REINFORCED SLOPE WITH GEOGRIDS

Final Report for
Iowa DOT Project HR-548

Federal Highway Administration
Project No. IA 90-02

March 1997

Project Development Division

Iowa Department
of Transportation

Final Report
For
Iowa Department of Transportation
Project HR-548

REINFORCED SLOPE WITH GEOGRIDS

GREENHILL ROAD BIKEWAY
WATERLOO, IOWA
PROJECT IX-6585(9)--79-07

By
Jeff Bales
Associate Engineer
319-291-4312
City of Waterloo Engineering Department
Waterloo, IA 50703

March, 1997

TECHNICAL REPORT TITLE PAGE

1. **REPORT NO.**

HR-548

2. **REPORT DATE**

March 1997

3. **TITLE AND SUBTITLE**

Reinforced Slope With Geogrids

4. **TYPE OF REPORT & PERIOD COVERED**

Final Report 7-89 to 3-97

5. **AUTHOR(S)**

Jeff Bales
Associate Engineer

6. **PERFORMING ORGANIZATION ADDRESS**

City of Waterloo Engineering Dept.
715 Mulberry
Waterloo, Iowa 50703

7. **ACKNOWLEDGEMENT OF COOPERATING ORGANIZATIONS**

8. **ABSTRACT**

The objective of this research study is to evaluate the performance, maintenance requirements and cost effectiveness of constructing reinforced slope along a concrete bikeway overpass with a Geogrid system such as manufactured by Tensar Corporation or Reinforced Earth Company.

This final report consists of two separate reports - construction and performance. An earlier design report and work plan was submitted to the Iowa DOT in 1989. From the Design Report, it was determined that the reinforced slope would be the most economical system for this particular bikeway project. Preliminary cost estimates for other design alternatives including concrete retaining walls, gabions and sheet pile walls ranged from $204/L.F. to $220/L.F.

The actual final construction cost of the reinforced slope with GEOGRIDS was around $112/L.F. Although, since the reinforced slope system was not feasible next to the bridge overpass because of design constraints, a fair cost comparison should reflect costs of constructing a concrete retaining wall. Including the concrete retaining wall costs raises the per lineal foot cost to around $122/L.F.

In addition to this initial construction cost effectiveness of the reinforced slope, there has been little or no maintenance needed for this reinforced slope. It was noted that some edge mowing or weed whacking could be done near the concrete bikeway slab to improve the visual quality of the slope, but no work has been assigned to city crews. It was added that this kind of weed whacking over such steep slope is more difficult and there could possibly be more potential for work related injury.

The geogrid reinforced slope has performed really well once the vegetation took control and prevented soil washing across the bikeway slab. To that end, interim erosion control measures might need to be considered in future projects. Some construction observations were noted. First, there is no specialized experience or equipment required for a contractor to successfully build a low-to-medium geogrid reinforced slope structure. Second, the adaptability of the reinforced earth structure enables the designer to best fit the shape of the structure to the environment and could enhance aesthetic quality. Finally, a reinforced slope can be built with relatively soft soils provided differential settlements between facing are limited to one or two percent.

9. **KEY WORDS**
Geogrid
Engineering fabric
Slope steepening
Reinforced earth

10. **NO. OF PAGES**
26

TABLE OF CONTENTS

INTRODUCTION/PROJECT DESCRIPTION

This final report consists of two separate reports, construction and performance, as well as conclusions and recommendations regarding the reinforced slope alternatives that were investigated for slope steepening in lieu of constructing conventional retaining wall structures.

A design report was submitted to the Iowa Department of Transportation on July 1989 and included cost comparisons of design alternatives and criteria. The special provisions for the reinforced slope were submitted to the Iowa Department of Transportation in June 1989.

A work plan was developed and submitted to the Iowa Department of Transportation in July 1989 and acknowledged both Tensar Corporation and Reinforced Earth Company geogrids. These two companies were the only two recognized by the Iowa Department of Transportation at the time the FHWA and State were pursuing this type of a project. The two companies subsequently provided plans, which were incorporated as alternatives in the contract bid documents. The project letting was held by the Iowa Department of Transportation on January 9, 1990, and the low bidder elected to use Tensar Corporation geogrids.

A construction report is included in this document and covers selected portions of the construction plans pertaining to the reinforced slope, bid prices and quantities and descriptions of the construction.

The project location is indicated by a Location Map shown in Appendix B, Figure A and extends from the intersection of Greenhill Road and Katoski Drive to Maynard Avenue with a total length of 0.6 miles.

Greenhill Road is a four-lane, divided arterial roadway which was constructed at a grade below that of the previous terrain between Katoski Drive and the ramp junction north of University Avenue. An adjacent bike trail traverses open country and residential areas between Waterloo and Cedar Falls.

The ten-foot wide bikeway passes under the west span of the six-lane University Avenue bridge over Greenhill Road.

The segment of bikeway included in this report is located between Katoski Drive and the ramp junction located north of University Avenue. Approximately 540 feet of the length of the bikeway is located between Katoski Drive and South Hackett Road. An additional 968 feet is between South Hackett Road and University Avenue and another 425 feet is between University Avenue and the ramps north of University Avenue. Photos A and B, in Appendix A are taken from the north and south sides of the bridge overpass, respectively.

CONSTRUCTION REPORT
REINFORCED SLOPE
GREENHILL ROAD BIKEWAY
WATERLOO, IOWA

PURPOSE OF REPORT

The purpose of this report is to provide construction cost data based on the construction contract that was awarded on the project and to describe construction procedures and problems encountered and to note any innovations. Sheets B.01, U.06 and U.07 (Figures B through D, respectively) from the project plans are included for reference in Appendix B and indicate typical cross sections of the reinforced slope.

CONSTRUCTION COST DATA—FINAL CONTRACT QUANTITIES

Table A on page 3 shows a tabulation of bid items, final contract quantities, contract unit bid prices and contract amounts (original contract quantities only) for bid items included in the reinforced slope construction. It should be noted that this table does not include revised quantities or extra-work orders.

The total lengths of reinforced slopes, within which the heights varied, amounted to approximately 1,874 lineal feet with approximately 520 feet of this length being located between Katoski Drive and South Hackett Road. Based on the grand total cost of $210,329.60, (which includes revised quantities and extra-work orders) the cost per lineal foot of reinforced slope averages $112.24 which is more than the original estimated $85.30 per lineal foot noted in the design report.

CONSTRUCTION PROCEDURES

The construction of the reinforced slope consisted of the following sequence of operations:

1. Strip, salvage and stockpile topsoil.

2. Excavate, salvage and stockpile Class 13 material to westerly limit of reinforced slope, benching cut into existing parent material.

3. Trench along heel of excavation and install subdrain.

TABLE A

FINAL CONSTRUCTION QUANTITIES AND COSTS (ORIGINAL CONTRACT)
GREENHILL ROAD BIKEWAY REINFORCED SLOPE

ITEM NO.	DESCRIPTION	UNIT	UNIT PRICE	QUANTITY	TOTAL AMOUNT
1	EXCAVATION, CLASS 13 ROADWAY AND BORROW	C.Y.	$ 8.80	1989	$ 17,503.20
2	TOPSOIL, STRIP, SALVAGE AND SPREADING	C.Y.	$ 12.50	980	$ 12,250.00
3.	REINFORCED SLOPE	C.Y.	$ 18.25	5505	$ 100,466.25
4	SEEDING, CROWN VETCH	Ac.	$ 300.00	1.17	$ 351.00
5	SEEDING	Ac.	$3,000.00	0.68	$ 2,040.00
6	FERTILIZING	Ac.	$ 300.00	1.17	$ 351.00
7	SLOPE PROTECTION, WOOD EXCELSIOR MAT	Sq.	$ 20.00	297.3	$ 5,946.00
8	SUBDRAIN, LONGITUDINAL, 4"	L.F.	$ 8.00	1901	$ 15,208.00
9	TRAFFIC CONTROL (2.7% OF CONSTRUCTION)	L.S.	$3,589.96	1	$ 3,589.96
10	FIELD LABORATORY (0.4%)	L.S.	$ 531.85	1	$ 531.85
11	MOBILIZATION (3.7%)	L.S.	$5,318.26	1	$ 5,318.46
12	FLAGGERS	L.S.	$ 125.00	1	$ 125.00

TOTAL CONSTRUCTION COST
REINFORCED SLOPE = **$ 163,680.72**
(Excluding EWO's and revised quantities)

4. Install engineering fabric along face of cut.

5. Place porous backfill into subdrain trench.

6. The top six inches of the subgrade below the reinforced slope was scarified and recompacted to 95 percent standard proctor density.

7. Place porous backfill along face of cut along with the concurrent placement of layers of geogrid and compacted earth fill (parent material compacted with moisture and density control). Geogrids were placed at 12 inch spacing, alternating full and partial widths. Parent material was placed in two, six inch lifts with a wheel loader and spread by a small dozer. The material was compacted with a self-propelled sheepsfoot roller.

8. Graded top surface of reinforced slope including the 1:1 face. The face was cut to grade from the top of the slope with a backhoe equipped with a plate on the bucket.

9. Spread topsoil.

10. Seed, fertilize and install wood excelsior mat and water.

The contractor used conventional construction equipment and material to place and compact fill materials. An offset backhoe was used to excavate the subdrain trench along the heel of the cut slope. The plan requirement to limit the length of full-depth excavation for the reinforced slope to 200 feet was found to be practical, and the contractor had no problems with stability of existing material beyond the benched cut slope.

FIELD MODIFICATIONS AND REVISED QUANTITIES

During the course of the construction, modifications were required due to previously unknown site conditions and due to changes in the design. The following is a list of changes and extra work order items:

1. Remove and dispose of and replace unsuitable soil

   Several areas of organic material (topsoil) were found within the existing soil (see Photo C) that had been planned to be removed and recompacted into the reinforced slope. This material was unsuitable for reinforced slope construction. Blue Glacial till material was imported and placed (see Photo D).

   Extra Work Order (EWO) No. 8017
   3,000 C.Y. at $3.00 = $9,000 Total Cost Increase

2. Additional depth of subdrain

Subdrain grade lowered due to soil conditions.

EWO No. 8002
1,843 C.Y. at $2.50 = $4,607.50 Increase

3. Adjust electrical conduits, alignment and grade.

Relocate electrical conduits to maintain continuity of the reinforced slope.

EWO Item No.	Description	Cost
8002	Realign 3" PVC	$4,702.50
8014	Salvage and Reinstall Conductors 2" PVC Conduit	297.00
8015	Salvage and reinstall Conductors 2" PVC Conduit	507.00

L.S. = $5,506.50 Increase

4. Stabilize existing subgrade below reinforced slope.

Remove and stabilize material

EWO 8018
Excavating 113.3 C.Y. at $17.60 per C.Y.
= $1,994.08 Increase

EWO 8019
Stabilize 93.9 Tons at $12.000 per Ton
= $1,126.80 Increase

5. Adjust drainage structures.

More adjustment required than was incidental to contract.

EWO 8020
3 manholes at $150.00 each = $ 450.00 increase

Reconstruct intake to complete reinforced slope.

EWO 8021
1 intake at $1,450.00 = $1,450.00 increase

6. Increase length of anchors for wood excelsior mat, revise seed mixture, increase waterings and increase area.

Standard length pins per Iowa DOT Design Office were too short to penetrate through topsoil and into reinforced slope. Photo E shows anchor pins being hammered through excelsior mat into ground.

Substituted perennial rye for creeping fescue in seed mixture to promote the root structure of the vegetation (see Photo F).

Added six weekly waterings because of being outside the seeding season (see Photo G).

Delete Item 7 - 297.3 squares at $20.00 = $5,946.00 Decrease

<u>EWO Item No. 8022</u>
Pins, Seed mix, waterings and area - 500.7 squares at $45.00 = $22,531.00 Increase

These efforts were taken in order to provide a better bond between the topsoil and the till material in the reinforced slope and to promote the growth of vegetation to reduce the erosion of the topsoil. Photos H and I indicate the magnitude of erosion that happened on the bare reinforced slope. The slope had to be regraded and then the topsoil was placed (see Photo J) and seeded. The surface of the 1:1 reinforced slope was also scarified horizontally in some areas to promote bonding of topsoil. Eventually, it took three seedings to establish a rich enough vegetation. Photos K and L were taken in September of 1993 after the third seeding had taken hold.

7. Additional Erosion Control Features.

There were two EWO items for additional EC but zero quantity was utilized.

<u>EWO No. 8025</u>
Silt fence for ditch checks, existing interceptor ditch—
0 LFF at $5.00 = zero

<u>EWO No. 8027</u>
Silt fence at top of slope 0 LF at $3.85 = zero

<u>EWO No. 8040</u>
Erosion Stone 15 ton at $38.00/ton = $570 Increase

The total net increase in construction costs due to modifications and increased and decreased quantities is $46,648.88 for work items associated with the construction of the reinforced slope. Adding this increased cost to the contract amount of $163,680.72 results in a final cost of $210,329.60.

Therefore, the final cost per lineal foot of reinforced slope, as adjusted for these increases, is $112.24/L.F. (for 1874 lineal feet).

CONCRETE RETAINING WALL AROUND BRIDGE BERM

Because of clearance and minimum slope design constraints around the University Avenue Bridge, a concrete retaining wall was built as shown in Photo M and Figure E of Appendix B.

In consideration of the cost effectiveness of the reinforced earth wall with geogrids, this structure should be accounted for as it is an integral part of the bikeway design around the bridge. The following is a list of construction quantities for the retaining wall:

Item	Description	Unit	Unit Cost	Quantity	Total
1	Excavation, Class 20	C.Y.	$ 12.50	447.10	$ 518.00
2	Subdrain, Longitudinal 4" diameter per plan	L.F.	$ 8.00	717	$ 5,736.00
3	Granular backfill	Tons	$ 12.00	203.80	$ 2,445.60
4	Structural Concrete	C.Y.	$275.00	104.15	$28,641.25
				TOTAL	$37,340.85

Total Cost of Reinforced Slope and Concrete Retaining Wall

Reinforced Slope Total	=	$210,329.60
Concrete Retaining Wall Total	=	$ 37,340.85
REVISED GRAND TOTAL	=	$247,670.45

There was approximately 150 feet of concrete retaining wall in between the ends of the Reinforced Slope around the bridge.

Concrete Wall Length (under bridge)	=	150 feet
Reinforced Slope Length	=	1,874 feet
GRAND TOTAL	=	2,024 feet
GRAND TOTAL COST PER LINEAL FOOT OF BOTH CONCRETE WALL AND REINFORCED SLOPE	=	$122.37/ L.F.

APPENDICES

APPENDIX A

PHOTOS

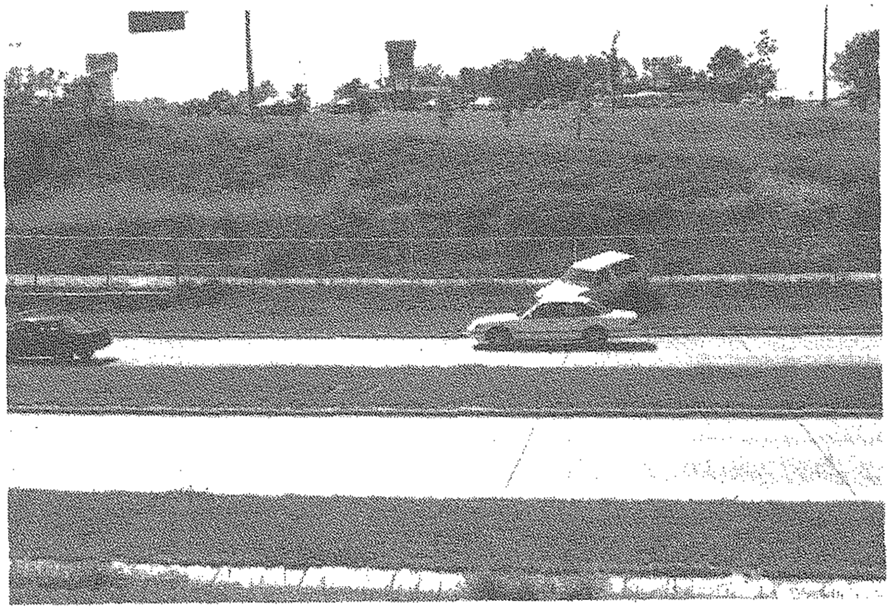


PHOTO "A"
Greenhill Road Bikeway North of University Avenue Bridge.

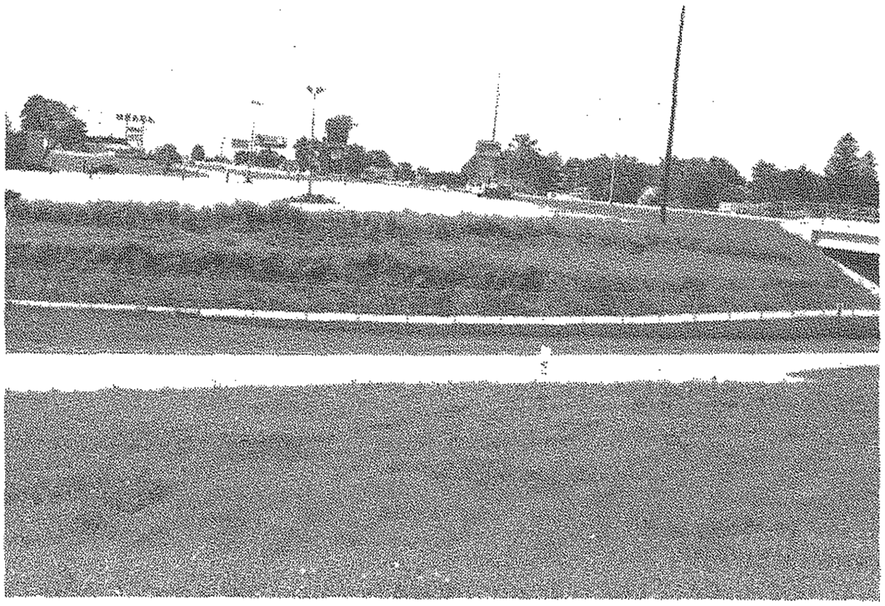


PHOTO "B"
Greenhill Road Bikeway South of University Avenue Bridge.

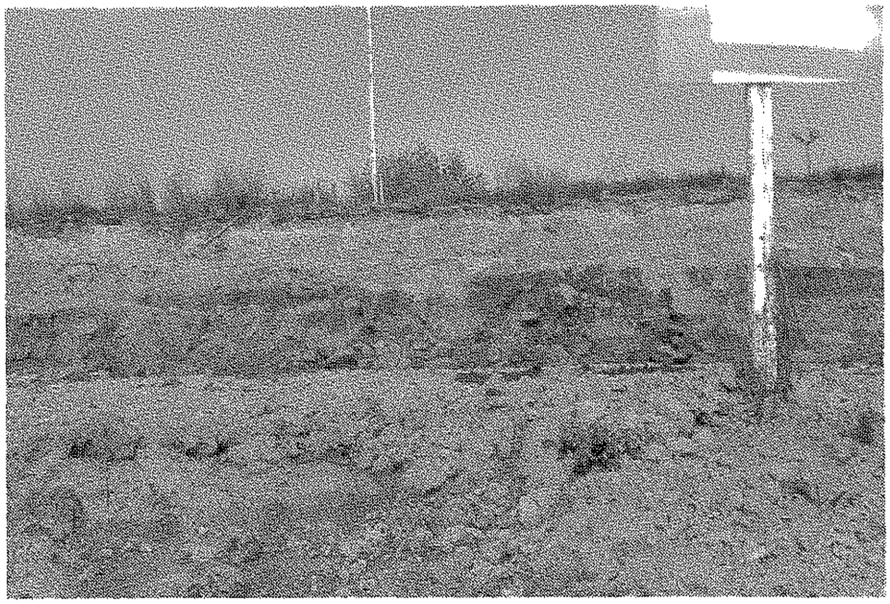


PHOTO "C"
Existing topsoil seam that was found. This material was removed and disposed of and replaced with imported material.

PHOTO "D"
Imported Blue Glacial Till material placed on top of existing clay material. Note protruding edges of geogrids.

PHOTO "E"
Anchor pin placement through wood excelsior mat

PHOTO "F"
Reinforced slope vegetation

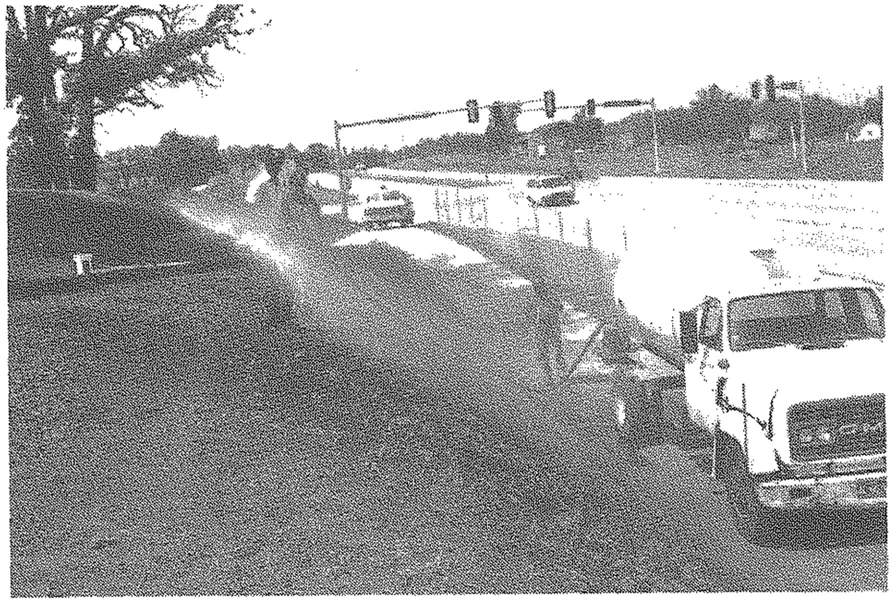


PHOTO "G"
Watering for vegetation development

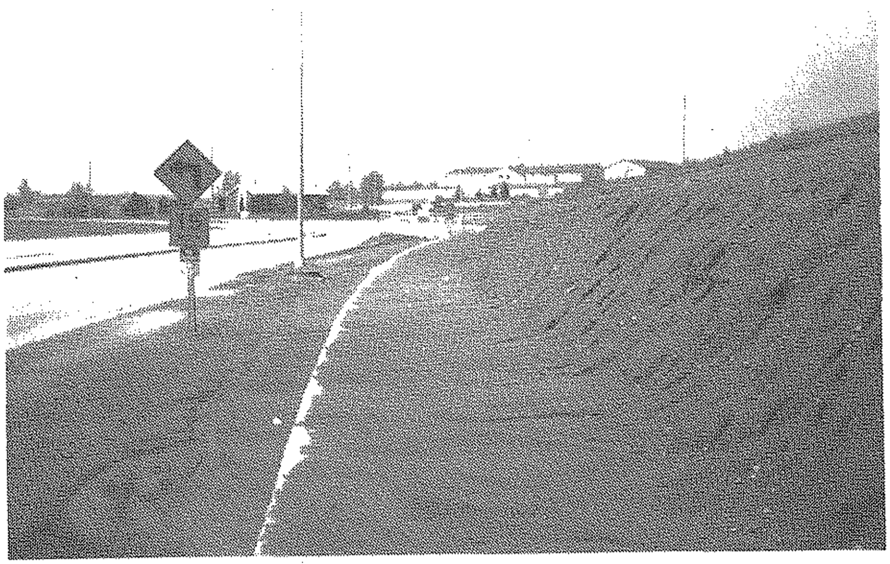


PHOTO "H"
May 1991—Before topsoil was placed, surface run-off erodes slope

PHOTO "I"
May 1991 - Before topsoil was placed—erosion or washout due to run-off—needed to be regraded and topsoil placed and seeded.

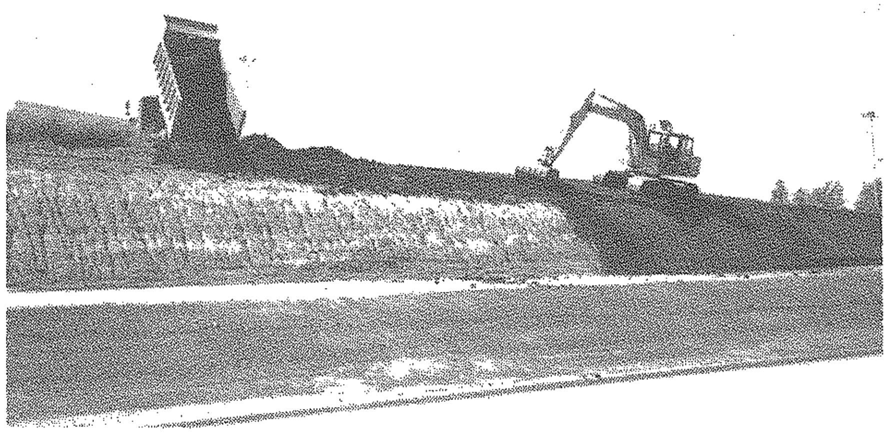


PHOTO "J"
Placement of 6" of topsoil

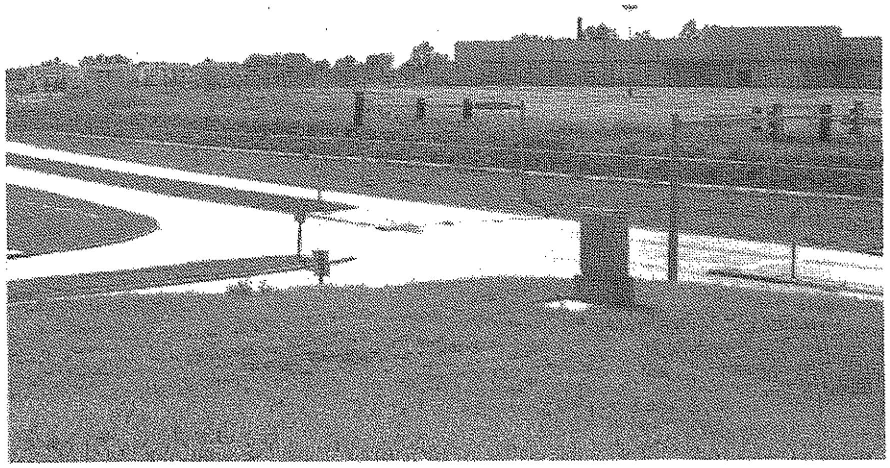


PHOTO "K"
September 1993 Reinforced slope vegetation after third seeding.

PHOTO "L"
September 1993 Reinforced slope vegetation after third seeding

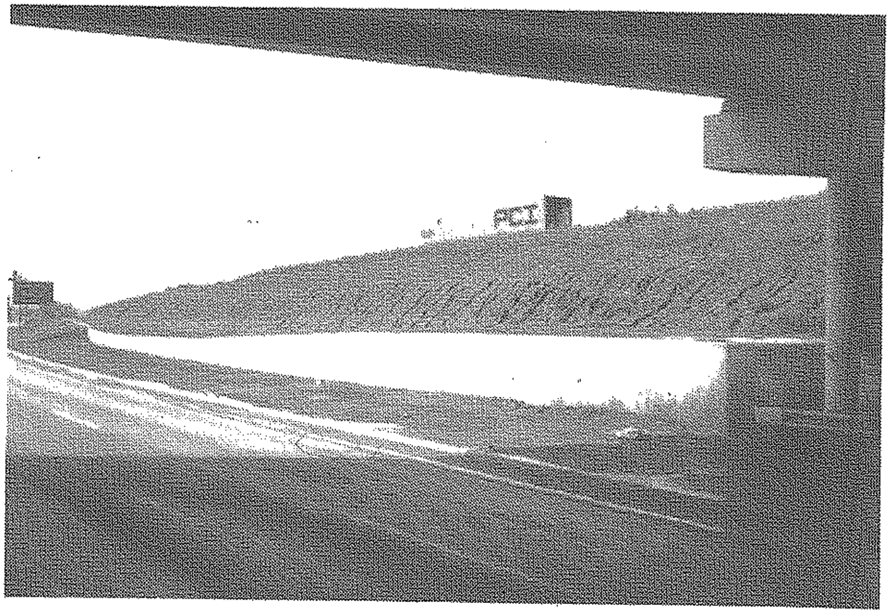


PHOTO "M"
Concrete retaining wall around University Avenue Bridge.

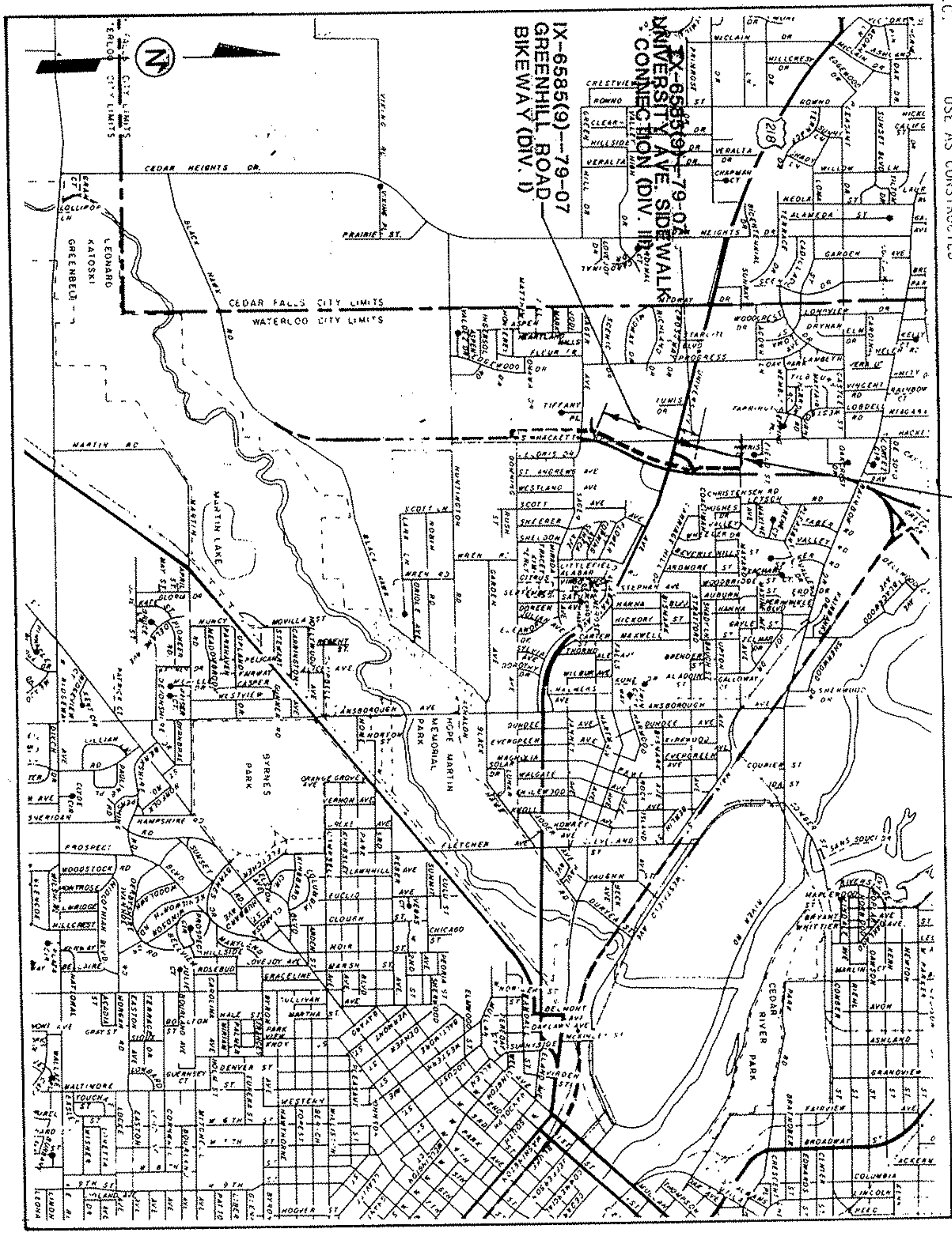
APPENDIX B

LOCATION MAP AND PROJECT PLANS

GRADING, DRAINAGE, P.C.C. PAVING,, RETAINING WALLS AND

BLACK HAWK COUNTY | IX-6585(9)--79-07

PROPERTY PIN EXISTING / NEW
TELEPHONE PEDESTAL
TELEPHONE JUNCTION BOX
SOIL BORING
USE AS CONSTRUCTED
U.A.C.

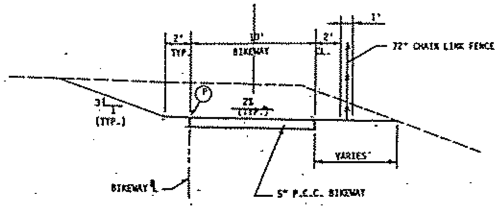


LOCATION MAP

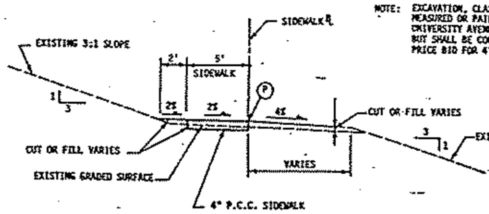
FIGURE A
Project Location Map

DIV.	
I	GREENH... STA. STA.
II	MAYNAR... STA.
III	UNIVER... STA.

PLUS CURRENT
SHALL

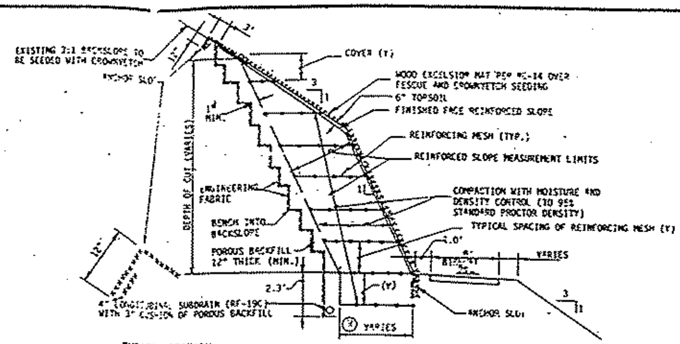


TYPICAL SECTION GREENHILL BIKEWAY
STA. 92+00.80 TO STA. 100+83.06

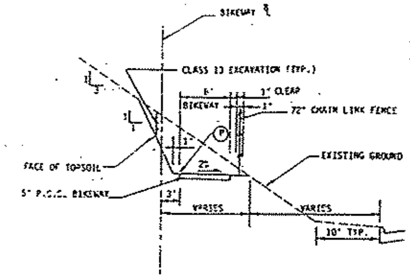


NOTE: EXCAVATION, CLASS 13 WILL NOT BE MEASURED OR PAID FOR SEPARATELY FOR UNIVERSITY AVENUE SIDEWALK CONNECTION BUT SHALL BE CONSIDERED AS INCIDENTAL TO PRICE BID FOR 4" P.C.C. SIDEWALK.

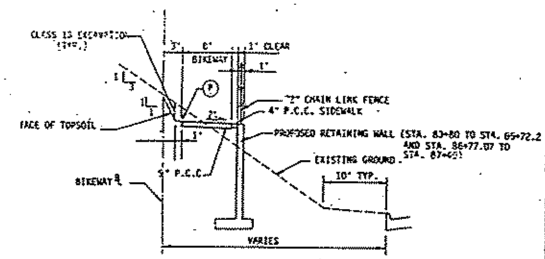
TYPICAL SECTION UNIVERSITY AVENUE SIDEWALK CONNECTION
STA. 186+98.00 TO STA. 190+65.67 (DIV. III)



TYPICAL SECTION
REINFORCED SLOPE
STA. 70+00 TO STA. 91+00 (APPROXIMATE)
DIVISION I



TYPICAL SECTION
STA. 71+14.1 TO STA. 83+80
STA. 87+40 TO STA. 91+14.66
DIVISION I



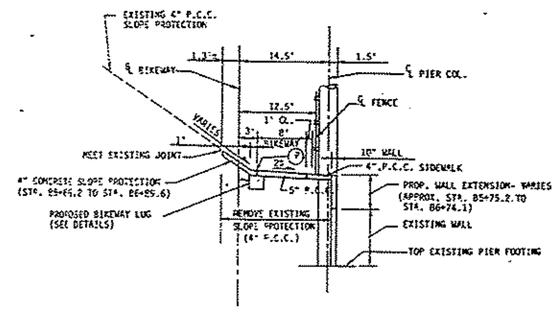
TYPICAL SECTION
STA. 83+80 TO STA. 85+66.6
STA. 86+89.6 TO STA. 87+40
DIVISION I

DIVISION I

NOTES FOR REINFORCED SLOPE

1. CONTRACTOR SHALL LIMIT LENGTH OF FULL-DEPTH EXCAVATION FOR REINFORCED SLOPE TO 200 FT. AND SHALL BEGIN CONSTRUCTION OF REINFORCED SLOPE ON OPENED SECTION IMMEDIATELY UPON EXCAVATION. ADDITIONAL SECTIONS OF FULL-DEPTH EXCAVATION MAY NOT BEGIN UNTIL CONSTRUCTION OF REINFORCED SLOPE HAS REACHED HALF OF CUT DEPTH FOR PRECEDING SECTION.
2. PRICE BID PER CUBIC YARD OF REINFORCED SLOPE SHALL INCLUDE ALL MATERIALS AND WORK TO CONSTRUCT THE REINFORCED SLOPE, INCLUDING REINFORCING MESH, EXCAVATION, COMPACTION OF EXCAVATED ON-SITE EARTHEN MATERIALS WITH MOISTURE AND DENSITY CONTROL, ADDITIONAL FILL MATERIAL, BENCHING INTO EXISTING SLOPE, POROUS BACKFILL AND ENGINEERING FABRIC.
3. DESIGN CALCULATIONS AND SHOP DRAWINGS RELATED TO DESIGN OF REINFORCED SLOPE SHALL BE SUBMITTED TO THE ENGINEER FOR REVIEW.
4. CONTRACTOR AND SUPPLIER SHALL ADHERE TO SPECIAL PROVISION FOR REINFORCED SLOPE.
5. ANY CHANGES IN THE REINFORCED SLOPE DESIGN REQUIRED DURING CONSTRUCTION SHALL BE SUBMITTED TO THE ENGINEER FOR REVIEW AND APPROVAL.
6. PROPRIETARY SUPPLIERS SHALL PROVIDE TRAINING FOR THE SUCCESSFUL CONTRACTOR AND SHALL PROVIDE AN EXPERIENCED REPRESENTATIVE AT THE SITE AT THE START OF CONSTRUCTION OF THE REINFORCED SLOPE AND THEREAFTER SHALL PROVIDE ASSISTANCE ON AN "AS NEEDED" BASIS.
7. THE DESIGN OF THE REINFORCED SLOPE IS BASED ON AN ESTIMATED SOIL FRICTION ANGLE OF 23°30'. THIS DESIGN IS SUBJECT TO REVISION BASED ON RESULTS OF ADDITIONAL SOIL TESTING.
8. FINISHED SURFACE OF TOPSOILED SLOPE IS TO BE SEEDED AND FERTILIZED AS FOLLOWS:

   CROWNVETCH - 10 LB. PER ACRE
   KENTUCKY 31 FESCUE - 30 LB. PER ACRE
   CREEPING FESCUE - 20 LB. PER ACRE
   FERTILIZER (13-13-13) - 400 LB. PER ACRE
9. ENGINEERING FABRIC BETWEEN BENCHED BACKSLOPE AND POROUS BACKFILL MATERIAL SHALL BE IN ACCORDANCE WITH REQUIREMENTS OF SUPPLEMENTAL SPECIFICATION SS-1070, SECTION 4196.01, PARAGRAPH B, SUBSURFACE DRAINAGE.



TYPICAL SECTION
STA. 85+65.5 TO STA. 86+89.6
DIVISION I

NO.	DATE	REVISIONS

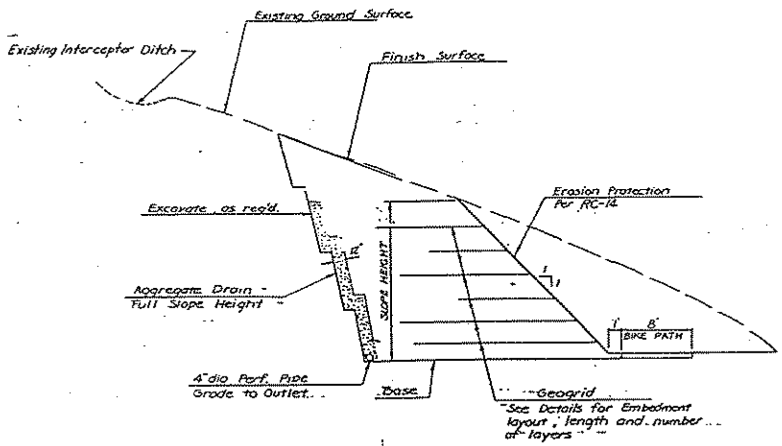
GREENHILL ROAD
PEDESTRIAN / BIKEWAY FACILITY
GRADING, P.C.C. SIDEWALK, REINFORCED SLOPES, RETAINING WALLS AND INCIDENTALS
CITY OF WATERLOO, IOWA

Brice, Petrides – Donohue Co.
Engineers & Architects
Waterloo and Des Moines, Iowa

TYPICAL CROSS SECTIONS

PROJECT NO.	STATE	FED. ROAD REG. NO.	FISCAL YR.	SHEET NO.	TOTAL SHEETS
IX-6525(9)--79-07	IOWA	5	1989	B.01	

FIGURE B
Project Plan Sheet B.01



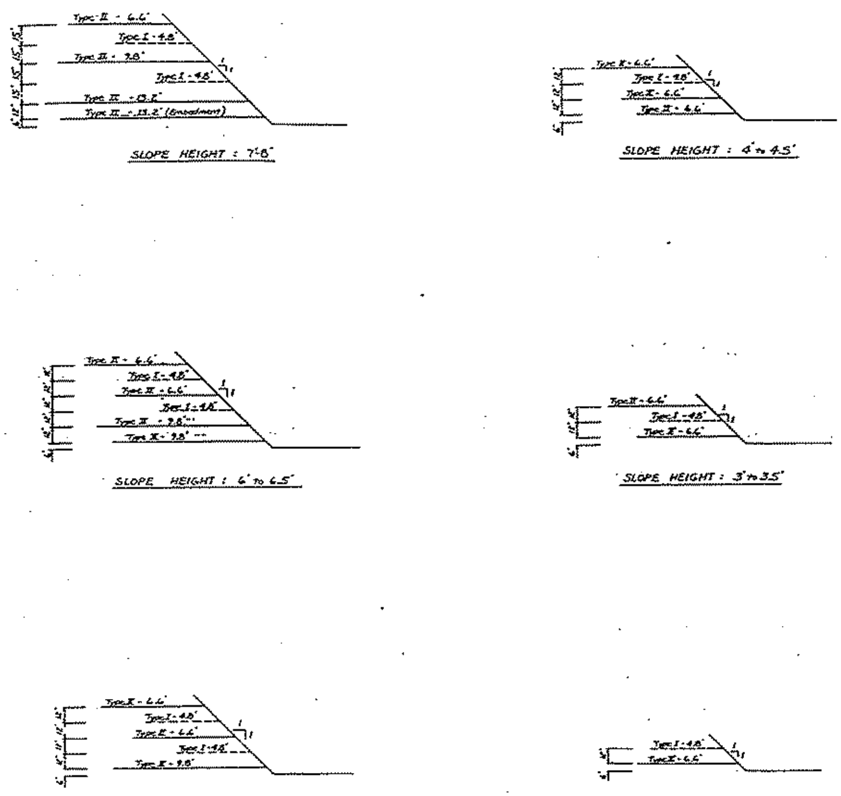
GEOGRID SLOPE REINFORCEMENT
STA 70+14.1 to STA 91+14.66
NO SCALE

NOTES:

1. No tracked equipment shall operate directly on Geogrid
2. Installation shall be per manufactures recommendations.
3. Grid Specifications :

	TYPE I	TYPE II
MATERIAL	Polypropylene	Polypropylene
APERTURE SIZE	1" × 1.3"	1" × 1.3"
OPEN AREA	70%	70%
TENSILE MODULUS per GGI-GGI-87(MIN)	14,000 lb/ft	MD 18,500 lb/ft CMD 30,000 lb/ft
JUNCTION STRENGTH per GGI - GG2-87	750 lb/ft	MD 1050 lb/ft CMD 1890 lb/ft

4. This drawing contains information that is based upon specific properties of TENSAR GEOGRIDS which are proprietary to the TENSAR CORPORATION, 1210 Citizens Parkway, Morrow Georgia 30260. This drawing is being furnished for use on this specific project only.



GEOGRID LAYOUT DETAILS
NO SCALE

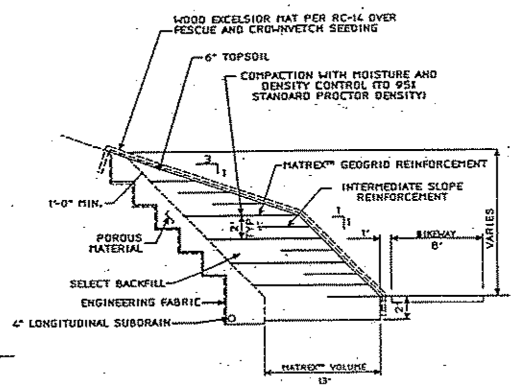
I hereby certify that this plan was prepared by me or under my direct personal supervision, and that I am a duly Registered Professional Engineer under the laws of the State of Iowa.

ROBERT L. MEINZER P.E.

Date : June 28, 1989 Reg. No. 10000

FIGURE C
Project Plan Sheet U.06

CITY OF WATERLOO, IOWA
Project IX-6505(3)--79-07
Greenhill Road
Bikeway



TYPICAL SECTION

NOT TO SCALE

STA. 70+00 TO 91+00

GENERAL NOTES

DESIGN CRITERIA

1. DESIGN IS BASED ON THE ASSUMPTION THAT THE MATERIAL WITHIN THE MATREX VOLUME, METHODS OF CONSTRUCTION AND QUALITY OF PREFABRICATED MATERIALS SHALL CONFORM TO THE CONTRACTING AGENCY'S TECHNICAL SPECIFICATIONS FOR MATREX RETAINING SYSTEMS.
2. ASSUMED SOILS CHARACTERISTICS :

   MATREX BACKFILL
   θ = 24 degrees, c = 0 p.s.f., γ = 115 p.c.f.

   RANDOM BACKFILL
   θ = 24 degrees, c = 0 p.s.f., γ = 115 p.c.f.

   FOUNDATION MATERIAL
   θ = 24 degrees, c = 0 p.s.f.

   IF THE ACTUAL CHARACTERISTICS OF THE SOIL MATERIALS DIFFER FROM THOSE ABOVE, THE REINFORCED EARTH COMPANY SHOULD BE NOTIFIED PRIOR TO CONSTRUCTION TO EVALUATE THE NEED FOR REDESIGN OF THE SYSTEM.
3. ANY UNSUITABLE FOUNDATION MATERIAL BELOW THE MATREX VOLUME, AS DETERMINED BY THE ENGINEER, SHALL BE EXCAVATED AND REPLACED WITH SUITABLE MATERIAL OR OTHERWISE STABILIZED AS DIRECTED BY THE ENGINEER.

SLOPE CONSTRUCTION

1. FOR LOCATION AND ALIGNMENT OF MATREX RETAINING WALLS OR STEEPENED SLOPES SEE CONTRACT DRAWINGS.
2. COMPACTION AND OPERATION EQUIPMENT SHALL BE KEPT A MINIMUM DISTANCE OF 3'-0" FROM FACE OF MATREX RETAINING SYSTEM. COMPACTION WITHIN 3'-0" OF FACE OF WALL OR SLOPE SHALL BE ACHIEVED WITH AT LEAST THREE (3) PASSES OF A LIGHTWEIGHT MECHANICAL TAMPER, ROLLER OR VIBRATORY SYSTEM.
3. BACKFILL MATERIAL WITHIN THE MATREX VOLUME SHALL BE COMPACTED TO 95 % OF ASTM D-698 METHODS C OR D UNLESS OTHERWISE DIRECTED BY ENGINEER.
4. CONTRACTOR SHALL LIMIT LENGTH OF FULL DEPTH EXCAVATION FOR REINFORCED SLOPE TO 200 FT. AND SHALL BEGIN CONSTRUCTION OF REINFORCED SLOPE ON OPENED SECTION IMMEDIATLEY UPON EXCAVATION. ADDITIONAL SECTIONS OF FULL DEPTH EXCAVATION MAY NOT BEGIN UNTIL CONSTRUCTION OF REINFORCED SLOPE HAS REACHED HALF OF CUT DEPTH FOR PRECEDING SECTION.
5. FINISHED SURFACE OF TOPSOIL SLOPE IS TO BE SEEDED AND FERTILIZED AS FOLLOWS:

   CROWNVETCH - 10 LB. PER ACRE
   KENTUCKY 31 FESCUE - 30 LB. PER ACRE
   CREEPING FESCUE - 20 LB. PER ACRE
   FERTILIZER (15-15-15) - 400 LB. PER ACRE

THE DESIGN CONTAINED ON THESE DRAWINGS IS BASED ON INFORMATION PROVIDED BY THE OWNER. ON THE BASIS OF THIS INFORMATION, THE REINFORCED EARTH CO. WAS DESIGNED AND IS RESPONSIBLE FOR THE INTERNAL STABILITY OF THE MATREX REINFORCED SLOPE. STABILITY OF THE SOIL AND FOUNDATION MATERIALS BEYOND THE MATREX VOLUME IS THE RESPONSIBILITY OF THE OWNER.

FIGURE D
Project Plan Sheet U.07

The Reinforced Earth Company

	MATREX OVERSTEEPENED SLOPE SYSTEM
	GREENHILL RD. BIKEWAY
	WATERLOO, IOWA
	CITY of WATERLOO
WEL	DATE
KAL	
PLA	6-29-89
SECTIONS & GEN. NOTES	

SHEET No.

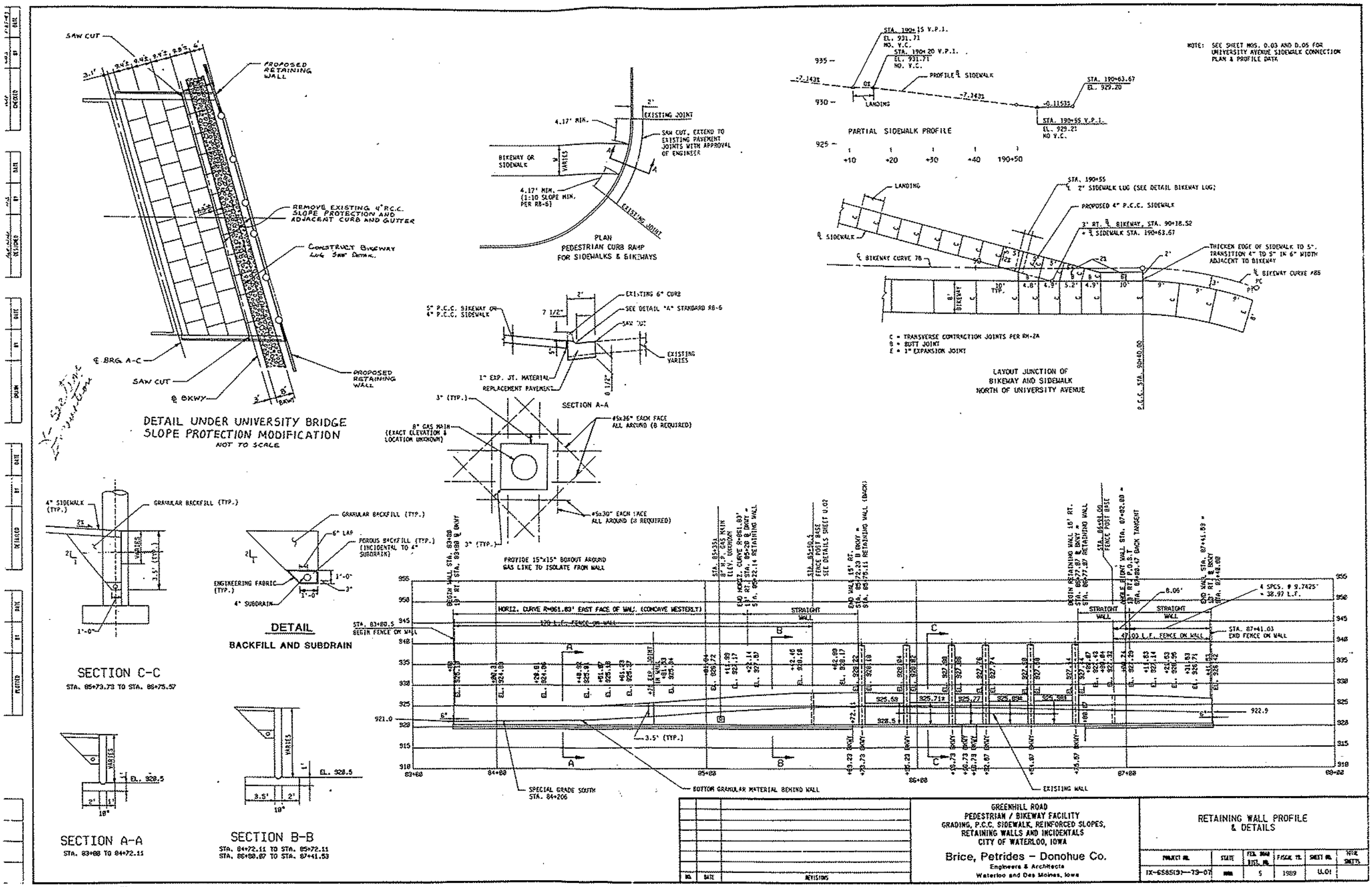


FIGURE E
Concrete Retaining Wall Details

FINAL PERFORMANCE REPORT

The purpose of this report is to show the relative extent of maintenance required for the reinforced slope for a period of three years following the completion of construction and to evaluate the performance of the slope.

The City of Waterloo Parks Department noted that there has been little or no maintenance needed since the construction was completed on this project. It was mentioned that some edge mowing or weed whacking may be worked on near the bikeway slab, but that this kind of work has yet to be assigned to city crews.

Also, Superintendent of Parks, Paul Huting, said that some manual removal of weedy spots could be done to improve the visual and aesthetic quality of the vegetation over the geogrid area, but again, no city crews have been assigned this particular job. It was noted that there might be more of a potential for maintenance personnel to sustain work-related injuries, since they would have to walk over this very steep slope while they are performing this kind of maintenance. Paul added that if the aforementioned edge mowing and removal of weedy spots would be done, it would probably be done twice a year at an annual cost of less than $1,000.

The geogrid reinforced slope has performed really well and there has not been a problem with soil washing across the bikeway slab after the vegetation took control. The bikeway concrete has held together relatively well, although there has been some early pavement deterioration in a couple of areas. However, this was not attributable or related to the geogrid reinforced slope. It was noted that the chain link fence had created a difficult snow removal and maintenance situation, but this would have been a problem with or without the geogrid slope.

From a transportation planning perspective, an observation was made that this land-use area is mostly commercial and that although vegetation on the other side of the bridge is more like that of a lawn which is regularly trimmed, the low maintenance vegetation used over the geogrid is adequate. This area is also an enhancement for the bikeway by providing a more aesthetically pleasing feature for bicyclists as opposed to a concrete retaining wall.

CONCLUSIONS/RECOMMENDATIONS

The objective of this research study is to document and evaluate the cost effectiveness of a reinforced earth system utilizing geogrids to steepen the cut slope for the bikeway along a portion of the Hackett Road Bypass Project, No. IX-6585(7)—79-07. The existing design constraints included: the bridge piers and slope protection under the University Avenue Bridge, existing right-of-way for Greenhill Road, existing utilities such as high pressure 8 inch gas main, electrical conduits and drainage structures.

A minimum 15 foot clearance was needed between the west curb of Greenhill Road and the chain link safety fence which resulted in the bikeway location falling within the existing 3:1 backslope of Greenhill Road. In the vicinity of the bridge, the grade of the bikeway needed to be raised to avoid conflict with underground utilities, thus, necessitating the construction of a retaining wall to the north and south of the bridge between the bikeway and Greenhill Road.

In the design phase of this project, many systems were considered: utilizing sheet pile walls, concrete retaining walls and gabions, or combinations thereof. It was determined that a reinforced slope would be the most economical (refer to Design Report) and therefore, this alternative was chosen. Preliminary cost estimates for all other alternatives ranged from $204/L.F. to $220/L.F. The actual final cost per lineal foot of reinforced slope was $112.24/L.F. However, a reinforced earth system was not feasible around the bridge because of design constraints. Therefore, a fair cost comparison should reflect the cost of constructing the concrete retaining wall. Including the concrete wall costs raises the per lineal foot cost to $122.37/L.F.

To that end, a conclusion can be drawn that the reinforced earth slope is a very economical alternative. Furthermore, a life cycle evaluation would seem to favor the reinforced slope whereas other systems eventually would have to be replaced. A reinforced slope has low annual maintenance costs and in theory should last a very long time without replacement.

Apart from the savings that can be realized over a conventional reinforced concrete or masonry retaining wall, there may be other advantages.

First, there is no specialized experience or equipment required for a contractor to successfully build a low-to-medium geogrid reinforced slope structure. Only mid-size construction equipment is necessary to construct the structure.

Second, the adaptability of the reinforced earth structure enables the designer to best fit the shape of the structure to the environment as well as add an architectural finish or facing to the earth wall or slope that could enhance the aesthetic quality.

Finally, a reinforced earth slope structure can be built with relatively soft soils provided differential settlements between facing are limited to one or two percent.

A downside to this project was the erosion susceptibility of the reinforced earth slope before permanent vegetation took hold. Interim erosion control measures might need to be considered in future projects.

All things considered, a reinforced earth slope should be considered and compared and contrasted to other structural systems during the preliminary design phase of a project.

ACKNOWLEGEMENTS

Special thanks are extended to the City of Waterloo's project consultant—RUST Environment & Infrastruture—Charles E. Spicher, P.E. and Don Nold. Also, the City of Waterloo Engineering Department, Eric Thorson, P.E., City Engineer.

The Federal Highway Administration participated in the construction funding of research project HR-548.