RESEARCH REPORT DOCUMENTATION PAGE

1. Report No.	2. Report Date	3. Contract No.	4. Project No.
ND 91-01	March 1998	N/A	F-5-085(026)102

5. Title and Subtitle	6. Report Type	7. Project No.
Base Reinforcement Using Geogrid	Work Plan ☐ Construction ☐ Evaluation ☐ **Final** ☒	8. Project No. 9. Project No. 10. Project No.

11. Author(s)/Principle Investigator(s)
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12. Performing Organization Name and Address		13. Sponsoring Agency Name and Address
NDDOT M+R ☒ NDDOT OTHER* ☐ NDSU ☐ UND ☐ UGPTI ☐ OTHER* ☐ *see supplementary notes	North Dakota DOT Materials and Research Division 300 Airport Road Bismarck ND 58504-6005	North Dakota DOT Materials and Research Division 300 Airport Road Bismarck ND 58504-6005

14. Supplementary Notes

15. Abstract

Purpose and Need

Western North Dakota has many aging highways that have very weak subgrades. Most of the local aggregates are either depleted or not suitable for road construction. The normal practice to improve areas of weak subgrade is to remove the weak soils and replace them with granular material. The North Dakota Department of Transportation is looking for ways to improve the pavement performance, decrease costs, and conserve aggregate resources.

Objective

The objective of this study is to evaluate the effectiveness of geogrid in reducing the amount of subcut needed and cost through an area of weak soil.

Scope

The experimental section is located on project ACF-5-085(026)102. The project begins north of Gorham on US 85 to Grassy Butte. This study will compare the performance of an asphalt roadway where a geogrid has been placed to reduce the amount of excavation to a section where the soils have been excavated and replaced with granular material to a control section. Performance evaluations will be conducted and reported annually for five years. Items to be studied are: Construction Details (A) Method and ease of construction (B) Equipment required (C) Construction sequence

Performance Measurements (A) Rutting (B) Cracking (C) Deflections.

Summary

There is no appreciable difference in the average rut data between the test and control sections. All sections were near the border where the rut rating changes from fair to good.

The deflection and modulus data indicate that the subgrade is acting uniformly. The variability of the data is insignificant. The slight variations in data may be related to differences in base and sub-base thickness.

The aggregate used on top of geogrids in subcut areas must meet the optimum gradation specified for geogrid use. On this project, a section thickness of 24 inches of aggregate was needed in a soft subcut where a geogrid was not used. If a geogrid was used the section thickness could be reduced an average of 6 inches. The cost of geogrid has decreased since 1991. Geogrid should be considered in a design where base or subgrade reinforcement is desired.

Recommendation

Geotextile use has increased steadily in roadway design and roadway rehabilitation. Woven fabrics are used in subgrade and base reinforcement.

In subgrade reinforcement applications, Geogrids can be an effective alternative to deep subcutting. It is important to use a material that closely follows the optimum gradation for placement on geogrids.

Although many problems have been encountered during the installation process of geogrids on this project, especially on soft subgrades, we recommend that consideration be given to the use of geogrid instead of deep subcuts. Valuable experience has been gained on the use of geogrid. Each project must be evaluated as to the gradation and quality of aggregate available to complete the roadway reconstruction.

16. Key Words	17. Distribution Statement	18. No. of Pages
Geogrid Base Reinforcement Subgrade	No restrictions. This document is available to the public from: North Dakota Department of Transportation Materials and Research Division: 300 Airport Road Bismarck ND 58504-6005 Office: (701) 328-6900	36 19. File type/Size PDF/1.0 mb

NORTH DAKOTA
DEPARTMENT OF TRANSPORTATION

MATERIALS AND RESEARCH DIVISION

Experimental Study ND 91-01

Base Reinforcement Using Geogrid

Final Report

Project F-5-085(026)102

March 1998

Prepared by

NORTH DAKOTA DEPARTMENT OF TRANSPORTATION
BISMARCK, NORTH DAKOTA

DIRECTOR
Marshall W. Moore

MATERIALS AND RESEARCH DIVISION
Ron Horner

RCS HHO-30-19

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

EXPERIMENTAL PROJECT REPORT

EXPERIMENTAL PROJECT

EXPERIMENTAL PROJECT NO. [1]	STATE: ND, YEAR: 91, NUMBER: 01, SUF.:
CONSTRUCTION PROJ. NO. [8]	ACF-5-085(026)102
LOCATION [28]	Billings & McKenzie Cos.
EVALUATION FUNDING [48]	1 ☒ HP&R; 2 ☐ CONSTRUCTION; 3 ☐ DEMONSTRATION; 4 ☐ IMPLEMENTATION
NEEP NO. [49]	
PROPRIETARY FEATURE? [51]	☐ YES ☒ NO

SHORT TITLE

TITLE [52]: Base Reinforcement Using Geogrid

THIS FORM

DATE [140]	MO. 03 – YR. 98
REPORTING [144]	1 ☐ INITIAL; 2 ☐ ANNUAL; 3 ☒ FINAL

KEY WORDS

KEY WORD 1 [145]	Geogrid
KEY WORD 2 [167]	Base Reinforcement
KEY WORD 3 [189]	Subgrade
KEY WORD 4 [211]	
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]
MO. __ – YR. 91	10 – 91	12 – 96	__ – __	12 – 96

QUANTITY AND COST

QUANTITY OF UNITS (Rounded to whole numbers) [297]	29713
UNITS [305]	1 ☐ LIN. FT.; 2 ☒ S.Y.; 3 ☐ S.Y.-IN.; 4 ☐ C.Y.; 5 ☐ TON; 6 ☐ LBS.; 7 ☐ EACH; 8 ☐ LUMP SUM
UNIT COST (Dollars, Cents) [306]	2.53

AVAILABLE EVALUATION REPORTS

[315] ☒ CONSTRUCTION ☒ PERFORMANCE ☒ FINAL

EVALUATION

CONSTRUCTION PROBLEMS [318]	PERFORMANCE [319]
1 ☐ NONE	1 ☐ EXCELLENT
2 ☐ SLIGHT	2 ☐ GOOD
3 ☒ MODERATE	3 ☒ SATISFACTORY
4 ☐ SIGNIFICANT	4 ☐ MARGINAL
5 ☐ SEVERE	5 ☐ UNSATISFACTORY

APPLICATION

[320]
1 ☐ ADOPTED AS PRIMARY STD.
2 ☒ PERMITTED ALTERNATIVE
3 ☐ ADOPTED CONDITIONALLY
4 ☐ PENDING
5 ☐ REJECTED
6 ☐ NOT CONSTRUCTED

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

REMARKS

[321] The test sections and control sections are performing almost the same. Base sections in both the test and control sections are weakening with time. Geogrid costs have decreased and make its use more favorable.

[700]

FORM FHWA 1461 (REV. 8-79) Previous Editions are Obsolete

Experimental Study ND 91-01

Base Reinforcement Using Geogrid

FINAL REPORT

Project F-5-085(026)102

March 1998

Written by

Bill Kuhlmann

and

Mike J. Marquart

Disclaimer

TABLE OF CONTENTS

REINFORCEMENT OVER WEAK SUBGRADE USING GEOGRID

PROJECT F-5-085(026)102

OBJECTIVE

The objective of this study is to evaluate the effectiveness of geogrid in reducing the amount of subcut needed through an area of weak soil.

SCOPE

The normal practice to improve areas of weak subgrade is to remove the weak soils and replace them with granular material. The scope of this study is to compare the performance of an asphalt roadway where a geogrid has been placed to reduce the amount of excavation to a section where the soils have been excavated and replaced with granular material.

LOCATION

This test section is located on U.S. Highway 85 in Billings County, North Dakota, nine miles south of Grassy Butte in reference miles 103 and 104.

The entire project comprised 10.885 miles. Of the 10.885 miles, 4,773 feet comprises the test section for the geogrid. Photo one is an overview of the roadway in the area of the test section.

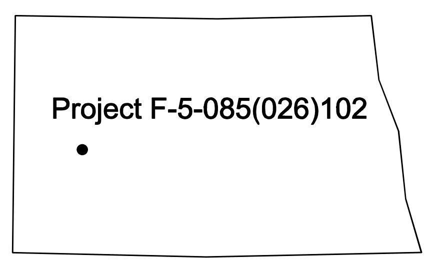


Photo 1: Looking south at the test section

Project History

Construction

The construction history for this project is presented in the following table:

Year Constructe d	Type of Construction	Depth (inches)	
1963	Graded		48
1991	Aggregate Base	18.0	46
1991	HBP	5.5	27
1991	Salvaged Material Shldrs	5.0	10
1991	Maint. Sand Seal Shls		10
1996	Contract Chip Seal		27

Table 1

Traffic

The traffic data for this project is presented in Table 2 for 1992 and 1996.

Year	Passenger	Trucks	Total	Flexible ESALs
1992	1050	250	1300	175
1996	890	260	1150	190
Flexible ESALS include both directions				

Table 2

Design

The project had a large amount of bituminous patching and rutting. Cores taken at each milepoint showed an average of nearly two inches of patch and seal material. Rutting was present in all miles with an average of approximately one-half inch. The deepest ruts were greater than one inch.

The plans called for removal of the existing bituminous material and leaving the existing aggregate base in place. The existing base was to be incorporated into the subgrade preparation which called for scarification to a depth of eighteen inches, reshaping of the roadway, and recompaction. The bituminous material removed was to be crushed to a maximum size of one and one-half inches.

The test section was to have the pavement section as shown in Figure 1. The geogrid was to be placed from station 465+21.6 to station 505+75.6 for a total length of 4054 feet.

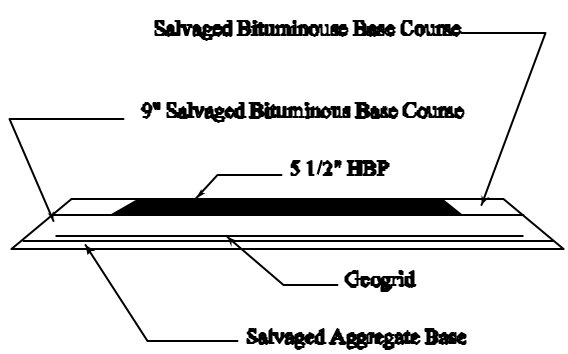


Figure 1

The control section was to be an area of subgrade repair constructed to the section shown in Figure 2. This section was to be constructed on each side of the test section from station 444+67.6 to station 465+21.6 and from station 505+75.6 to station 522+88.6 for a total length of 4054 feet.

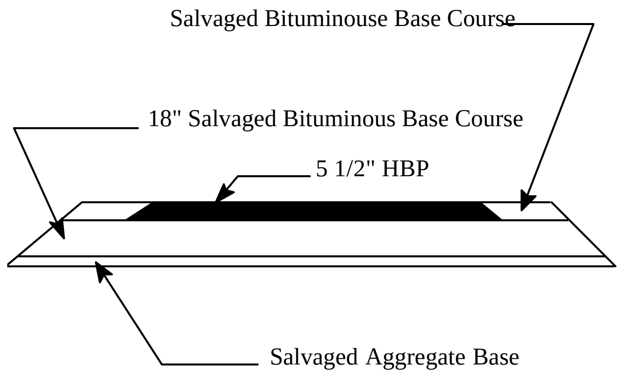


Figure 2

Construction

For all of the sections, the hot bituminous pavement and aggregate base were milled off and the subgrade preparation started. Problems were encountered during the subgrade preparation with very high subgrade moistures as can be seen in photo 2. This condition made specified compaction difficult to achieve. The depth of the subcut was increased because of these conditions.

Photo 2: Soft subgrade

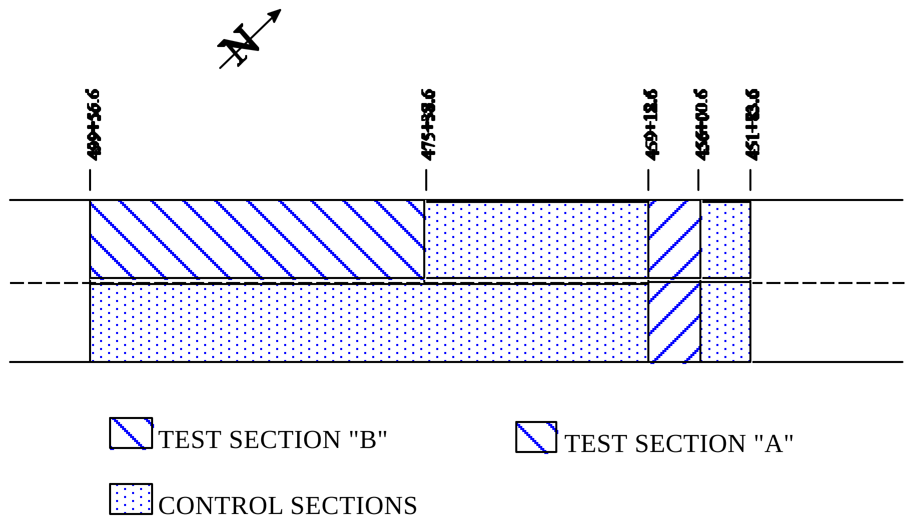


Figure 3

A good placement of the geogrid was accomplished across both lanes from station 456+00 to station 459+18 (section A) and under the southbound lane only from station 475+38 to station 499+56 (section B). The control sections were then selected as the areas as shown in figure 3. Figure 4 shows the constructed section for test section A. Figure 5 shows the constructed section for test section B. Figure 6 shows the constructed section for the control sections. Photo 3 shows the installation in section B.

TEST SECTION A

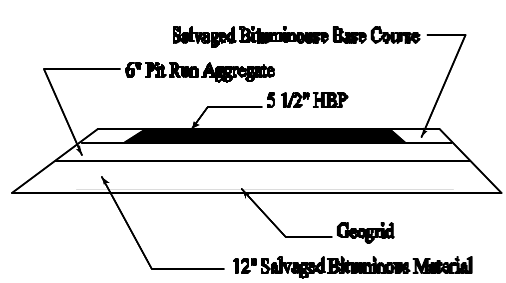


Figure 4

TEST SECTION B

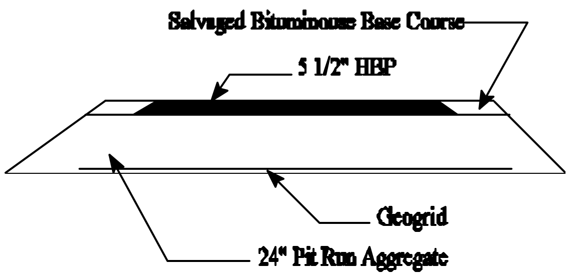


Figure 5

CONTROL SECTION

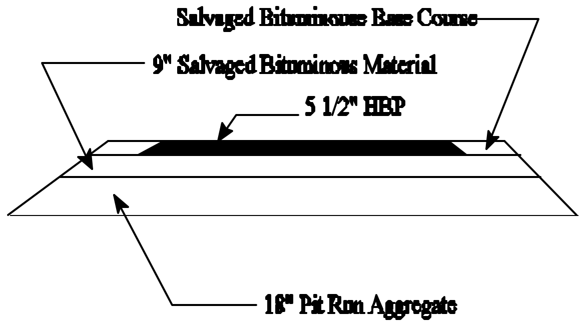


Figure 6

Photo 3: View of geogrid installation at test section B

Evaluation

The evaluation of this project was conducted using Pave Tech data, falling weight deflectometer (FWD) data, and site visitation. The Pave Tech data and video tapes were used to determine the average rut and the number of transverse cracks for the pavement. The FWD data was processed to determine the average subgrade modulus of elasticity. The site was visited on July 12, 1996 to evaluate the condition of the asphalt.

The average rut data for each section is presented in tables 3 and 4:

NORTHBOUND LANE					
SECTION	**1992**	**1993**	**1994**	**1995**	**1996**
CONTROL	N/A	N/A	0.22	0.26	0.23
SECTION A	N/A	N/A	0.21	0.34	0.20

Table 3

RUT DATA (inches)					
SOUTHBOUND LANE					
SECTION	**1992**	**1993**	**1994**	**1995**	**1996**
CONTROL	N/A	0.13	0.22	0.32	0.26
SECTION A	N/A	0.08	0.25	0.35	0.29
SECTION B	N/A	0.06	0.24	0.36	0.33

Table 4

Photo 4 shows the rutting typical in test section A and photo 5 shows the rutting typical in the control section.

Photo 4: View of rutting in test section A

Photo 5: View of rutting in control section

The number of transverse cracks for each section is presented in tables 5 and 6:

TRANSVERSE CRACKING (cracks per 1000 ft)						
NORTHBOUND LANE						
SECTION	**STATION**	**1992**	**1993**	**1994**	**1995**	**1996**
CONTROL	451+83.6 to 456+00.6	N/A	0.0	4.8	4.8	7.2
	459+18.6 to 475+38.6	N/A	1.9	2.5	2.5	13.0
	475+38.6 to 499+56.6	N/A	0.4	0.8	0.8	15.7
TEST SECTION A	456+00.6 to 459+18.6	N/A	3.1	3.1	3.1	12.6

Table 5

TRANSVERSE CRACKING (cracks per 1000 ft)						
SOUTHBOUND LANE						
SECTION	**STATION**	**1992**	**1993**	**1994**	**1995**	**1996**
CONTROL	451+83.6 to 456+00.6	N/A	0.0	4.8	4.8	9.6
	459+18.6 to 475+38.6	N/A	1.9	2.5	2.5	11.7
TEST SECTION A	456+00.6 to 459+18.6	N/A	3.1	3.1	3.1	9.4
TEST SECTION B	475+38.6 to 499+56.6	N/A	0.0	0.8	0.8	16.1

Table 6

Photo 6 is a view of a typical crack in the control section near station 476+78. All of the cracks evaluated were tight with very little or no ravelling.

Photo 6: View of crack in control section

The average subgrade modulus for each section is presented in tables 7 and 8:

Modulus (psi) Northbound Lane						
Year	**Base 1**		**Base 2**		**Subgrade**	
	control	**section**	**control**	**section**	**control**	**section**
1992	N/A	N/A	N/A	N/A	8,200	7,500
1993	24,000	19,400	14,300	11,600	5,300	6,400
1994	23,100	19,500	13,800	11,600	5,200	5,500
1995	N/A	N/A	N/A	N/A	N/A	N/A
1996	17,700	13,000	10,500	7,700	4,600	4,600

Table 7

Modulus (psi) Southbound Lane									
Year	Base 1			Base 2			Subgrade		
	control	section		control	section		control	section	
		A	B		A	B		A	B
1992	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1993	31,200	20,200	31,000	18,600	12,000	18,500	5,200	5,800	5,400
1994	28,500	20,000	25,000	16,800	15,700	14,900	5,500	5,200	5,800
1995	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1996	23,200	16,000	19,600	13,600	8,500	11,700	5,900	4,800	5,300

Table 8

Looking at tables 5 and 6, the number of transverse cracks per 1000 feet is nearly the same for test sections either contiguous to or adjacent to control sections.

The subgrade of the test and control sections are considered near equal in strength. The southbound lane does have a slightly higher strength than the northbound lane.

Modulus: Tables 7 and 8 show that from 1993 to 1996 the base modulus in the test sections has decreased more than in the control sections. The base in section B of the southbound lane has the largest percent decrease at 37%. The control base section had a 26% modulus decrease.

The deflection data was averaged for each section and is shown in tables 9 and 10.

Northbound Lane					
SECTION	**1992**	**1993**	**1994**	**1995**	**1996**
CONTROL	N/A	23.2	22.5	N/A	43.8
SECTION A	N/A	32.6	33.0	N/A	58.7

Table 9

Total Deflection (Milli-inches)					
Northbound Lane					
SECTION	**1992**	**1993**	**1994**	**1995**	**1996**
CONTROL	N/A	21.6	22.2	N/A	40.0
SECTION A	N/A	26.5	25.3	N/A	47.4
SECTION B	N/A	24.1	25.3	N/A	46.4

Table 10

Deflections: The higher the deflection number, the weaker the section. Northbound lane deflections have increased 89% in the control section and 80% in section A. In the southbound lane the deflections increased by 85% in the control, by 79% in section A and by 93% in section B.

Control sections were subcut 27". Geogrid section B was subcut 24" and geogrid section A was subcut 18". Since the control and test sections are considered similar, it would indicate that you could reduce the subcut by 3 to 9 inches if a geogrid was used. A lot depends on material gradation. Information shows that 10" of Tensar reinforced base equals 16" of non-reinforced base material. This is a difference of 6 inches. Using this design, let's use a 500 foot section of roadway 24 feet wide and subcut 6 inches deep for a cost comparison of geogrid verses subcutting for 1991 and 1996.

Geogrid		Subcut		
Square Yard	Cost $2.53 Per Square Yard	222 Cu. Yds--Pit Run at $5.18 per ton or $9.71 Cu. Yd.	222 Cu. Yds Common Excavation at $1.20 Cu. Yd.	Total Cost of subcut
1333	$3,372.49	$2,155.62	$266.40	$2,422.00
Subcutting cost is 28% less than Geogrid. Saving $10,036.96 per mile				

Table 9

1996 cost comparison of a 500 ft. section, 24 ft. wide and 0.50 ft. deep				
Geogrid		Subcut		
Square Yard	Cost $1.60 Per Square Yard	222 Cu. Yds--Class #3 at $6.50 Cu. Yd.	222 Cu. Yds Common Excavation at $3.06 Cu. Yd.	Total Cost of subcut
1333	$2,132.80	$1,443.00	$679.98	$2,122.32
Subcutting costs 0.5% less than Geogrid. Saving $110.66 per mile.				

Table 10

Geogrid prices have decreased from 1991, making geogrid more cost effective. The geogrid used was type BX 1100 and was $2.53 per square yard. The pit run backfill material was $5.18 per ton. Common excavation for subgrade repair was $1.20 per cubic yard.

The optimum gradation of aggregate for use with geogrid is as follows:

Sieve Size	Percent Passing
1½"	100
¾"	90-100
#4	23-50
#10	15-36
#40	8-22
#200	0-8

Gradation of the pit run material used was as follows:

Sieve Size	Percent Passing
1½"	100
¾"	97.8
#4	77.9
#10	68.2
#40	53.4
#200	14.7

Gradation of the salvaged bituminous material used was as follows:

Sieve Size	Percent Passing
1½"	100
¾"	98.3
#4	42.2
#10	20.2
#40	5.8
#200	1.8

It can be seen from the gradations that the pit run material was significantly finer than the optimum gradation to be used with geogrid. The sections failed where pit run was placed on the geogrid in depths less than 24 inches. In areas where less than 24" of pit run was used on the geogrid, the geogrid could not confine the pit run material. This is directly related to the gradation of the pit run. The sections that hold up the best are those where salvaged bituminous material is placed on top of the geogrid and finished to grade with pit run material. The gradation of the salvaged bituminous material was very close to the optimun gradation of aggregate to be used with a geogrid.

Summary

There is no appreciable difference in the average rut data between the test and control sections. All sections were near the border where the rut rating changes from fair to good.

The deflection and modulus data indicate that the subgrade is acting uniformly. The variability of the data is insignificant. The slight variations in data may be related to differences in base and sub-base thicknesses.

The aggregate used on top of geogrids in subcut areas must meet the optimum gradation specified for geogrid use. On this project, a section thickness of 24 inches of aggregate was needed in a soft subcut where a geogrid was not used. If a geogrid was used the section thickness could be reduced an average of 6 inches. The cost of geogrid has decreased since 1991. Geogrid should be considered in a design where base or subgrade reinforcement is desired.

Recommendations

Geotextile use has increased steadily in roadway design and roadway rehabilitation. Woven fabrics are used in subgrade and base reinforcement.

In subgrade reinforcement applications, Geogrids can be an effective alternative to deep subcutting. It is important to use a material that closely follows the optimum gradation for placement on geogrids. The gradation recomended for use with geogrid is :

Sieve Size	Percent Passing
1½"	100
¾"	90-100
#4	23-50
#10	15-36
#40	8-22
#200	0-8

Although many problems have been encountered during the installation process of geogrids on this project, especially on soft subgrades, we recommend that consideration be given to the use of geogrid instead of deep subcuts. Valuable experience has been gained on the use of geogrid. Each project must be evaluated as to the gradation and quality of aggregate available to complete the roadway reconstruction.

Appendix A

JOB#

FHWA REGION	STATE	PROJECT	SHEET NO.
8	N.D.	F-5-085(026)102	1

DESIGN DATA

Traffic		Average Daily					Est. 30th Max. Hr.
Current (1991)	1150 Pass.	300	Trucks	1450	Total		150
Forecast (2011)	1150 Pass.	300	Trucks	1450	Total		150

Design Speed 70 MPH
Traffic Classification "M"
Minimum Sight Distance (Stopping) 850'
Minimum Sight Distance (Safe Passing) 3200'
Minimum Passing Sight Distance for Marking 1200'

NORTH DAKOTA
DEPARTMENT OF TRANSPORTATION

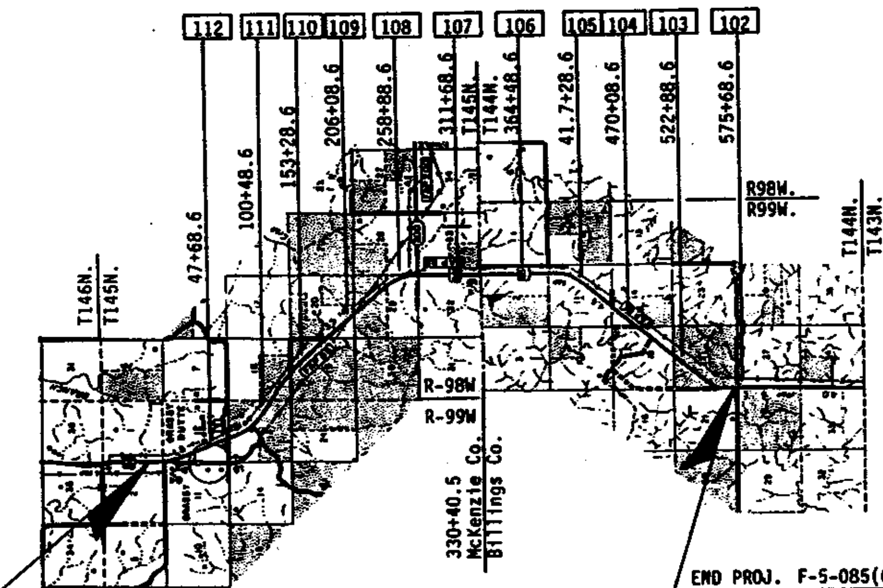
FEDERAL AID PROJECT NO. F-5-085(026)102
IN
BILLINGS AND MCKENZIE COUNTIES
SALVAGE BITUMINOUS BASE COURSE,
HOT BITUMINOUS PAVEMENT,
AND INCIDENTALS

COVERNING SPECIFICATIONS:

Standard Specifications for Road and Bridge Construction, adopted by the North Dakota State Highway Department, November 1986, shall apply to all North Dakota Department of Transportation contracts, standard drawings currently in effect, and other contract provisions submitted herein.

LENGTH OF PROJECT

Project	Miles-Gross	Miles-Net
F-5-085(026)	10.885	10.885



END PROJ. F-5-085(026)102 Sta. 574+74.0
Sec. 22, Twp. 144 N., Rge. 99 W.

Beg. Proj. F-5-085(026)102 Sta. 0+00
A point 632.1' N. of the S.W. Corner of Sec. 1, Twp. 145 N., Rge. 99 W.

N

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

APPROVED

DIVISION ADMINISTRATOR DATE

APPROVED DATE 1/25/91

Ray Zink

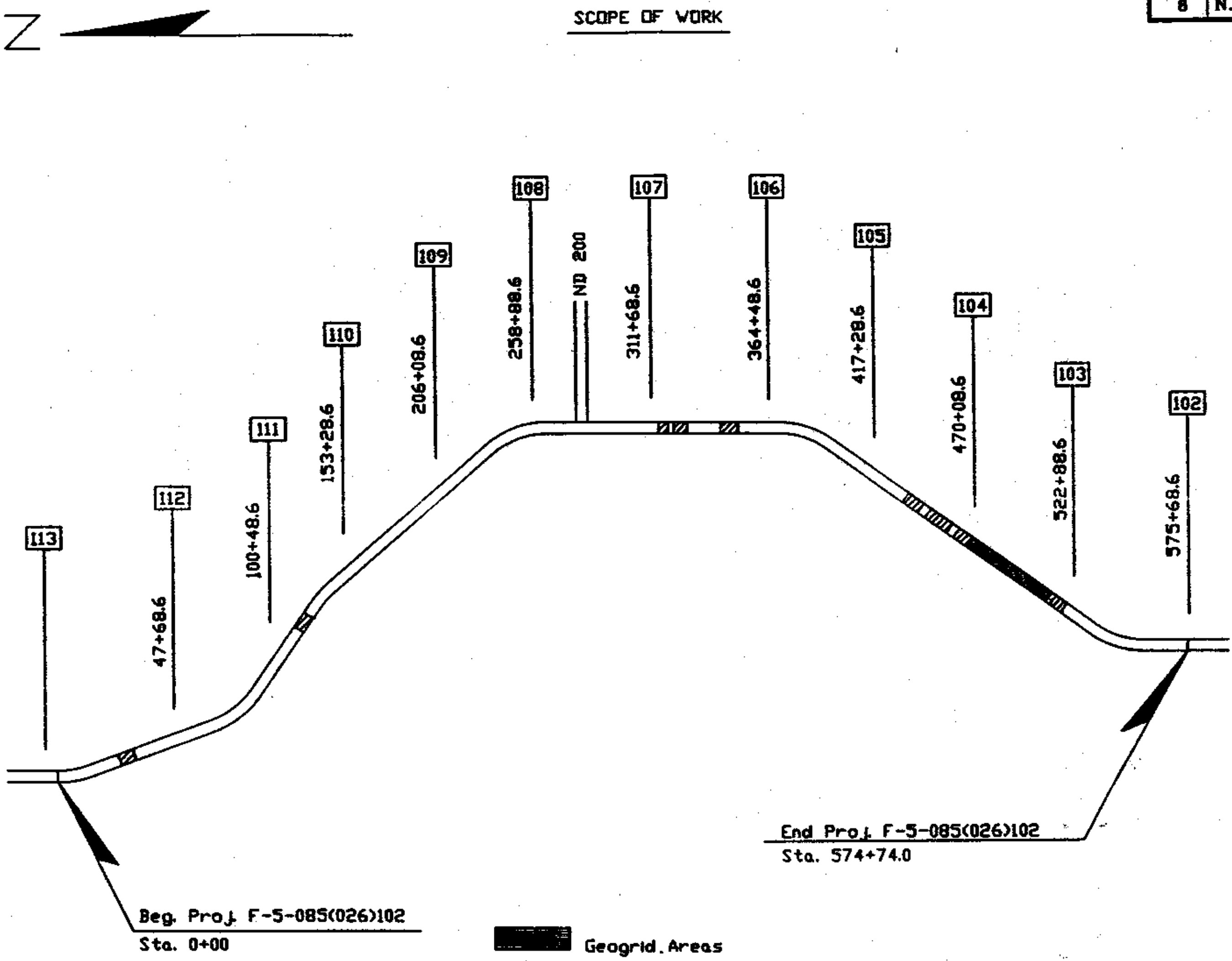
DIRECTOR OF HIGHWAYS AND ENGINEERING

NORTH DAKOTA DEPARTMENT OF TRANSPORTATION

RAY ZINK REGISTERED PROFESSIONAL ENGINEER P.E. 972 NORTH DAKOTA

FHWA REGION	STATE	FED. AID PROJ. NO.	SHEET NO.
8	N.D.	F-5-085(026)102	3

SCOPE OF WORK



Geogrid Areas

Subgrade Repair Areas (See Subgrade Repair Location and Estimated Excavation Sheet for Stationing and Depth)

GENERAL NOTES

100 COOPERATION BETWEEN CONTRACTORS: A paving contract will be active to the immediate south of this project. This contractor and any subcontractors will assure that their activities will not interfere with the other contractor or subcontractors operations.

106 P01 CONTROL OF MATERIAL: All of the salvaged bituminous base and salvaged bituminous surfacing shall be processed, by crushing, to the maximum size shown on the plans. The material will be used for "Salvaged Bituminous Base Course." It is intended that all salvaged material shall be used on this project.

200 150 COMPACTION AND DENSITY CONTROL: Compaction shall be in accordance with Section 203.02 F as determined by AASHTO T-180.

230 P01 SUBGRADE PREPARATION, TYPE A: In addition to the general requirements of Section 230.02 B.1, subgrade preparation shall include the following: After the existing bituminous surfacing and bituminous base have been removed, the exposed surface shall be throughly scarified to a depth of 18 inches, shaped and recompacted in accordance with Section 230.02 B.1.

302 100 SALVAGED BITUMINOUS BASE COURSE: The salvaged bituminous base course will consist of blending the salvaged bituminous surfacing material and the salvaged bituminous base material. The salvaged material quantities used for calculating plan quantity for recycled base course reflect a 10% allowance for losses.

The salvaged materials used in the salvaged bituminous base course shall be blended and processed to provide a uniform mixture of salvage materials with a maximum particle size of 1 inch. The contractor will be responsible for providing a blending and processing method which meets these requirements. All blending and processing shall be completed prior to weighing the salvaged bituminous base course for payment.

After blending and processing the salvaged material shall be placed on the prepared roadway, windrowed, spread, shaped, and compacted to the required cross section. Compaction shall be in accordance with Ordinary Compaction, Section 302.04 F.1. All costs for this work including processing, crushing, screening, blending, loading, hauling, depositing, shaping, and compacting of the salvaged material shall be included in the unit price bid for "Salvaged Bituminous Base Course."

320 400 AGGREGATE FOR SUBGRADE REPAIR: Approximately 20,801 tons of aggregate will be required to backfill the subgrade repair areas. Aggregate for subgrade repair shall meet the following requirements:

Sieve Size	Maximum Percent Passing
3"	100
No. 4	85
No. 30	50
No. 200	15

Maximum shale content shall be 12%.

PI shall not exceed 4.

All aggregate for subgrade repair shall be subject to approval of the engineer and costs for providing, hauling, placing, and compacting the material shall be included in the unit price bid for "Aggregate for Subgrade Repair."

405 P01 REMOVE AND SALVAGE BITUMINOUS SURFACING BASE COURSE: The existing bituminous surfacing and the bituminous treated base course shall be removed for the entire length of the project and salvaged and crushed and used as part of the salvaged bituminous base course. The bituminous material to be removed may be done by milling or with tracked or wheeled front-end loaders. Earth movers shall not be used for removal of the salvaged bituminous base course. The contractor shall prevent any material from being contaminated by the removal, stockpiling and replacing operations. If a crusher or pugmill type operation is going to be used to blend the salvaged material, the salvaged bituminous treated base course and bituminous surfacing shall each be deposited in separate stockpiles. An additional 12 foot width (minimum of existing surfacing, adjacent to the mainline surfacing shall be removed from approaches and flared intersections. The contractor shall provide a 8:1 (min.) aggregate transition for public traffic. At no time shall the removal of bituminous surfacing exceed one mile in length ahead of subgrade preparation work and no more than three miles ahead of the placement and priming of the nine inch salvaged bituminous base course. The contractor shall maintain access to abutting property during the time this work is performed. Cost of providing access shall be incidental to other items. All cost for this work including removing, loading, hauling, and stockpiling the bituminous surfacing and the bituminous treated base course shall be included in the unit price bid for "Remove and Salvage Bituminous Surfacing."

405 P02 PREPARE STOCKPILE SITE: The lump sum bid for Prepare Stockpile Site" shall be full payment for the required site preparation and restoration regardless of the number of sites used. If the contractor uses additional sites for his operation, then these items of work shall be at his own expense for these sites. All salvaged bituminous pavement and base material stockpiled at the plant site shall be considered the property of the contractor. No payment shall be made for salvaged bituminous material which is stockpiled and not incorporated into the project. All other stockpiled material shall become the property of the contractor. The contractor shall remove his property from the stockpile site upon completion of this project.

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QUANTITIES

SPEC	CODE	ITEM DESCRIPTION	UNIT	MAINLINE	(8) SL-RW (10) SL-RAD (45) P.D. APPROACHES	(1) FLARED INTERSECTIONS	TOTAL
103	0100	Contract Bond	L. Sum	1			1
203	0137	Common Excavation, Subgrade Repair	Cu. Yd.	9,814			9,814
216	0100	Water	M Gal.	6,532			6,532
230	0170	Subgrade Preparation - Type A	Mile	10.885			10.885
302	0241	Aggregate for Subgrade Repair	Tons	20,801			20,801
302	0305	Salvaged Bit. Base Course	Ton	127,849			127,849
401	0103	MC-70, 250 Liquid Asphalt or SP-6 Emuls. Asphalt	Gal.	63,863			63,863
401	0152	SS-1h or CSS-1h Emul. Asphalt	Gal.	28,247	570	38	28,855
401	0160	Blotter Material Cl. 44	Ton	914			914
405	0110	Remove & Salv. Bit. Surfacing	Ton	143,563	702	67	144,332
408	0197	Hot Bituminous Pavement Special	Ton	56,592	1,385	77	58,054
408	0320	120-150 Asph. Cement	Ton	3,396	84	4	3,484
408	9605	Cored Samples (Bit. Pvmt.)	Ea.	345			345
410	0120	Prepare Stockpile Site	L. Sum	1			1
702	0100	Mobilization	L. Sum	1			1
704	0100	Flagging	M. Hr.	550			550
704	1000	Traffic Control Signs	Unit	1,718			1,718
704	1052	Type III Barricade	Ea.	4			4
950	0100	Trainee	M. Hr.	2,000			2,000

QUANTITIES

SPEC	CODE	ITEM DESCRIPTION	UNIT	MAINLINE	(8) SL-RW (8) SL-RAD (45) P.D. APPROACHES	(1) FLARED INTERSECTIONS	TOTAL
704	1080	Vertical Panels	Ea.	64			64
704	1185	Pilot Car	Hrs.	230			230
706	0300	Field Laboratory - Type C	Ea.	1			1
708	2240	Seeding, Type B, Class II	Acre	14			14
754	0122	Fuse Joints - All Sizes - Steel	Ea.	10			10
754	0210	Steel Galv. Posts - Std. Pipe	Lbs.	1,025			1,025
754	0472	3½" St. Galv. Multi.-Dir. Breakaway Bases	Ea.	10			10
754	0531	Panel for Signs - Type 2	Sq. Ft.	93			93
754	0592	Reset Sign Panel	Ea.	2			2
754	1100	Class AE Conc. - Sign Foundations	C.Y.	3.5			3.5
762	0102	Pavement Marking Painted Line	L. Ft.	143,700		1,400	145,100
762	0140	Temporary Striping Broken Line (Painted, Tape or Raised Markers)	L. Ft.	17,242			17,242
762	0141	Temporary Striping - Solid Line No Passing (Painted, Tape of Raised Markers)	L. Ft.	43,105			43,105
920	1215	Geogrid Reinforcement Blanket	Sq. Yd.	20,720			20,720
980	0700	Install Mailbox	Ea.	1			1

MAXIMUM SIZE OF AGGREGATE

Description	Type of Aggregate	Max. Size
Salv. Bit. Material	Crushed	1"
Salv. Bit. Base Course	Crushed	1"
Hot Bit. Pvmt., Special*	Crushed	5/8"

* The aggregate shall meet the following gradation and physical requirement specification:

Sieve Size	Percent Passing
5/8	100
1/2	90-100
3/8	76-91
No. 4	54-66
No. 8	38-50
No. 16	26-38
No. 30	16-29
No. 50	8-20
No. 100	6-14
No. 200	4-9
Shale	5% maximum
L.A. Abrasion	40% maximum
Placticity Index	nonplastic

A minimum of 95% of the material retained on the No. 4 sieve and a minimum of 75% of the material passing a No. 4 sieve shall be composed of fractured material produced by a crushing process. The contractor shall demonstrated that the crushing operation produces this result.

If a source of aggregate other than the pit located at NW¼ 4-16-56 is used the asphalt absorption of the aggregate as determined by the project mix design shall not exceed 1.5% when tested in accordance with AASHTO T-209, T-166, T-84, T-85, and T-228.

CURVE DATA

Sta.	to	Sta.	Degree	Length	Trans. Length
PC 0+00		PT 13+53.3	1°-30'	1353.3'	100'
PC 70+53.8		PT 94+37.1	1°-30'	2383.3'	100'
PC 145+44.6		PT 160+32.9	1°-30'	1488.3'	100'
PC 249+52.9		PT 277+05.1	1°-30'	2752.2'	100'
PC 381+04.2		PT 404+64.2	1°-30'	2360.0'	100'
PC 545+17.2		PT 568+96.1	1°-30'	2378.9'	100'

TEMPORARY STRIPING
2-LANE ROADWAY - BASIS OF ESTIMATE
PAVEMENT MARKING, PAINTED, TAPE, OR RAISED MARKERS

Centerlines Broken Line 528 L.F./Mi. 17,242 L.F.
Barrier Lines, Solid Line 1,320 L.F./Mi. 43,105 L.F.

2-LANE ROADWAY - BASIS OF ESTIMATE
PAVEMENT MARKING PAINTED - LINE

Edge Lines - 4 inch white - 10,560 L.F./Mi. 114,900 L.F.
Centerlines - 4 inch yellow, 10' line,
30' skip - 1320 L.F./Mi. 14,400 L.F.
Barrier Lines - 4 inch yellow, 3 in. between
lines - 1,320 L.F./Mi. 14,400 L.F.

Additional Barrier Quantity for:

(1) Type II Flared Intersection - 1,400 L.F./Ea. 1,400 L.F.

NOTE: Edge lines shall be continued through private drives and broken for intersections.

LIST OF PROVISION

Description	S.P. No.
Geogrid Base Reinforcement	SP161
Trainee	

EXISTING HOT BITUMINOUS PAVEMENT CORES

102	1.50	2.75	0.25	4.50	9.25
103	2.25	4.50	0.25	4.50	11.25
104	2.50	3.75	0.25	5.00	11.50
105	1.50	5.25	0.25	4.75	11.25
106	2.25	3.75	0.25	5.00	11.25
107	0.50	3.25	0.25	6.00	10.00
108	1.00	3.00	0.25	6.00	10.25
109	2.25	2.50	0.25	6.00	11.00
110	2.00	3.50	0.25	5.50	11.25
111	1.25	3.00	0.25	5.50	10.00
112	1.25	2.50	0.25	5.00	8.75

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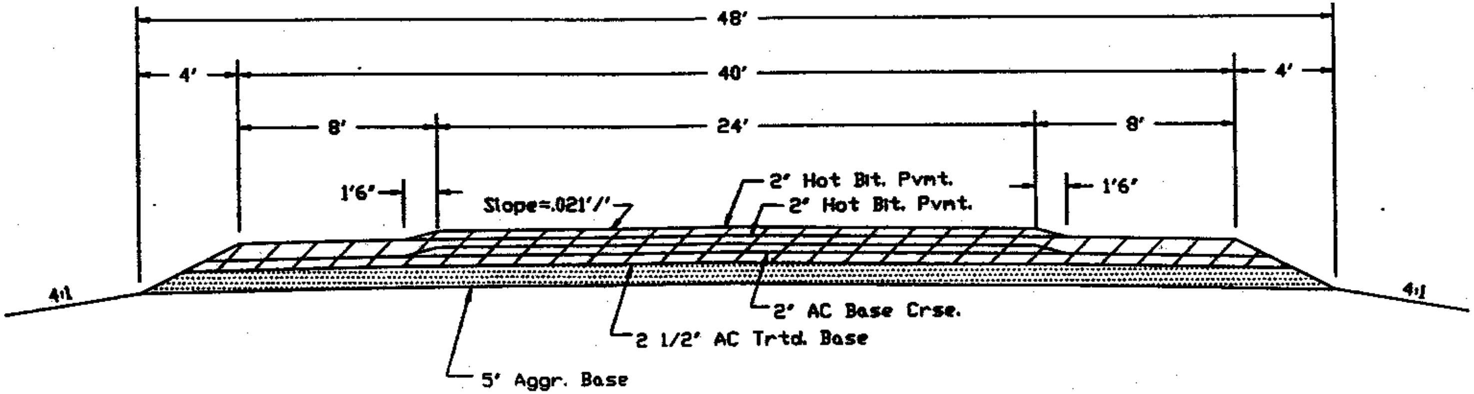
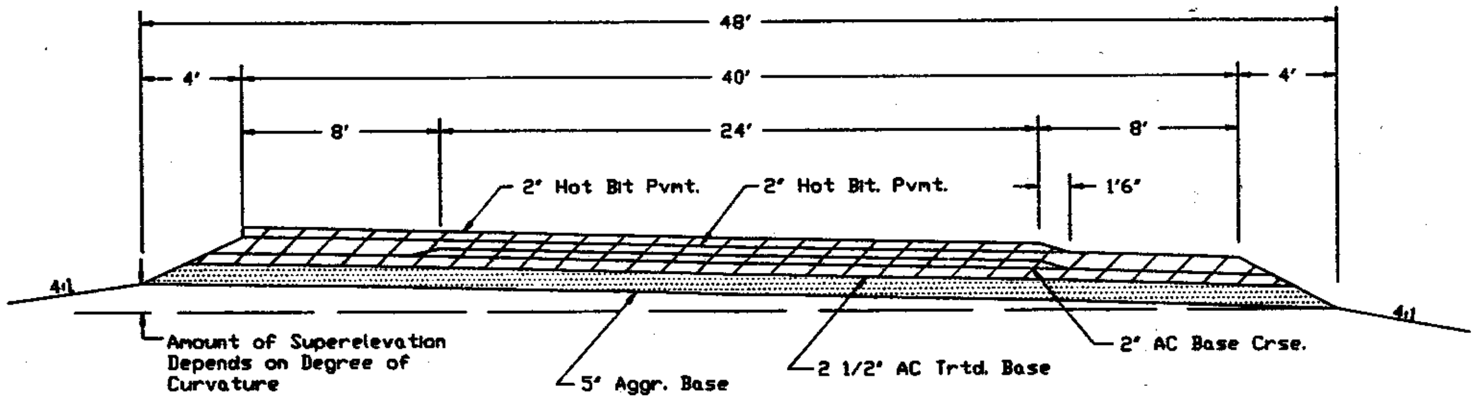
EXISTING TYPICAL SECTIONS

STA. 0+00 TO 574+74.0



TANGENT



CURVE

LEGEND

To be removed and salvaged.

Aggregate to be mixed into subgrade.

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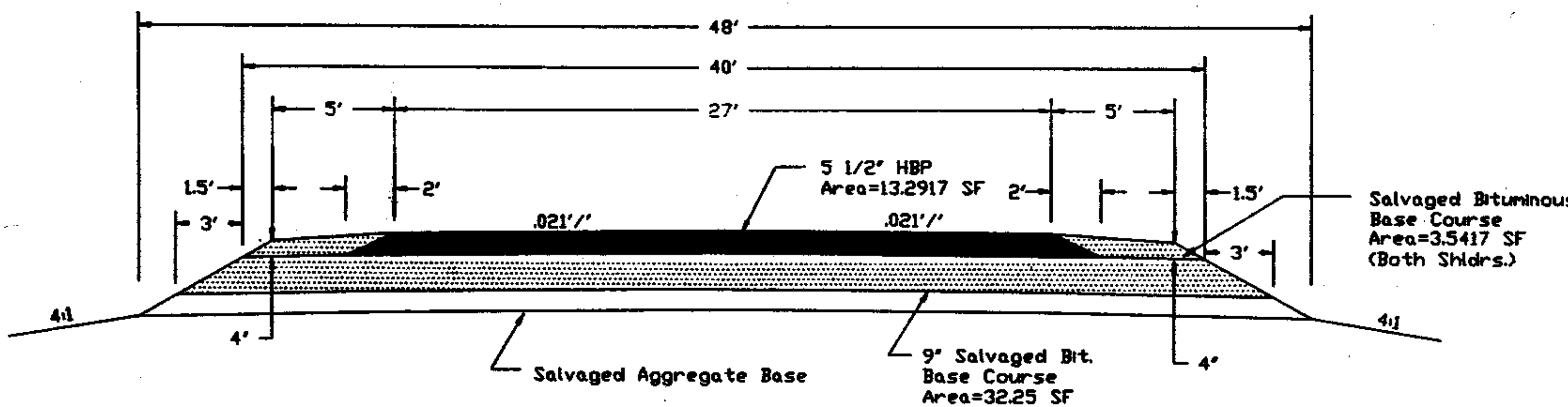
PROPOSED TYPICAL SECTION

STA. 0+00 TO 574+74.0



TANGENT

NOTE: Curve section same as Tangent except for Superelevation

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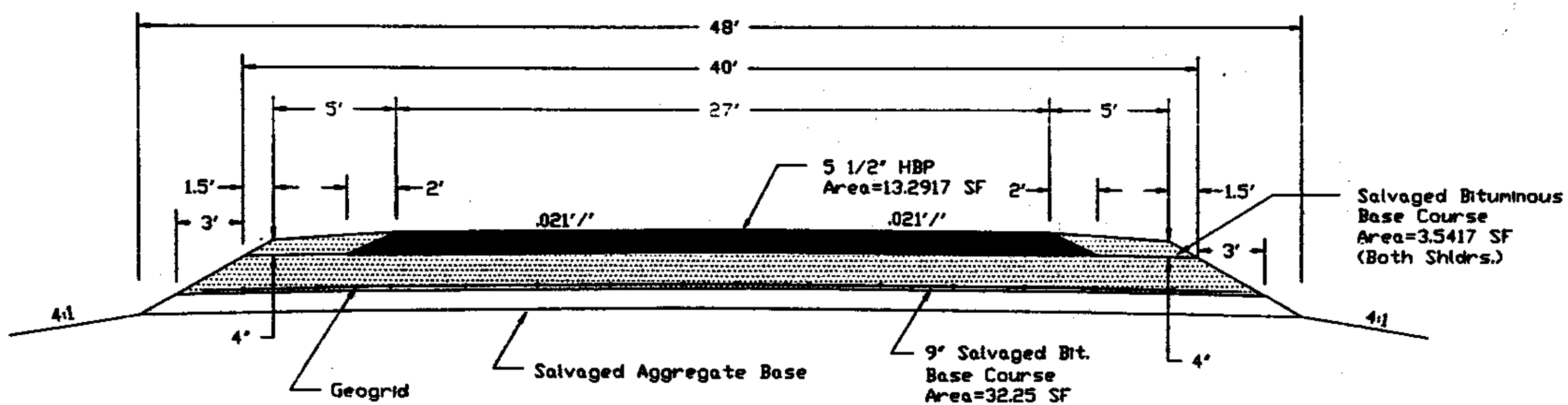
PROPOSED TYPICAL SECTION

STA. 465+21.6 TO 505+75.6



TANGENT

NOTE: Curve section same
as Tangent except
for Superelevation

Appendix B

NORTH DAKOTA DEPARTMENT OF TRANSPORTATION

SPECIAL PROVISION

GEOGRID BASE REINFORCEMENT

PROJECT NO. F-5-085(026)102

MARCH 22, 1991

DESCRIPTION

This work shall consist of furnishing and installing a geogrid reinforcement blanket for base reinforcement.

MATERIALS

The geogrid shall be a regular grid structure formed by biaxially drawing a continuous sheet of select polypropylene material and shall have aperture geometry and rib and junction cross-sections sufficient to permit significant mechanical interlock with the material being reinforced. The geogrid shall have high flexural rigidity and high tensile modulus in relation to the material being reinforced and shall also have high continuity of tensile strength through all ribs and junctions of the grid structure. The geogrid shall maintain its reinforcement and interlock capabilities under repeated dynamic loads while in service and shall also be resistant to ultraviolet degradation, to damage under normal construction practices, and to all forms of biological or chemical degradation normally encountered in the material being reinforced.

The geogrid shall also conform in all respects to the property requirements listed below:

PROPERTY	TEST METHOD	UNITS	VALUE
Interlock			
Aperture size[1]	I.D. Calipered[2]		
MD		in	1.0 (nom)
CMD		in	1.3 (nom)
Open area	COE Method[3]	%	70 (min)
Thickness	ASTM D 1777-64		
Ribs		in	0.03 (nom)
Junctions		in	0.11 (nom)

MATERIALS (CONTINUED)

PROPERTY	TEST METHOD	UNITS	VALUE
Reinforcement			
Flexural rigidity	ASTM D1388-64[4]	mg-cm	250,000 (min)
Tensile modulus	GRI GG1-87[5]	lb/ft	14,000 (min)
Junctions	GRI GG2-87[6]		
Strength		lb/ft	750 (min)
Efficiency		%	90 (min)
Material			
Polyproplyene	ASTM D 4101 Group 1/Class 1/Grade 2	%	98 (min)
Carbon Black	ASTM 4218	%	0.5 (min)

Notes:

1 MD dimension is along roll length. CMD dimension is across roll width.
2 Maximum inside dimension in each principal direction measured by calipers.
3 Percent open area measured without magnification by Corps of Engineers method as specified in CW 02215 Civil Works Construction Guide, November 1977.
4 ASTM D 1388-64 modified to account for wide specimen testing as described in Tensar test method TTM-5.0 "Stiffness of Geosynthetics."
5 Secant modulus at 2% elongation measured by Geosynthetic Research Institute test method GG1-87 "Geogrid Tensile Strength." No offset allowances are made in calculating secant modulus.
6 Geogrid junction strength and junction efficiency measured by Geosynthetic Research Institute test method GG2-87 "Geogrid Junction Strength."

CONSTRUCTION REQUIREMENTS

The geogrid shall be placed where specified so that the roll length runs parallel to the roadway. The geogrid material shall be tensioned by hand to remove all slack and secured at the roll ends by driving stakes, staples, hooks, or nails with washers through the grid apertures into the ground. Joints shall be overlapped a minimum of 24 inches in the direction that the fill will be spread so that the previous roll overlaps the subsequent roll.

When the aggregate is placed, construction equipment shall be limited in size and weight to limit the amount of rutting. If rutting does occur, additional aggregate shall be placed to fill the ruts. The ruts shall not be bladed out. Turning and short stopping shall be avoided to prevent the grid from shifting. A minimum of 4 inches of material shall be spread before equipment may operate on the grid. The granular fill shall be compacted according to Section 302.04 F. 1, Ordinary Compaction.

The Engineer may order the removal of at least 4 square yards of material to inspect for damage to the grid. Tears in the grid shall be patched, at the Contractor's expense, with the grid being lapped a minimum of 36 inches around the tear.

METHOD OF MEASUREMENT

The geogrid shall be measured by the actual surface area covered to the nearest square yard. No allowance will be made for overlaps.

BASIS OF PAYMENT

The quantity measured as provided will be paid for at the Contract Unit Price for the square yards of geogrid accepted by the Engineer.