NORTH DAKOTA
DEPARTMENT OF TRANSPORTATION

MATERIALS AND RESEARCH DIVISION

Experimental Study MR 96-01

Evaluation of Epoxy-Coated Reinforcing Steel

Final Evaluation Report

Project IM-1-094(017)156

June 2006

Prepared by

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Disclaimer

The contents of this report reflect the views of the author or authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not reflect the official views of the North Dakota Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

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Evaluation of Epoxy-Coated Reinforcing Steel

MR 96-01

Objective

Reinforced concrete structures may experience premature deterioration due to the effects of corrosion of the reinforcing steel. When the reinforcing steel is exposed to moisture and oxygen, corrosion is formed. The use of salt can accelerate the corrosion process. The objective of this report is to determine if epoxy-coated reinforcing steel will serve as a corrosion-protection system for concrete structures and ultimately extend the service life of the pavement.

Scope

The North Dakota Department of Transportation (NDDOT) has substituted epoxy-coated reinforcing steel for regular reinforcing steel in a portion of the continuous reinforced concrete pavement project, IM-1-094(017)156 westbound. This portion of roadway served as a test section and compared to a section of roadway containing regular reinforcing steel.

Location

Project IM-1-094(017)156 (WB) is located on I-94 from RP 155.026 (West Midway Interchange) to RP 161.434 (East Bismarck Interchange). The epoxy-coated reinforcing steel test section is located between the Washington and 4th Street Bridges from Station 363+03.0 to Station 380+97.8. The control section lies adjacent and to the east of the test section between Station 382+42.8 and Station 400+37.6. The project location is shown in Figure 1.

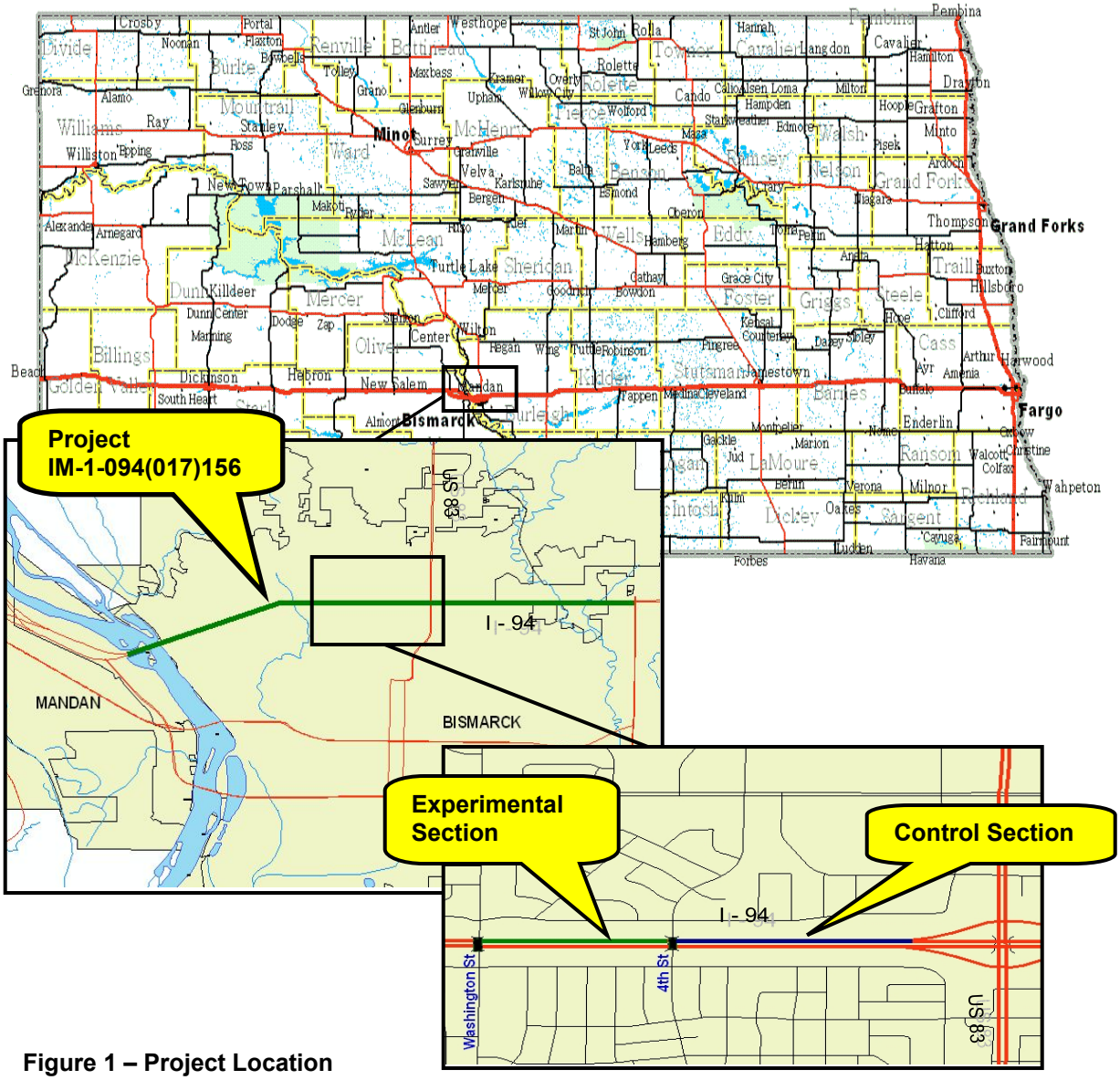


Figure 1 – Project Location

Traffic

Table 1 shows the 1998, 2003, and 2004 one-way traffic for the experimental and control sections.

Year	Pass>Car	Trucks	Total	Max Hour	Rigid ESALs
1998	6,750	780	7,530	940	980
2003	7,963	738	8,700	870	1,033
2004	7,650	1,150	8,800	880	1,552

Table 1

Design

The design of the epoxy-coated reinforcing steel section of this project was the same as the conventional reinforcing steel section. Both the epoxy-coated reinforcing steel section and the control section are 9” of CRCP with #6 longitudinal bars spaced 6.86” apart and #5 transverse bars spaced 48” apart. The longitudinal bars were spliced with a minimum 19” overlap. Typical sections are given in Appendix A.

Construction

Northern Improvement was the prime contractor on the project. Installation of the epoxy-coated reinforcing steel was performed in late August of 1996.

Before and during construction, extra care was taken in handling the epoxy-coated reinforcing steel. While unloading the epoxy-coated reinforcing steel from supply trucks, the contractor provided for multiple pick-up points to prevent abrasion in the bundles. The contractor also stored the material prior to construction on multiple supports that were close enough together to prevent any excess sagging.

Photo 1 depicts a view of the transverse and longitudinal bars, lying on top of the permeable stabilized base, just prior to being picked up by a rebar alignment machine. The longitudinal steel was then run through an alignment machine, while

the transverse steel was left lying on the roadway. Workers tied the transverse steel to the longitudinal steel and the epoxy-coated steel chairs to the reinforcing steel with epoxy-coated ties.

Photo 1 – Photo of the epoxy-coated reinforcing steel lying on top of the stabilized base.

Photo 2 shows the finished product placed and fastened prior to the placing of the concrete.

Photo 2 – View of finished product placed and fastened.

Construction of the epoxy-coated reinforcing steel did not present any major difficulties. Incidental items, such as extra care in handling and placing were the only differences encountered as compared to installing regular reinforcing steel.

Cost

The bid price for Grade 60 epoxy-coated reinforcing steel on the project was $0.80/lb. The bid price for regular Grade 60 reinforcing steel was $0.60/lb. The bid for 9” continuous epoxy reinforced recycled concrete pavement on the project was $18.50/sy and the bid price with regular reinforcing steel was $15.00/sy.

Evaluation

Transverse cracks were counted during five evaluations. The transverse cracks were counted in a 150' segment in both the control and experimental sections. The 150' segment in the experimental section started at the first shoulder joint east of station 370+00 (heading east) and the 150' segment in the control segment started at the first joint west of Equation 388+66.6 Bk. = 388+69.8 Ah. (Eastbound).

The results of the five evaluations are shown in Table 2.

Experimental Segment					
Date	**Temp °F**	**Total Transverse Cracks**	**Partial Cracks**	**Narrow Cracks**	**Wide Cracks**
11-17-98	33	65	6	-	-
09-06-01	80	80	10	27	43
12-31-02	20	83	11	25	47
09-17-03	70	86	13	19	54
12-29-04	28	103	30	18	55
Control Segment					
Date	**Temp °F**	**Total Transverse Cracks**	**Partial Cracks**	**Narrow Cracks**	**Wide Cracks**
11-17-98	33	67	6	-	-
09-06-01	80	94	18	35	41
12-31-02	20	103	21	37	45
09-17-03	70	95	26	19	50
12-29-04	28	123	38	34	51

Table 2

The first evaluation was conducted on November 17, 1998. Photo 3 shows an overall view of the test section looking east. The cracks were counted as being either fully or partially across the width of the driving lane. The width of the cracks ranged from 0.10 mm to 0.60 mm.

Photo 3 – Depicts an overall view of the test section looking east.

The second evaluation occurred on September 6, 2001. For this evaluation full width cracks were further classified as wide or narrow cracks. The determination of whether a crack was narrow or wide was performed subjectively as each crack's width was not measured to classify it. Photo 4 shows the difference between the narrow, wide, and partial transverse cracks located in the test section.

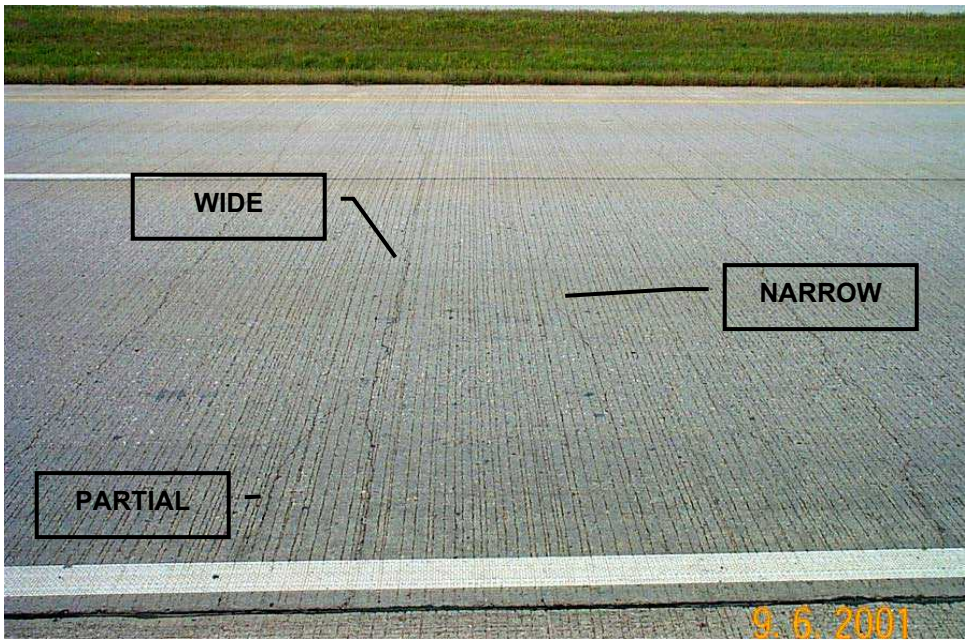


Photo 4 – Depicts the narrow, wide and partial transverse cracks in the test section.

The third evaluation was performed on December 31, 2002. The number of narrow cracks in the experimental section decreased to 25 from 27 in 2001. Because the total number of cracks in the experimental section increased from 2001 to 2002, it appears that the number of narrow cracks decreased because some cracks were counted as narrow in 2001 and then counted as wide in 2002.

The fourth evaluation occurred on September 17, 2003. The widths of the cracks continued to range from 0.10 mm to 0.60 mm. In the experimental segment the number of narrow cracks decreased from 25 in the previous evaluation to 19. Because the number of wide cracks increased during this period, it is likely that the number of narrow cracks decreased because some cracks were counted as narrow in 2002 and then counted as wide in 2003. A total of 95 transverse cracks were counted in the 150 foot control segment. This is a decrease from 103 transverse cracks that were counted in 2002. The number of partial cracks and wide cracks both increased from 2002 but the number of narrow cracks decreased to 19 from 37 in 2002. The number of narrow cracks counted may have decreased because; some were counted as wide cracks, warm temperatures at the time of the evaluation may

have caused the narrow cracks to close, or there may have been an error in counting.

The fifth evaluation occurred on December 29, 2004. The width of the cracks remained, approximately, 0.10 mm to 0.60 mm. The number of cracks in every category for both segments had increased from the fourth evaluation. The large increase in the number of cracks may have been partially caused by the difference in temperatures of when the evaluations were performed. The fifth evaluation was performed at a temperature of 28°F and the fourth evaluation was performed at 70°F.

To determine the relative amounts of deterioration to the reinforcing steel, cores were taken from the experimental and control segments. Two cores were taken from each of the 150' long segments in the control and experimental segments in which the transverse cracks had been counted. The locations of the cores were chosen so that the cores would contain both a transverse crack and reinforcing steel.

The cores are shown in Photos 5, 6, 7, and 8. Both of the cores containing regular reinforcing steel showed some evidence of rust. The cores containing epoxy coated reinforcing steel showed no evidence of rust or corrosion.

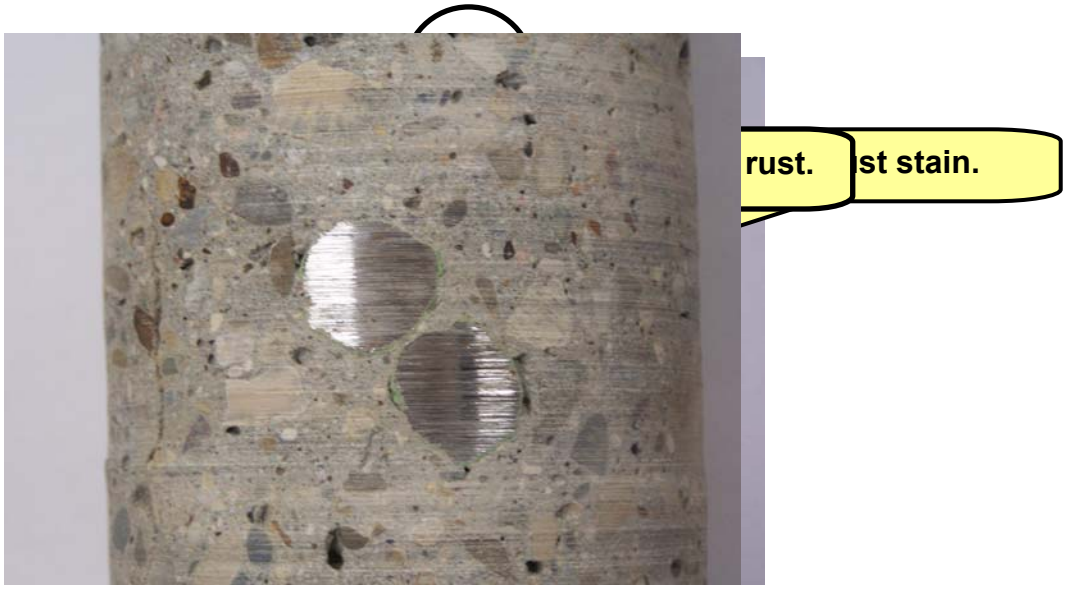


Photo 7 – Core containing epoxy coated reinforcing steel.

Photo 8 – Core containing epoxy coated reinforcing steel.

Summary

After approximately ten years of service, there appears to be little difference in performance between that portion of the CRCP constructed with epoxy-coated reinforcing steel and that which was constructed with plain reinforcing steel.

For both of the segments evaluated, the widths between the transverse cracks were typical for reinforced concrete.

At this time, the number of transverse cracks is slightly higher in the control section to that of the test section. The difference mainly appears to be in the number of narrow and partial transverse cracks. The crack widths are approximately the same in both segments.

Cores taken in the control and experimental segments show that the regular reinforcing steel has evidence of rust and the epoxy coated reinforcing steel does not.

Recommendation

Epoxy coated reinforcing steel doesn't appear to negatively affect the performance of CRCP and cores show that the epoxy coated reinforcing steel resisted corrosion better than regular reinforcing steel. However, the distresses that CRCP, typically, exhibits are not related to corrosion of the reinforcing steel. It is likely, within the currently used 30 year design life, that using epoxy coated reinforcing steel would not significantly reduce the distresses of the CRCP.

For the construction of this project in 1996, the bid price for epoxy-coated reinforcing steel was $0.80/lb and $0.60/lb for regular reinforcing steel. The bid for 9" continuous epoxy-coated reinforced recycled concrete pavement was $18.50/sy and the bid price with regular reinforcing steel was $15.00/sy. The NDDOT does not have current bid prices for epoxy-coated reinforcing steel in pavement. The Minnesota Department of Transportation's 2006 average bid price for epoxy-coated reinforcing steel was $0.99/lb and $0.82/lb for regular reinforcing steel. For structures, NDDOT's 2006 average bid price for epoxy-coated reinforcing steel was $0.90/lb and $0.87/lb for regular reinforcing steel.

Due to the additional cost of using epoxy-coated reinforcing steel and its limited benefits; it is recommended not to use epoxy coated reinforcing steel on CRCP projects.

DESIGN DATA I-94 Main Line (W BND RDWY ONLY)				
Traffic	Average Daily			Est Max Hr
Current 1995	Pass 8,220	Trucks 640	Total 8,860	900
Forecast 2015	Pass 12,330	Trucks 960	Total 13,290	1,330
Minimum Sight Dist for		Design Speed	70 MPH	
Stopping 600 FT				
Full Control of Access				
No Point of Access Other Than at Interchange Ramps				

JOB# 15

NORTH DAKOTA DEPARTMENT OF TRANSPORTATION

IN BURLEIGH AND MORTON COUNTY

FEDERAL AID PROJECT NO
IM-1-094(017)156
SU-1-981(049)059
Grading, Surfacing, Storm Drains, Structural, Signing, Marking, Guardrail & Incidentals

WEST BOUND ROADWAY ONLY

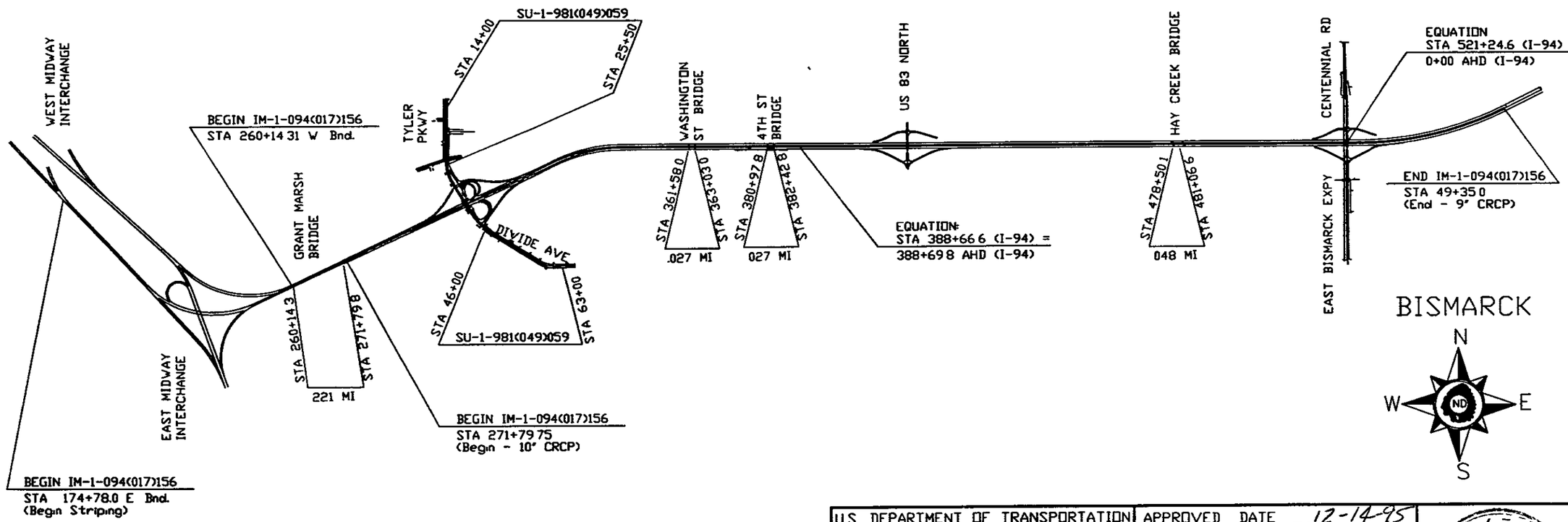
FHWA REGION	STATE	PROJECT NO	SHEET NO.
8	ND	IM-1-094(017)156 SU-1-981(049)059	1

GOVERNING SPECIFICATIONS

Standard Specifications adopted by the North Dakota Department of Transportation September 1992, Standard Drawings currently in effect, and other Contract Provisions submitted herein.

LENGTH OF PROJECT

PROJECT	MILES-GROSS	MILES-NET
IM-1-094(017)156	7 4959	7 1717
SU-1-981(049)059	0 5398	0 5398



PAVING SECTION _____
URBAN SECTION _____
TRAFFIC SECTION _____
RURAL SECTION _____
RECOMMEND APPROVAL 12-14, 1995
DESIGN ENGINEER _____

US DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

APPROVED

DIVISION ADMINISTRATOR _____ DATE _____

APPROVED DATE 12-14-95

DIRECTOR OF HIGHWAYS AND ENGINEERING
NORTH DAKOTA DEPARTMENT OF TRANSPORTATION

FHWA REGION	STATE	FED. AID PROJ. NO.	SHEET NO.
8	N.D.	IM-1-094(017)156 SU-1-981(049)059	20

ESTIMATED QUANTITIES

SPEC	CODE	ITEM DESCRIPTION	UNIT	IM-1-094(017)156	SU-1-981(049)059	TOTAL
550	0240	DOWELED CONTRACTION JOINT ASSEMBLY	LF	644		644
550	0423	STD ANCHORAGE UNIT J-BOLTS 5/8IN	EA	104		104
550	0809	PREFORMED ELASTOMERIC COMPRESSION JT SEAL 9/16IN	LF	15,679		15,679
550	0912	WF BEAM TERMINAL JOINT	LF	192		192
550	0958	LONGITUDINAL JOINT SILICONE SEAL	LF	5,079		5,079
550	0959	CONTRACTION JOINT SILICONE SEAL	LF	14,685		14,685
550	2040	PORTLAND CEMENT	TON	7,072		7,072
550	2044	FLYASH	TON	1,664		1,664
560	1580	PREPARE STOCKPILE SITE	L SUM	1		1
560	1590	REMOVAL OF CONCRETE PAVEMENT	SY	79,748		79,748
560	1591	REMOVAL OF CONTINUOUS REINF CONCRETE PVMT	SY	6,760		6,760
560	2005	10IN NON-REINFORCED RECYCLED CONCRETE PAVEMENT	SY	1,120		1,120
560	3056	9IN CONTINUOUS REINF RECYCLED CONC PVMT CL AE	SY	57,417		57,417
560	3081	10IN CONTINUOUS REINF RECYCLED CONC PVMT CL AE	SY	27,191		27,191
560	8000	9IN CONT EPOXY REINF RECYCLED CONCRETE PVMT CL AE	SY	5,258		5,258
602	0130	CLASS AAE-3 CONCRETE	CY	415.4		415.4
602	1130	CLASS AE-3 CONCRETE	CY	316.1		316.1
602	1200	JERSEY BARRIER - FORMED OR SLIPFORMED	LF	3,284		3,284
602	1250	PENETRATING WATER REPELLENT TREATMENT	SY	1,140		1,140
612	0115	REINFORCING STEEL - GRADE 60	LBS	61,756		61,756
612	0116	REINFORCING STEEL - GRADE 60 (EPOXY COATED)	LBS	83,563		83,563
616	0362	STRUCTURAL STEEL M183	LBS	602		602
616	5890	STRUCTURAL STEEL	L SUM	1		1

NOTES

550 EPOXY COATED REINFORCING BARS: A CRCP test section shall be made with
P06 epoxy coated reinforcing bars on I-94 between Washington and Fourth Street bridges. This reinforcing steel shall be included in the price bid for "10-Inch Cont Epoxy Reinforced Recycled Concrete Pavement Cl AE."

550 WF BEAM: A 28' WF-Beam for a terminal joint is located in the Bismarck
P07 District storage yard and shall be used for one of the terminal joints placed on this project and shall be included in the price bid for "WF Steel Beams."

602 JERSEY BARRIER FORMED OR SLIPFORMED: This item consists of
P01 constructing the median slab and Jersey barrier, which includes: furnishing and installing Class 5 aggregate, reinforcing steel, drilling Class AE-3 concrete, expansion joint material, sawing and silicone sealing joints, surface finish "D" and drilling existing concrete and installing adhesive and reinforcing.

The item "Jersey Barrier Formed or Slipformed" shall be measured by the linear foot of barrier wall installed.

The quantity measured will be paid for at the contract price and shall be full compensation for all materials labor and equipment required to complete the installation.

704 BARRIER MARKERS: The contractor shall furnish, install, and
210 remove barrier markers as specified on Standard D-748-9. The cost of furnishing, installing, and removing barrier markers shall be included in the price bid for "Precast Concrete Median Barriers (State Furnished)."

704 FLEXIBLE DELINEATOR: The flexible delineator shall be installed
501 in the location shown on the plans. The post shall be tough, resilient PVC in orange color, similar to Services and Material Co., Inc., Deluxe delineator post, or polyethylene similar to Safety Guide Traf-Flex Post. The post shall have 4" wide white bands as shown on the plan. The reflective intensity of the bands shall meet the requirements of Type 3 or 4, flexible reflective sheeting. The delineator base shall be bolted to the pavement. The contractor shall maintain the delineators until they are removed. The delineators shall be removed as soon as the new roadway is opened to traffic. The flexible delineators shall remain the property of the contractor. The flexible delineators shall be measured by the number installed and accepted by the engineer. All costs for providing, installing, maintaining, and removing the flexible delineators shall be included in the unit price bid for "Flexible Delineators."

704 RAISED PAVEMENT MARKERS: Raised pavement markers shall be placed
P01 along the centerline of the I-94 roadway as shown on the traffic-control plans. The markers shall be placed in pairs, 4 inches apart, spaced at 5 feet along the centerline. Raised pavement markers shall also be placed on the median crossovers at the begin and end project locations and on the interchange ramp connections. The markers shall be placed as shown on the Traffic Control System Median Crossover sheets and Interchange Ramp Connection sheets. The spacing of raised pavement markers shall be 5 feet on median crossovers and interchange ramp connections. The raised pavement markers shall be Stimsonite NO. 66, Flex-O-Lite RCM construction marker or equal. The raised pavement markers shall be cleaned when necessary to retain reflectivity as specified in Section 704.03 W. At completion of the project, the markers shall be removed in accordance with the manufacturer's recommendations and when removed, shall have the adhesive removed down to the pavement. The raised pavement markers shall be measured by the number complete in place and accepted by the Engineer. The cost of furnishing, installing, maintaining, and removing shall be included in the price bid for "Raised Pavement Markers".

704 TRAFFIC CONTROL:
P02 A. The contractor shall provide a qualified traffic maintenance person with the following minimum qualifications and duties:

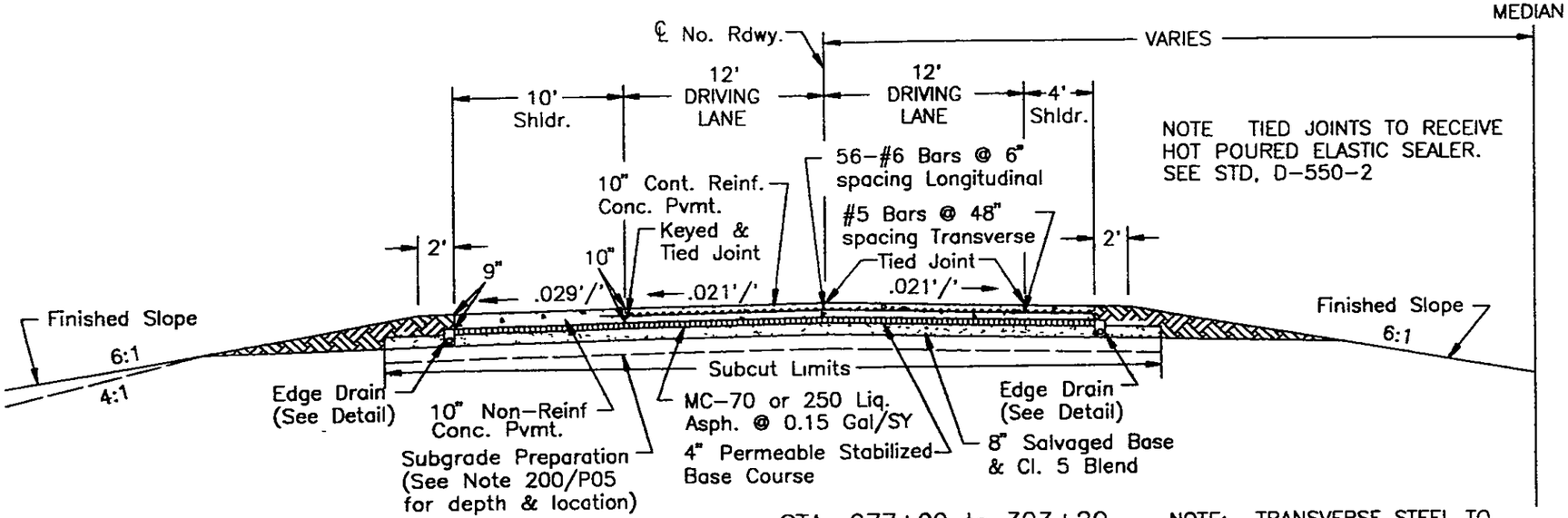
1. This person shall:
   a. Have completed a course of study based on MUTCD and furnish proof.
   b. Be conversant with the contents and intentions contained within the MUTCD and the NDDOT Specifications.
   c. Have previous experience working with maintenance and protection of traffic.
   d. Be competent to supervise personnel with lesser training in traffic maintenance operations.
   e. Be present on the project on a daily basis unless released by the engineer.

2. Duties:
   a. To provide traffic control as required by the plans, Standard Specifications, Special Provisions, or MUTCD or as directed by the engineer.
   b. The traffic control person shall provide documentation of each day's inspection results and remedial activities

FHWA REGION	STATE	FED AID PROJ. NO.	SHEET NO.
8	N.D.	IM-1-094(017)156	34

TYPICAL SECTIONS

I-94 MAIN LINE NORTH ROADWAY



NOTE TIED JOINTS TO RECEIVE HOT POURED ELASTIC SEALER. SEE STD. D-550-2

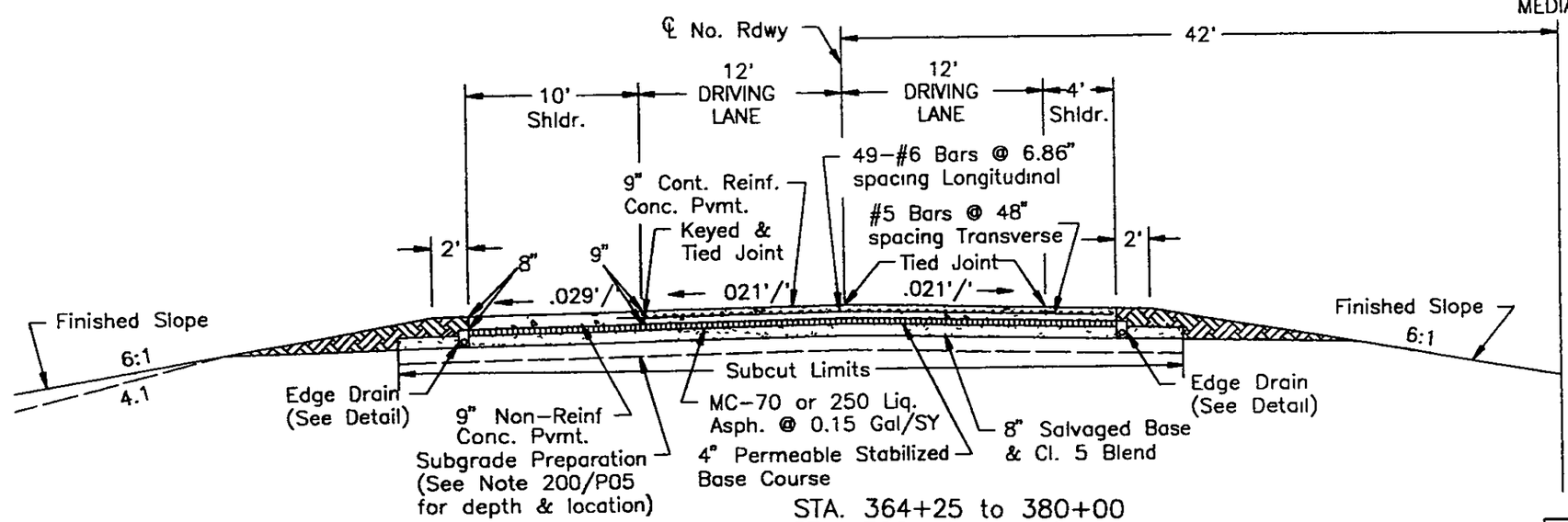
EQUATION:
STA 521+24.6 = 0+00

Tie bars to be inserted directly below longitudinal steel.

NOTE: TRANSVERSE CONTRACTION JOINTS IN THE NON-REINF. CONC. PVMT. SHALL BE SAWED AT 15' SPACING (APPROX.) & PREFORMED ELASTOMERIC COMPRESSION JOINT SEALED. SEE STD. D-550-3

STA. 277+00 to 303+20
STA. 305+20 to 360+60

NOTE: TRANSVERSE STEEL TO TERMINATE 3" FROM VERTICAL EDGE OF C.R.C. PVMT.



REINF. STEEL PLACED @ A DEPTH OF 4.25" FROM TOP OF 10" PVMT. TO MID-POINT OF STEEL.

REINF STEEL PLACED @ A DEPTH OF 3.75" FROM TOP OF 9" PVMT. TO MID-POINT OF STEEL.

SEE SP113(92) FOR REINF STEEL TOLERANCE.

LONGITUDINAL STEEL SHALL BE PLACED ON TOP OF TRANSVERSE STEEL.

KEYWAY ON 4' SHOULDER FROM STA 274+97 TO 292+00

STA. 364+25 to 380+00
STA. 386+43 to 413+80
STA. 416+05 to 478+30
STA. 482+00 to 520+15
STA. 0+75 to 49+35

NOTE: SEE WF STEEL BEAM TERMINAL JOINT DETAIL FOR CONNECTION TO BRIDGE APPROACH SLABS.

TYPICAL SECTIONS		
I-94 MAINLINE NORTH ROADWAY STA. 274+97 TO 49+35		
DATE	FILE 95MLNR P8'	DRAWING NO: