-03
* Age to be Tested, Days	28	28
* Slump (inches)	N/A	N/A
* Air Content (%)	N/A	N/A
* Location of Placement	N/A	
* Specified Strength @ 28 Days	N/A	
* Mix Proportions		
Cement	850#	
Fine Aggregate	1079#	
Coarse Aggregate	1526#.	
Water	255#	
Admixture	Air 2.975 oz.	
	W/R 102.0 oz.	
	Accelerator 340.0 oz.	
* Concrete Furnished by	N/A	

COMPRESSIVE STRENGTH: Test Method-ASTM:C39, 6"x12" Cylinder, Area 28.26 Sq. In.

* Laboratory Number	ND27970-1	ND27970-2
* Date Received	9-11-03	9-11-03
* Method of Curing:		
Days on Job & Enroute	28	28
Days Lab. Cured-ASTM:C192	0	0
* Age at Test, days	28	28
* Load at Failure, pounds	338,250	299,200
* Strength, psi	11,970	10,590
* Typical Failure	Shear (Long Plane)	Shear (Long Plane)

GEOSERV, INC.

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geoservinc@quest.net

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Appendix D: Flexural Strength

28-Day Flexural Strength

Set A = 982 psi

Set B = 1,099 psi

Set C = 1,093 psi

Set D = 1,188 psi

Appendix E: Freeze/Thaw

MEMORANDUM

TO: BYRON FUCHS

FROM: CEMENT AND CONCRETE SECTION

DATE: 12-18-03

SUBJECT: DOWEL BAR RETROFIT MIX "MR0301"
PROJECT # PSPR 001 0025 01 02 CASS COUNTY

Freeze/thaw bars molded at the Fargo experimental site were subjected to 300 freeze/thaw cycles from 9-3-2003 to 11-3-2003.

The results are listed below:

	Durability Factor	Weight Change(%)	Length Change(%)
Bars set A	93.1	+.16	-.002
Bars set B	89.8	+.17	0
Bars set C	98.9	+.04	-.001
Bars set D	96.9	0	-.002

None of the bars showed any signs of flaking, scaling, or cracking. Irregular projections along some edges, resulting from less-than-perfect molding, did not break off. This would not have been the case with "regular" concrete.

From all appearances, the mortar mix appears to be very durable.