DESIGN AND EVALUATION OF ROADWAY WIDENING

SECTIONS THROUGH SWAMPS

INVESTIGATION NO. 199

INITIAL REPORT

Prepared by
Erland O. Lukanen
Research Project Engineer
Gerald Teig
Research Assistant

RESEARCH AND STANDARDS SECTION
OFFICE OF MATERIALS, RESEARCH AND STANDARDS
MINNESOTA DEPARTMENT OF TRANSPORTATION
ABSTRACT

Six methods of floating roadway widening sections over a peat swamp were designed and constructed on a two-lane roadway in 1976. The project location was on T.H. 53 between International Falls and Ray. Peat depths ranged from 8 to 15 feet.

The investigation to date has shown that widenings can be floated on peat when fill height and loading rates are controlled. Performance of the sections will be monitored for a period of at least three years.
FORWARD

There are many miles of roads that are narrow and have narrow shoulders. Upgrading these roads requires widening to be constructed on one or both sides to provide 12-ft (3.66 m) lane widths and 10-ft (3.0 m) shoulders. Whenever these roads cross areas where unstable foundation conditions exist, such as peat swamps, past practices have been to excavate the unstable material and fill back with a granular material. This procedure is expensive and also exposes the existing road to potential slide failures.

Because of all the problems, personnel from District 1, the Soils Unit, and Physical Research got together and initiated this investigation. Investigation 199 was originally set up under the direction of Donald L. Raisenan, now Grading and Base Engineer. The widening designs were presented and chosen by a panel consisting of Donald C. Bacon, Duluth District Materials Engineer, Arnold E. Skjegstad, Duluth District Design Engineer, William N. Yoerg, Chief Soils Engineer (now St. Cloud Area Maintenance Engineer), Virgil V. Mikkelson, Foundations Engineer George R. Cochran, Subgrade and Base Design Engineer (now Acting Chief Soils Engineer), Richard C. Ingberg, Physical Research Engineer, Glenn R. Korthage, Research Operations Engineer, Donald L. Raisenan, Research Project Engineer (now Grading and Base Engineer), and Erland O. Lukanen, Assistant Research Project Engineer.

The project used for this investigation was Trunk Highway 53 between Ray and International Falls. Construction was done by Ulland Bros. under the control of Russ L. Jettenberg, Project Supervisor, Virginia. Observation of construction and the data collection were done by Gerald Teig, Research Assistant.
SUMMARY

OBJECTIVE

This study was initiated to design and evaluate methods of widening roadways over areas of very weak soils such as peat swamps in Minnesota.

SCOPE

The test project is located on Trunk Highway 53 between Ray and International Falls. Six different methods of widening were designed and are being evaluated. These methods were constructed on three swamps in the area, and each swamp has one control section using the conventional method of floating the widening.

FINDINGS & CONCLUSIONS

1. Floated widenings can be successfully constructed.

2. Drainage ditches or other disturbances in the surface vegetation root mat adjacent to the embankment can cause longitudinal cracking in the adjacent pavement.

3. The ditch fabric and chip embankment sections are presently the best performers.

RECOMMENDATIONS

1. The test sections should be monitored visually and with extensometer readings on a reduced basis for the life of the sections.

2. It is recommended that the existing vegetation root mat over the peat be left intact in the vicinity of the widening on any future projects.

3. If the ditch fabric design is used in the future, test sections should be set up to monitor the performance of the various brands of fabric available.
# TABLE OF CONTENTS

INTRODUCTION .................................................. 1
SITE DESCRIPTION .............................................. 2
DESIGN .......................................................... 6
  Stage Conventional ......................................... 7
  Corduroy ...................................................... 7
  Wood Chip Working Platform .............................. 7
  Wood Chip Embankment .................................... 7
  Full Width Fabric ........................................... 10
  Ditch Fabric .................................................. 10
  Weakened Plane ............................................. 10
GENERAL CONSTRUCTION ...................................... 14
INSTRUMENTATION .............................................. 16
  Extensometers ................................................ 16
  Piezometers .................................................. 18
ALIGNMENT AND PROFILE ..................................... 19
FINDINGS AND CONCLUSIONS ................................ 20
RECOMMENDATIONS ............................................ 21
APPENDIX A - COST ANALYSIS .............................. 23
APPENDIX B - DETAILED SPECIFICATIONS ................. 24
APPENDIX C - DETAILED CONSTRUCTION PROCEDURES .... 25
APPENDIX D - INSTRUMENTATION DATA ..................... 34
LIST OF TABLES

Table
1. Test sections ......................................................... 5
A-1 Test section cost comparisons .................................. 23
D-1 Measured strain of extensometers ............................... 34

LIST OF FIGURES

Figure
1. Project location ...................................................... 3
2. Swamp locations ..................................................... 4
3. Stage conventional section ........................................ 8
4. Corduroy section ...................................................... 8
5. Wood chip working platform section .............................. 9
6. Wood chip embankment section ................................... 9
7. Fabric (ditch) section ................................................. 11
8. Fabric (full width) section .......................................... 12
9. Weakened plane section ............................................. 13
10. Wood chips inplace .................................................. 14
11. Ditch filling procedure ............................................. 15
12. Extensometer .......................................................... 16
13. Extensometer positions ............................................. 17
A-1 Typical section for excavation quantity computations .... 23
C-1 Placement of corduroy .............................................. 26
C-2 Corduroy inplace .................................................... 26
C-3 Placement of clay .................................................... 28
C-4 Compaction of clay ................................................. 28
C-5 Clay after compaction ............................................... 29
C-6 Fabric rolled into tack .............................................. 29
C-7 Fabric pickup by roller ............................................. 29
C-8 End dumping of bituminous mixture ............................. 30
C-9 Full width fabric section after paving ......................... 32
C-10 Placement of fill in ditch fabric section .................... 32
D-1-6 Piezometer readings .............................................. 35
INTRODUCTION

A number of roads in Minnesota are constructed over peat swamps, or in other words, the embankment fill is floating on the peat. Many of these roads need improvements in the form of surface widening and the addition of shoulders. Most widenings are now constructed by keying them into the peat on each side of the roadway. This means that the peat has to be excavated on each side of the road core and the excavation filled in with a selected material. Several problems exist with keying. Slide failures can occur before the fill is placed, endangering the foundation of the existing road or other nearby structures. Also, the cost of excavation and the granular backfill can be high, particularly in aggregate-poor areas, making keying undesirable.

Constructing the widening over the peat may be the only alternative if the roadway alignment is to be maintained. At the time this investigation was initiated, no design was available to construct widenings over peat. This investigation attempts to compare six widening designs for ease of construction and performance. The final objective will be a design for constructing widenings over peat or other soft unstable soils.

This report describes the design and construction of the widening sections and tests and observations made during and after construction.
SITE DESCRIPTION

A total of nine test sections and three swamps (Table 1) are located on Trunk Highway 53 (Figures 1 and 2) between Ray and International Falls. The swamps in this area are shallow lakes left after the last glaciation which have filled in with vegetation. They are known as peat swamps.

The first two swamps have tree growth over the peat on the west side of the roadway and have grassy vegetation over the peat on the east side. Also, there is a railroad running parallel to the roadway 90 ft. (28 m) to the east. These swamps average 8 to 10 ft. (2.4 to 3.0 m) deep with a maximum depth of 15 ft. (4.6 m).

The third swamp is not as deep. It ranges from 2 to 7 ft (0.6 to 2.1 m) and does not have the railroad paralleling it.

The peat is a semi-fibrous material with an organic content of 85 to 90 percent by weight and a moisture content of 400 to 500 percent by weight.
Figure 2. Swamp locations.
Table 1. Test sections.

<table>
<thead>
<tr>
<th>Test Section No.</th>
<th>Location</th>
<th>Design</th>
<th>Station</th>
<th>Date of Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>First Swamp</td>
<td>Corduroy</td>
<td>430+00 to 436+00</td>
<td>Sept. - Oct., 75</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>Stage fill (conventional)</td>
<td>436+00 to 449+00</td>
<td>Sept. - Oct., 75</td>
</tr>
<tr>
<td>3</td>
<td>Second Swamp</td>
<td>Stage fill (conventional)</td>
<td>509+00 to 518+00</td>
<td>Sept. - Oct., 75</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>Wood chips as a working platform</td>
<td>518+00 to 526+00</td>
<td>May - June, 76</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>Wood chips as a light weight fill</td>
<td>526+00 to 534+00</td>
<td>May - June, 76</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>Placing fabric the full width of the widening</td>
<td>534+00 to 541+00</td>
<td>May - June, 76</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>Placing fabric under the widening fill only</td>
<td>541+00 to 550+00</td>
<td>May - June, 76</td>
</tr>
<tr>
<td>8</td>
<td>Third Swamp</td>
<td>Weakened plane</td>
<td>846+00 to 852+00</td>
<td>May - June, 76</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td>Conventional</td>
<td>852+00 to 856+00</td>
<td>May - June, 76</td>
</tr>
</tbody>
</table>
DESIGN

Present Minnesota Department of Transportation (Mn/DOT) design and construction practice for placing an embankment or embankment widening across an area of weak unstable soils, such as a peat swamp, is usually to excavate the weak unstable soils and backfill with some suitable fill material such as a select granular (15 percent or less passing No. 200 sieve).

In cases in which there is adequate side pressure on the fill to prevent its slow lateral spreading after all the unstable material has been removed, this method provides a good foundation for a pavement subgrade. However, there can be problems with this method as in the Ray to International Falls portion of TH 53. First, the original highway embankment has been floated across the peat swamps, leaving up to about 13 ft (4 m) of peat beneath the road core. Second, the highway centerline runs parallel to and 90 ft (27 m) from the centerline of a railroad grade. Third, granular fill is scarce in this area and thus is very expensive. Fourth, minimum traffic disruption was required.

For this project, the prime concern was to not disturb the existing road core or pavement surface. The construction history for this section of highway goes back to the late 1920’s. The original grading took place about that time, and it has been concluded from discussion with local residents that the fill in the swamp areas was placed on corduroy or on a windrow of brush cut from the proposed embankment area. The fill has shown itself to be quite stable and has carried traffic to the present with no indications of major trouble. This history indicated that a fill could be successfully floated across the peat.

Improvement of the existing road required the placement of ten-foot shoulders on each side and flatter shoulder slopes. The two basic alternatives for this were to excavate the peat on each side of the road core and backfill with a granular material (keying) or to float the widening over the peat. Keying could result in the sliding failure of the road core or railbed during construction. Since TH 53 and the adjoining railroad are the only direct surface transportation links between International Falls and Duluth, it was felt that the risk of keying was too great. The decision to float the widening did not appear to be as great a risk, particularly to the railbed. Also, the cost of excavating and disposing of the peat and refilling with a select granular could have increased the costs over the test sections by about $150,000 (See Appendix A).

A brief literature search did not turn up any information on floating widenings. Also, no design analysis procedure could be found that could be used to limit the height of fill or the amount of settlement. Several designs were then developed by the Mn/DOT Physical Research Unit, the Mn/DOT Soils Unit and Mn/DOT Duluth District design and materials personnel. They are as follows:
STAGE CONVENTIONAL (TEST SECTIONS 2, 3 & 9)

This design is simply the placement of a widening fill as shown in Figure 3. Construction restrictions include limiting the height of additional fill at any one time to two feet (0.6 m). The outer portion of the fill is placed before the inside (fill from outside to inside) and equally placed on each side of the roadway. The granular material adjacent to the existing road core is to provide a drainage channel to prevent water buildup in the base under the existing pavement and in the shouldering aggregate. All other designs used in this investigation are variations of the stage conventional design.

CORDUROY (TEST SECTION 1)

This section is the same as the stage conventional design except that a 12-ft (3.7 m) wide log raft, as shown in Figure 4, is placed between the chip leveling and the fill. The logs are restricted to a minimum diameter of four inches and placed adjacent to each other in the ditch in a transverse direction. Stringers are then fastened to the logs on each side of the corduroy. The specifications state that the corduroy is to be evenly loaded with fill to prevent the possibility of tipping. The function of the corduroy is to provide a platform to work on and to prevent localized differential settlement. Also, one end of the corduroy is butted against the inplace road core, which could anchor the shoulder fill to the existing road.

WOOD CHIP WORKING PLATFORM (TEST SECTION 4)

This design (Figure 5) is a modification of the corduroy section where wood chips are used instead of corduroy to provide a working platform. This does not provide the rigidity of corduroy or provide an anchor against the existing road core. However, it still does provide some support to the construction equipment and fill material and also acts as a separating membrane between the peat and the fill material. The wood chips are capped with a 6 inch (15 cm) minimum clay cap to reduce their exposure to air.

WOOD CHIP EMBANKMENT (TEST SECTION 5)

This design (Figure 6) is used in areas of high fill in an attempt to limit the total fill weight to the same general amount as the other designs. The wood chips in this design are covered with a clay cap about two feet (0.6 m) thick to reduce exposure to the air.

---

Figure 3. Stage conventional section (Test Sections 2, 3 to 9).

Figure 4. Corduroy section (Test Section 1).
1. Remove the upper 4" of soil from the inp. inslope to 2.5' below shoulder.

Figure 5. Wood chip working platform (Test Section 4).

1. Remove the upper 4" of soil from the inp. inslope to 2.5' below shoulder.

Figure 6. Wood chip embankment (Test Section 5).
FULL WIDTH FABRIC SECTION (TEST SECTION 6)

This design (Figure 7) is the same as a stage conventional section and in addition it has 80 ft (24 m) fabric strips placed transversely across the road and into each ditch between the wood chip leveling and the fill. The fabric in this section should limit horizontal movement and also transfer some of the load of the widening onto the road core thereby reducing the differential settlement. This is the most difficult design to construct because the fabric has to be protected from traffic during the placement and filling operation.

DITCH FABRIC SECTION (TEST SECTION 7)

This design (Figure 6) is the same as a stage conventional section and in addition it has fabric placed from 17 to 40 ft (5 to 12 m) of each side of the centerline between the wood chip leveling and the fill. The fabric serves as a separating membrane and a tensile reinforcer for the fill, allowing equipment to work on a thinner lift of fill.

WEAKENED PLANE SECTION (TEST SECTION 8)

This design (Figure 9) also is the same as the stage conventional section except that prior to any filling, a narrow trench (less than six inches (15 cm) wide) is cut three ft. (0.9 m) deep, 15 ft (4 m) on each side from the centerline in the existing floating road bed. The trench is then loosely backfilled. This trench is to serve as a stress relief plane so that shear will not be transferred into the road core. This should allow the shoulder fill to settle without causing distress in the pavement surface.
Figure 7. Fabric (ditch) section (Test Section 7).
1. Remove the upper 4" of soil from the in-p. inslope to 2.5' below shoulder.

2. Center 80' rolls of fabric on \( \mathcal{C} \), and place over in-p. road and ground rt. and lt. Place 1" of bituminous on traffic lane and proceed with embankment.

3.  
   - 1-1/2" 2341 Bit. Wearing Course (Future) Tack Coat (Future)
   - 1-1/2" 2341 Bit. Wearing Course Tack Coat
   - 2-1/2" 2331 Bit. Leveling Course Tack Coat
   - 1" 2331 Bit. Leveling Course Fabric, 2 Tack Coat

Figure 8. Fabric (full width) section (Test Section 6).
Excavate trench 3' deep and Max. 6' wide, parallel with on both sides and backfill with uncompacted material.

Place 4" topsoil on granular exposed slopes only.

Selected Grading Material

18" Class 3

Gran. Mat. I.

Wood Chips

Bottom of Muck

1. Remove the upper 4" of soil from the inp. inslope to 2.5' below shoulder.

Figure 9. Weakened plane section (Test Section 8).
GENERAL CONSTRUCTION

The project was constructed during the summer of 1976 under the direction of personnel from the Mn/DOT Construction Office at Virginia. The location and date of construction of each test section is given in Table 1.

The clearing of the trees in the swamps was close-cut with no grubbing. This means cutting trees flush with the natural ground surface and leaving the root structure. The top soil was removed from the existing shoulder slopes.

After clearing, the existing drainage ditches and irregularities in the ditch section in all the test sections were filled and leveled with wood chips before other construction began. The chips were spread by a small bulldozer with wide tracks. In place chips after leveling are shown in Figure 10.

The granular material in all the sections was placed in the following way. Both belly dumps and end dumps with pup trailers were used. The end dumps and pups dumped over the shoulder. The belly dumps dumped directly onto the roadway and a motor grader then pushed the fill into the ditch. The fill was leveled in the ditch by a bulldozer. These operations are shown in Figure 11.

Figure 10. Wood chips in place.
A problem envisioned was that of the granular fill pushing and displacing the wood chips; this did not materialize. Also, rains and high water levels in the swamp did not float the chips away after they had been placed. There was sufficient interlock to hold them under 0.5 ft (15 cm) of water.

One stage conventional section was constructed in each of the three swamps as a control. All test sections in any swamps were required to be completed in the same construction season.

Detailed specifications for wood chips, corduroy and fabric are shown in Appendix B. Detailed construction procedures are shown in Appendix C.

Figure 11. General fill procedure.
EXTENSOMETERS

One of the most common signs of distress on a road built over soft materials is longitudinal cracks. This infers that there is a general transverse horizontal tensile strain that develops in the pavement. To detect this movement, extensometers (Figure 12) were fabricated and placed in the aggregate base at the bottom of the bituminous layer of each test section as shown in Figure 13. The extensometer readings are being used to compare the performance of one test section against the others. Also, it gives some general information about the amount of transverse strain that develops in the bituminous mat.

Figure 12. Extensometer.
Figure 13. Extensometer positions.
A high percentage of extensometer failures were encountered. This was later diagnosed to be caused by breaks in the electrical leads at the sensor, which occurred when the extensometers were handled in transit from St. Paul to the project site. If extensometers are to be installed again in the future, this problem can be avoided by securing the extensometers in the compressed position.

Each extensometer has a nominal length of 73 inches (185 cm). The sensor spacing can be measured to the nearest thousandth of an inch with the Bison Soil Strain Gage Model 4101A. This is less than 15 micro strains, which is far below strain level necessary to fracture bituminous courses.

The readings (Appendix D) of the functional extensometers showed some general trends among all the sections.

1. Generally, the strain at the edge of the pavement was about twice as large as the strain at the centerline.

2. The pavement was placed in transverse compression for up to about two months after the widening fill was placed.

3. All the test sections went into tension after the initial period of compression.

PIEZOMETERS

Three piezometers were installed in the second stage conventional section (Station 518) and in the wood chip embankment section (Station 531). The water levels (Appendix D) in these piezometers were monitored during the construction to determine the increase in pore pressure in the peat. Typically, the pore pressure increased only about 0.5 ft (0.15 m) and then returned to normal within three days after the fill was placed. This indicates the two-foot (0.6 m) limit on the fill height and the seven-day rest period between lifts were adequate to protect against excessive pore pressure. The rest period in this case could have been cut down to four days. In other projects of this nature, lift thicknesses and rest periods could be controlled by piezometers; this would enable the contractor to proceed more quickly than he could if he were controlled by specified lift height and rest periods.
The piezometer at 15 ft (4.3 m) right of Station 531 showed a continual rise in water level throughout the summer. This is probably due to the nature of the section, which provides an impermeable cap over the wood chips and impermeable plugs at a box culvert which passes through the section. Water is able to drain down along the wood chips from the high end of the section and fill up the cavity occupied by the wood chips at the lower end. If excessive side pressure builds up, a slide condition could exist in the shoulder slope. A small slide did occur in the fill section on the other side of the road from this location.

ALIGNMENT AND PROFILE

The alignment and profile of the road and railroad were checked several times with a transit and level. Movement was not detectable.
FINDINGS AND CONCLUSIONS

All of the test sections were filled by end dumping off the existing road or belly dumping onto the existing road and blading the fill into the ditch with a grader. This procedure appeared to work very well provided that the fill was kept at the same level across the widening. In other words, the height of fill progressed forward evenly from inside to outside.

Wood chips provide a good working platform upon which fill can be placed and light machinery can operate. It did not displace in front of machinery or fill and had sufficient stability to withstand submersion in water. Running water, however, may easily displace wood chips.

Any kind of disturbance of the existing vegetation mat appears to cause problems. A drainage ditch was cut into the root mat adjacent to Test Sections 3, 4, and 5 and longitudinal cracking appeared in the lane adjacent to the ditch. A judicial ditch was cut adjacent to the widening over a shallow swamp, and longitudinal cracking appeared in the pavement for several hundred feet along the ditch. Later borings showed the fill to be setting on three to five feet of peat in this area.

The test sections were built in three separate swamps, each with a stage conventional control section (Test Sections 2, 3, and 9). Two of the swamps show no distress in any of the sections, so no conclusions can be made about the corduroy (Test Section 1) and the weakened plane (Test Section 8) at this time. However, the largest swamp containing the ditch fabric section (Test Section 7), the full width fabric section (Test Section 6), the chip embankment section (Test Section 5), the wood chip working platform (Test Section 4) and a stage conventional section (Test Section 3) shows varying signs of distress. The performance of the test sections in this swamp can be classified from best to worst as follows:

T.S. 7 Ditch Fabric - very little longitudinal cracking  
T.S. 5 Chip Embankment - little longitudinal cracking  
T.S. 4 Wood Chip Working Platform - moderate longitudinal cracking  
T.S. 6 Full Width Fabric - numerous longitudinal cracks  
T.S. 3 Stage Conventional - numerous longitudinal cracks

The construction costs of floated widenings is much cheaper than the keying method. Floating widenings are also much quicker to construct than keyed widenings.
RECOMMENDATIONS

Annual inspections, including visual test section condition surveys and extensometer readings, should be conducted for several years to determine the relative performance of the test section.

At this time, the ditch fabric, chip embankment or chip platform sections are recommended for future widenings. If the ditch fabric method is to be used, test sections should be set up to monitor the performance of different brands of fabric.

Any drainage ditches that have to be constructed in conjunction with widening on future projects should be placed a sufficient distance away from the road to prevent transverse movement and the formation of longitudinal cracks in the pavement.
APPENDIX
**APPENDIX A - COST ANALYSIS**

Table A-1 Test section cost comparisons:

<table>
<thead>
<tr>
<th>Section</th>
<th>Float Section</th>
<th>Swamp Exc.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wood Corduroy</td>
<td>Haul Exc.</td>
</tr>
<tr>
<td></td>
<td>Wood Chips</td>
<td>Fill Exc.</td>
</tr>
<tr>
<td></td>
<td>Fabric</td>
<td>Total</td>
</tr>
<tr>
<td>Corduroy</td>
<td>$6825</td>
<td>$5490</td>
</tr>
<tr>
<td>Stage &quot;1&quot;</td>
<td>$1280</td>
<td>$2910</td>
</tr>
<tr>
<td>Stage &quot;2&quot;</td>
<td>$3760</td>
<td>$23580</td>
</tr>
<tr>
<td>Chip Plat.</td>
<td>2160</td>
<td>4860</td>
</tr>
<tr>
<td>Chip Emb.</td>
<td>4230</td>
<td>5830</td>
</tr>
<tr>
<td>Fabric, Full</td>
<td>11700</td>
<td>5100</td>
</tr>
<tr>
<td>Fabric, Ditch</td>
<td>2620</td>
<td>1930</td>
</tr>
<tr>
<td>Trench and Stage &quot;3&quot;</td>
<td>9320</td>
<td>5640</td>
</tr>
<tr>
<td></td>
<td>7510</td>
<td>3680</td>
</tr>
<tr>
<td></td>
<td>2400</td>
<td>1000</td>
</tr>
<tr>
<td>TOTAL</td>
<td>$25750</td>
<td>$17750</td>
</tr>
<tr>
<td></td>
<td>$16830</td>
<td>$4300</td>
</tr>
<tr>
<td></td>
<td>$2400</td>
<td>$5830</td>
</tr>
<tr>
<td></td>
<td>$51805</td>
<td>$144120</td>
</tr>
<tr>
<td>Grand Total</td>
<td>$195400</td>
<td></td>
</tr>
</tbody>
</table>

Costs for float sections were obtained from the contractor's bid prices and plan quantities. These prices are only for the material which is in addition to the conventional stage section.

Costs for swamp work are based on:

- Exc. is $0.85/cu.yd. from Mn/DOT Road Plans Estimating Unit
- Haul is $0.45/cu.yd. from Mn/DOT Road Plans Estimating Unit
- Fill is $3.65/cu.yd. from contractor's bid price

Swamp excavation volume computed on the following typical section:

![Diagram](image)

Figure A-1. Typical section for excavation quantity computations.
## APPENDIX B - DETAILED SPECIFICATIONS

<table>
<thead>
<tr>
<th>Material</th>
<th>Specification</th>
<th>Brand or Species Used</th>
<th>Bid Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood Chips</td>
<td>Wood chips shall be cut from sound live trees of any species and may be either &quot;clean chips&quot; cut from debarked tree trunks or &quot;total tree chips&quot; cut from whole trees (including bark and branches but excluding leaves). The chips shall have a minimum nominal length of 3/4 inches, (1.9 cm) width of 1/2 inch (1.3 cm) or more and a maximum fiber length of 6 inches (15 cm).</td>
<td>Balm of Gilead and Poplar trunks with bark</td>
<td>$5.50/cu yd</td>
</tr>
<tr>
<td>Corduroy</td>
<td>Corduroy shall consist of log rafts constructed of 12-ft long (3.6 m) logs of sound wood from any variety of tree. The logs shall be a minimum of 4 inches (10 cm) in diameter.</td>
<td>Poplar Balsam Birch</td>
<td>$5.25/ln ft ea. side</td>
</tr>
<tr>
<td>Fabric</td>
<td>Fabric material for embankment construction shall be Style 2532/75 as manufactured by Burlington Glass Fabrics Company or an approved equal. The fabric shall be furnished in roll lengths of 80 ft (25 m) plus or minus 2 ft (0.6 m) and a minimum width of 6 ft (1.8 m).</td>
<td>Burlington Glass Fabric style 2532 in 6 ft (1.8 m) widths.</td>
<td>$1.50/sq yd</td>
</tr>
</tbody>
</table>
APPENDIX C - DETAILED CONSTRUCTION PROCEDURES

STAGE CONVENTIONAL

In all stage fill sections (Test Sections 1, 3 and 9) the procedure was the same. After the wood chip leveling course, the initial 12-ft (3.6 m) wide lift of select granular material, two to three feet thick (0.6 to 0.9 m) as necessary, was placed. One side of the roadway would be filled in the morning and the other in the afternoon in order to keep the fill rate even. Seven days was required between lifts to allow for consolidation, drainage and strength gain. Only one lift plus some material for leveling was required before the Class 3 shoulder material was added on all the stage conventional sections.

CORDUROY (TEST SECTION 2)

The ditch was leveled with wood chips before placing of the corduroy. The logs for the corduroy were 12 ft (3.6 m) long and were limited to a 4-inch (10 cm) minimum diameter. Longitudinal stringers placed 2 ft (0.6 m) from the inside and outside edges of the corduroy were nailed to the logs, (Figures C-1 and C-2). The stringer splices were alternated to provide continuity to the corduroy. The fill was then placed the same way as it was for the stage fill sections.

WOOD CHIP WORKING PLATFORM (TEST SECTION 4)

This section was originally designed to have 2 ft (0.6 m) of wood chips, placed over the natural vegetation mat, covered by a minimum of 6 inches (15 cm) of clay material. The ditch was not deep enough for 2 ft (0.6 m) of chips, and the design thickness of the shouldering aggregate and clay was thought to be more important, so the thickness of the wood chip platform was reduced to hold the planned finished grade. The wood chips were placed by end dumping them into the ditch. They were then leveled with a light, wide-tracked dozer. No effort was made to compact them. A clay cap was then placed over the chips. No compacting of the clay was done at this point other than that of the equipment. Shouldering aggregate was then placed over the clay.
Figure C-1. Placement of corduroy.

Figure C-2. Corduroy inplace.
LIGHTWEIGHT WOOD CHIP EMBANKMENT (TEST SECTION 5)

This test section had the highest fill. Five to six feet (1.5 to 1.8 m) of wood chips were placed at the deepest part of the section. No effort was made to compact the wood chips. They were capped with 2 ft (0.6 m) of clay. The clay material was end dumped over the shoulders and spread by a bulldozer (Figure C-3). It was then compacted with a vibratory sheepfoot roller. The surface of the clay fill became very hard during the compaction process; in fact, the sheepfoot did not visibly mark the surface on the last pass (Figures C-4 and C-5). The 18 inch (46 cm) lift of select granular was placed over the clay after the one-week waiting period.

FULL WIDTH FABRIC (TEST SECTION 6)

Following the placement of the wood chip leveling, the first step in the construction of this test section was to place the fabric over the existing pavement. Fabric placement had to be done one lane at a time in order to maintain traffic across the section. The fabric also had to be overlaid before traffic could be returned to that lane in order to protect the fabric.

The evening before the fabric was placed, two tack coats with a combined total of 0.20 gal/sq yd (0.90 l/m²) of CRS-1 were placed. The next day work started at 5:00 A.M. A third tack at 0.16 gal/sq yd (0.72 l/m²) was placed. The fabric was precut into 80-ft (25 m) lengths and rolled from both ends toward the middle. It was placed on the northbound lane with 4-inch (10 cm) overlaps starting at the south end of the section. When unrolled the fabric extended 40 ft (12.5 m) on either side of centerline. The fabric was nailed to the pavement at the overlaps with PK nails and washers. The unrolled portion was left at the centerline and at the existing shoulder P.I.

A pneumatic roller embedded the fabric into the tack as shown in Figure C-6 and was able to travel both with and against the lap of the fabric with just a little problem with fabric pick up. After about 300 feet (91 m) along the centerline, nailing was discontinued, and the rolling of the fabric into the tack continued in the same manner, but fabric pick up became a problem (Figure C-7). The roller could only travel from north to south, the direction of the overlap.

A rubber tired paver began at the north end to place a 2-inch (5 cm) lift of bituminous on the fabric. The first 5 axle truck that brought the bituminous mixture to the paver had some problems with fabric pick up as it drove out after it was empty. The next 5 axle truck could not back up to the paver against the overlap without picking up the fabric. To prevent fabric pick up, a thin layer of plant mix was end dumped from a dump truck while it backed up, providing a covering over the tack coat and fabric (Figure C-8).
Figure C-3. Placement of clay.

Figure C-4. Compaction of clay.
Figure C-5. Clay after compaction.

Figure C-6. Fabric rolled into tack.
Figure C-7. Fabric pickup by roller.

Figure C-8. End dumping of bituminous mixture.
An initial 2-inch (5 cm) lift, 13 ft (4 m) wide, was placed on the fabric with a rubber tired paver. No problem occurred with the paver except that about one half of one strip was tore at Station 535+00 on the right edge of the mat due to a mound of dirt on the shoulder under the fabric.

The southbound lane fabric placement took about a half hour with no additional problems. It was then rolled into the tack coat and paved. A second lift of 1-1/2 inches (4 cm) was placed and traffic was restored to both lanes by mid afternoon (Figure C-9).

Before the widening fill was placed over the fabric, 137 ft (42 m) of the material on the east side was cut off and stolen. This was from Station 537+00 to 537+51 and from 538+41 to 539+27. More fabric was fastened to the existing ends with Weldwood Plus 10. After the fabric was glued and the fill placed, it was found that this adhesive was water based and mildew susceptible; (Weldwood Plus 10 is probably not the right adhesive to use in an underground environment.) The performance of this adhesive could greatly affect the results in this section although it has not up to the present time.

The fill procedure in this section was the same as a stage conventional section.

DITCH FABRIC SECTION (TEST SECTION 7)

After the initial wood chip leveling was placed fabric strips 6 ft (1.8 m) wide and 26 ft (8 m) long were placed transversely in the ditches and overlapped 4 inches (10 cm). To aid in assembling the fabric strips, they were fastened together with hog rings every 2 ft (0.6 m). About 4 strips of fabric would be fastened together in the ditch bottom where it was flat and easier to work. These prefastened units were then moved into position transverse to the slope and fastened to other preassembled units. The fabric was staked at the top of the ditch and weighted down with rocks and logs at the other end to prevent movement. Fill was then pushed down over the fabric from the mat by a bulldozer until the bulldozer could get down on the fill. When this was accomplished the fill was then dumped onto the mat and pushed into the ditch by a grader. It was then spread over the fabric with the bulldozer. About 1 ft (0.3 m) of sand was initially placed on the fabric (Figure C-10). This supported a D-6 bulldozer very well although the entire area shook as it worked. The remainder of the fill was then placed as if the test section were a stage conventional section.
Figure C-9. Full-width fabric section after paving.

Figure C-10. Placement of fill in ditch fabric section.
WEAKENED PLANE (TEST SECTION 8)

After the wood chip ditch leveling had been placed in this test section, a trench was to be cut on each side of the road. However, the trenching machine could not cut the trench as desired until a small amount of fill was placed to give it a level area on which to work. After the trenching was completed, the trench was loosely refilled with the material that had been removed by the trenching machine. The remainder of the fill was then placed as if it were a stage conventional section.
## APPENDIX D - INSTRUMENTATION DATA

### Table D-1. Measured strain of extensometers.

<table>
<thead>
<tr>
<th>Test Section and Extensometer No.</th>
<th>Date/Microstrain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corduroy 2</td>
<td></td>
</tr>
<tr>
<td>9.17-75 9.23-75 9.24-75 9.25-75 10.3-75 11.18-75 4.19-76 5.18-76 5.20-76 5.21-76 5.25-76 5.26-76 6.10-76</td>
<td></td>
</tr>
<tr>
<td>2 137 622 686</td>
<td>685 959 959 822 411 -411 -411 685</td>
</tr>
<tr>
<td>9.17-75 9.23-75 9.24-75 9.25-75 10.3-75 11.18-75 4.19-76 5.18-76 5.20-76 5.21-76 5.25-76 5.26-76 6.10-76</td>
<td></td>
</tr>
<tr>
<td>Stage Conv. 3</td>
<td></td>
</tr>
<tr>
<td>7.8-76 8.17-76 10.20-76 5.23-77</td>
<td>411 274 -685 -959</td>
</tr>
<tr>
<td>137 137 274 685</td>
<td>137 1096 -685 -685</td>
</tr>
<tr>
<td>5.20-76 5.21-76 5.25-76 5.26-76 5.27-76 6.10-76 6.22-76 7.8-76 8.18-76 10.20-76 5.23-77</td>
<td></td>
</tr>
<tr>
<td>Stage Conv. 1</td>
<td></td>
</tr>
<tr>
<td>1 0 137</td>
<td>5479 5753 6301 7397</td>
</tr>
<tr>
<td>2 -274</td>
<td>-137 274 9589 13700 31500</td>
</tr>
<tr>
<td>3 -685 -685 -1233 -1370 -1233 -822 -822 -685 -411 1096 1233</td>
<td></td>
</tr>
<tr>
<td>4 -274 -274 -959 -1096 -1086 -1370 -1644 -1507 -1370 274 1370</td>
<td></td>
</tr>
<tr>
<td>Chip Platform 2</td>
<td></td>
</tr>
<tr>
<td>5 -137 -274 -548 -959 -1096 -3014 -2192 -2740 -411 -137 1644</td>
<td></td>
</tr>
<tr>
<td>6.23-76</td>
<td></td>
</tr>
<tr>
<td>Chip Embankment 3</td>
<td></td>
</tr>
<tr>
<td>1 0 137</td>
<td>1096 1096 1507 1507</td>
</tr>
<tr>
<td>5 1096 959 1096 1507 1507 1096 1233 1370 2192 3288 4521</td>
<td></td>
</tr>
<tr>
<td>Full Fabric 1</td>
<td></td>
</tr>
<tr>
<td>1 274 137</td>
<td>0 0 0 274 1096 1233 1233 1781 1818 1781 137 1644 1644</td>
</tr>
<tr>
<td>4 137 0</td>
<td>137 0 274 3288 5342</td>
</tr>
<tr>
<td>Ditch Fabric 1</td>
<td></td>
</tr>
<tr>
<td>1 548 548</td>
<td>411 1644 3630 4137 5791 7986 8041 11123 9753</td>
</tr>
<tr>
<td>2 137 -274 -137 -274 -274 -137 -274 -274 -274 -137 -274 -137</td>
<td></td>
</tr>
<tr>
<td>3 -137 -137 -274 -137 -274 -137 -274 -274 -274 6.23-76 7.8-76 10.20-76 5.23-77</td>
<td></td>
</tr>
<tr>
<td>4 -137 -137 -274 -548 -222 -1096 -822 -1233 -959 -685 274</td>
<td></td>
</tr>
<tr>
<td>Stage Conv. 2</td>
<td></td>
</tr>
<tr>
<td>2 -137 -274 -1370 -1918 -2055 10.20-76 5.23-77</td>
<td></td>
</tr>
<tr>
<td>3 -137 -274 -685 -685 -969 -982 -274 -548</td>
<td></td>
</tr>
<tr>
<td>Weakened Plane 3</td>
<td></td>
</tr>
<tr>
<td>1 0 -274 -411 -411 -548 137 -411</td>
<td></td>
</tr>
<tr>
<td>4 0 -274 -274 -274 -411 1096 548</td>
<td></td>
</tr>
</tbody>
</table>
Figure D-1. Piezometer readings, Station 518+00, 15 ft. right (Test Section 3).
Figure D-2. Piezometer readings, Station 518+00, 60 ft. right (between road and RR) (Test Section 3).
Figure D-3. Piezometer readings, Station 518+00, 39 ft. left (Test Section 3).
Figure D-4. Piezometer readings, Station 531+00, 15 ft. right (Test Section 5).
Figure D-5. Piezometer readings, Station 531+00, 60 ft. right (between road and RR) (Test Section 5).
Figure D-6. Piezometer readings, Station 531+00, 65 ft. left (Test Section 5).