Settlement at Culverts

Final Report
Project HR-219

Iowa Department of Transportation
Highway Division
May 1984

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FINAL REPORT

FOR

PROJECT HR-219

SETTLEMENT AT CULVERTS

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The author wishes to express his appreciation to Iowa DOT personnel for their participation in the research. The special features were incorporated into the plans by Road Design personnel. Office of Materials personnel developed the proportions for the flowable mortar. Project inspection was provided by the Creston Resident Engineer and his staff.

The excellent cooperation of the contractors contributed to the success of the research. The prime contractor was Irving F. Jensen Company, Inc. of Sioux City, Iowa who retained Reilly Construction Company of Ossian, Iowa and GNA Concrete, Inc. of Grimes, Iowa as subcontractors for the special culvert backfilling.

SETTLEMENT AT CULVERTS

INTRODUCTION

Past construction methods have resulted in the need for leveling wedges of asphaltic cement concrete or mud jacking at locations where a reinforced concrete box culvert was replaced with a pipe culvert.

With the restraint of limited funds, more reconstruction, restoration, repair and resurfacing (4R) projects will be constructed. This will result in using existing pavements with trench replacement of small box culverts.

PROBLEM

The installation of culverts in trenches does not provide adequate space for compaction equipment other than hand tampers or small vibratory plate compactors. To increase the size of the trench and increase the size of the full depth pavement repair is expensive.

OBJECTIVES

The objective of this research is to develop and evaluate various methods of backfilling adjacent to culverts to reduce the need for future leveling or mud jacking to maintain a smooth pavement surface.

LOCATION

The research on culverts was incorporated in Dallas County Project EACF-44-5(15)--2K-25. This research is on the rural sections of Iowa 44 from the junction with U.S. 169 east to the Polk County Line.

CONTRACTOR AND CONTRACT

This project was let July 15, 1980 as a reconstruction project involving grading, P.C.C. Paving, P.C.C. Widening, and A.C.C. Resurfacing. The prime contractor was Irving F. Jensen Company, Inc. of Sioux City, Iowa who sublet the grading and culvert installations to Reilly Construction Company of Ossian, Iowa. The contract included Special Provision number 321 (Appendix A), Installation and Backfill of Culvert Pipe, which described the construction methods and materials.

The plan for this contract contained a sheet specifically identifying the method of construction.

CONSTRUCTION OVERVIEW

This project had three reinforced box culverts, either 2' x 2' or 3' x 2', and four corrugated metal pipes 18" in diameter to be replaced by concrete pipe culverts in trenches with a small amount

of full depth P.C.C. pavement repair. Two concrete pipes were installed in new locations.

Five different methods of backfill were used in the nine locations in an effort to determine the best method of backfilling.

1. At Stations 955+60, 1081+75, and 1215+50 the backfill method was flowable mortar in a minimum width trench.
2. At Stations 748+51 and 1226+74 the backfill method was granular backfill (either Class "A" Road Stone or Class "C" Gravel) in 6" lifts with adequate moisture for compaction.
3. At Stations 952+80 and 1094+64 the backfill method replaced the excavated soil with moisture control.
4. At Station 1008.00 the backfill was soil with moisture control and Class "B" bedding (a 2" cushion of sand below the pipe culvert plus sand for 15% of the pipe diameter).
5. At Station 1041+40 the concrete pipe culvert was relocated to the location of the existing pipe culvert (Sta. 1041+85) and installed using Class "B" bedding and normal backfill (2416.04D).

FLOWABLE MORTAR

Site preparation involved the removal of the pavement, Class 20 excavation and pipe installation. (Fig. 1)

Figure 1 - Site preparation for pipe installation.

The excavation limits for the area to be filled with flowable mortar were only 11" wider than the outside diameter of the pipe (Appendix B). The shoulder area was excavated wider to allow for compaction of soil that would act as a dam at each end to contain the flowable mortar under the paved roadway until it set (Fig. 2).

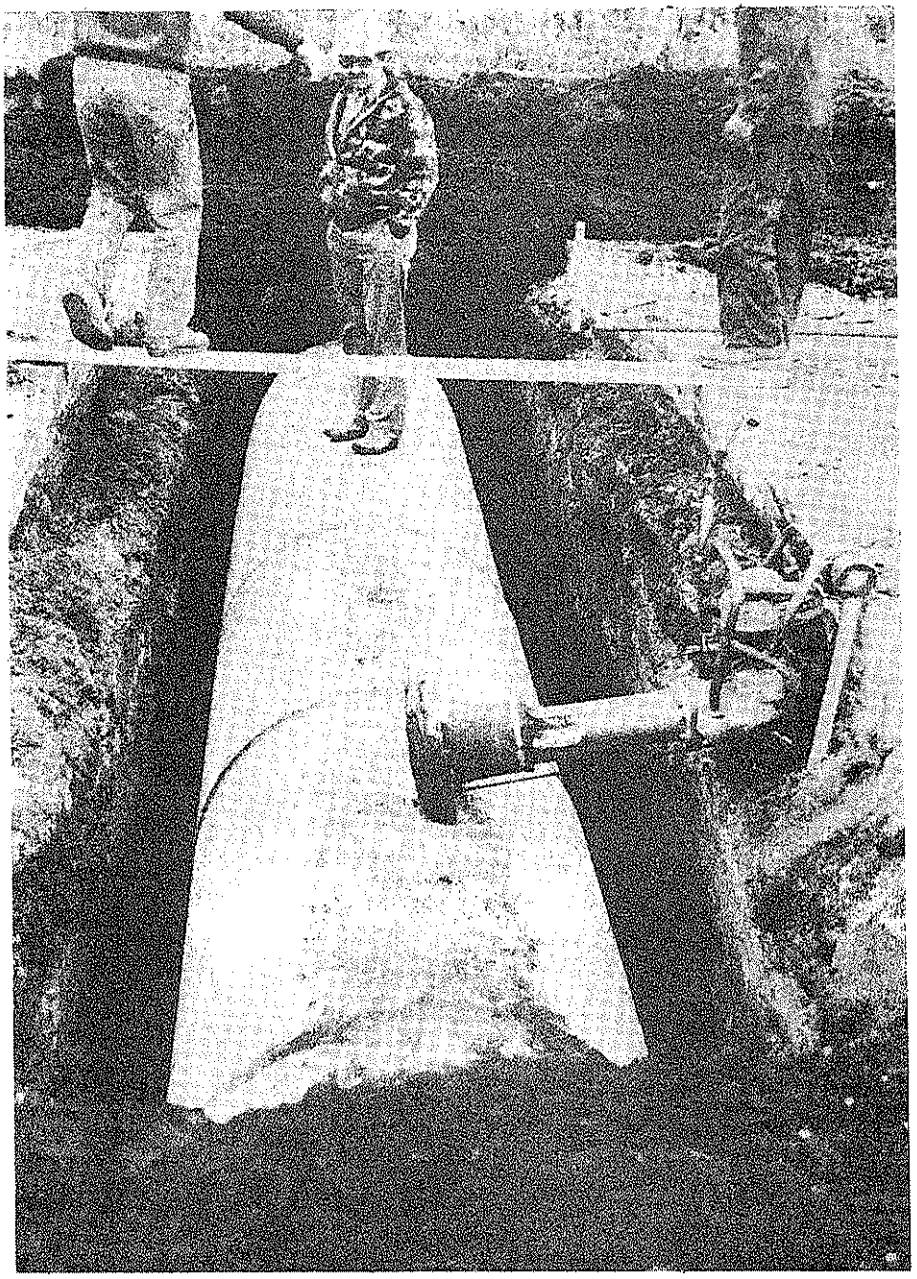


Figure 2 - Site preparation for Flowable mortar backfill.

The flowable mortar was placed in the trench and covered the pipe at this location (Fig. 3)

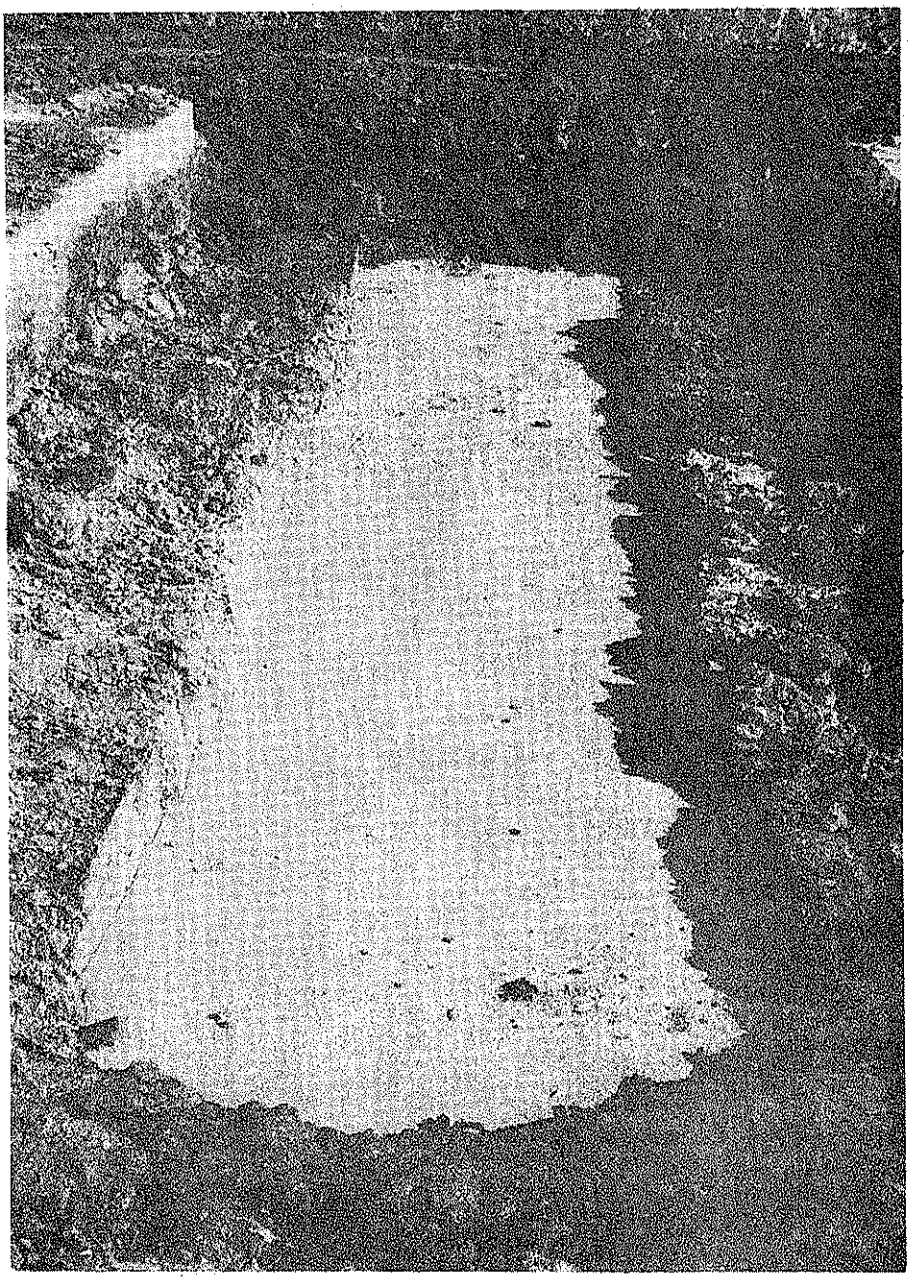


Figure 3 - Flowable mortar covering the pipe.

Special Provision 321.02E identifies the proposed flowable mortar as follows:

Flowable Mortar shall be a mixture meeting the following requirements:

1. Proportions shall be:

ABSOLUTE VOLUME (Percent)				
Cement	Fly Ash	Sand	Water	Air
0.040	0.125	0.500	0.260	0.075

APPROXIMATE QUANTITIES (Pounds/Cu.Yd.)			
212	505	2232	438

2. Cement shall be Type I cement described in Section 4101.

3. Fly ash shall comply with requirements of ASTM C 618, Class F, and the following additional requirements:

Loss on ignition	5.0% Maximum
Available Alkalies, as Na_2O	1.5% Maximum
Silicon Dioxide plus Aluminum Oxide plus Iron Oxide	65% Minimum

Fly ash shall be from a source approved by the engineer.

4. Sand shall be a mortar or plaster sand or other fine sand similar to that described in Section 4112.

5. Air entraining agent shall meet requirements of Section 4103.

6. Proportioning and Mixing shall be according to 2001.20 and 2001.21. The mixture shall be under continuous agitation until discharged.

Other flowable mortars having similar properties could be used. The mix design had to be submitted to the engineer for approval. This special provision was modified to allow use of a Class C fly ash meeting the following requirements:

Loss on ignition	3.0% Maximum
Available Alkalies, as Na_2O	1.5% Maximum
Silicon Dioxide plus Aluminum Oxide plus Iron Oxide	50% Minimum
Specified Gravity	2.68

The modification also involved a change from fine sand specification 4112 to fine aggregate for concrete specification 4110. This required a change in the weight of sand because of the different specific gravity.

The resulting mix per cubic yard is as follows:

Cement	Ash	Sand	Water
212 lb.	515 lb.	2316 lb.	438 lb.

The special provision required 7½% air. The air entraining agent used was Masterbuilder's AE-10. The initial entraining agent used was 2 oz./cu.yd. which resulted in only 1.3% air in the mortar. This was adjusted at the plant using a total amount of air entraining agent of 29 oz./cu.yd. On the grade 4 3/4 oz./cu.yd. of air entraining agent were added giving an air content of 6.6%. The total air entraining agent was 33 3/4 oz./cu.yd. On the other two culverts backfilled with flowable mortar 35 oz./cu.yd. of air entraining agent were used resulting in 7% air content.

The change to Class C fly ash caused some concern initially in that the mortar might set too quickly, however this did not occur or cause any problem. The first batch was loaded into the ready mix truck at 9:00 A.M. and was still flowable at 10:45 A.M. when the last mortar was placed.

There was some concern expressed that the flowable mortar would settle as it cured. This did not occur at any of the three locations. Some fine hair line cracks developed in the surface after the mortar set.

When the flowable mortar was being placed in the trench there was a tendency for the pipe to float off of the bedding. This was corrected by loading the center section of the pipe culvert using a backhoe bucket for down pressure. Once the placement of the mortar was completed the load was removed and the pipe remained in place.

Some of the joints in the pipe culvert allowed mortar to flow to the inside of the pipe. This flow was choked off using rags and resulted in a very small loss of mortar. Before the mortar set this was removed from the inside of the pipe.

The design quantity of flowable mortar was used in each location resulting in 6" to 10" less depth of flowable mortar than anticipated. In all three locations this difference was not believed to be significant as far as pavement settlement was concerned.

The culverts were backfilled with soil outside the area in which the flowable mortar was placed so forms were not required.

The contract item for flowable mortar was bid at $50.00 per cubic yard (Appendix C). The flowable mortar was furnished by GNA Concrete, Inc. of Grimes, Iowa. The plant manager indicated that their delivered price was $35/cu.yd.

GRANULAR BACKFILL AND BEDDING

The width of excavation for the two culverts backfilled with Class "C" gravel (Stations 748+51 AND 1226+74) was 42" plus the specified diameter of the pipe according to specification 2402.12A. The granular backfill was used around the pipe only under the paved roadway and also for bedding material. The shoulder areas were backfilled with soil. The granular material for bedding was bid at $15.00 per cubic yard.

Filter fabric (Marifi 140S manufactured by Celanese Fibers Marketing Company) was used between the granular backfill and the soil in each shoulder area to prevent contamination of the granular backfill. The filter fabric will also reduce the possibility of washout around the pipe culvert (Fig. 4). The filter fabric was bid at $1.50 per square yard.

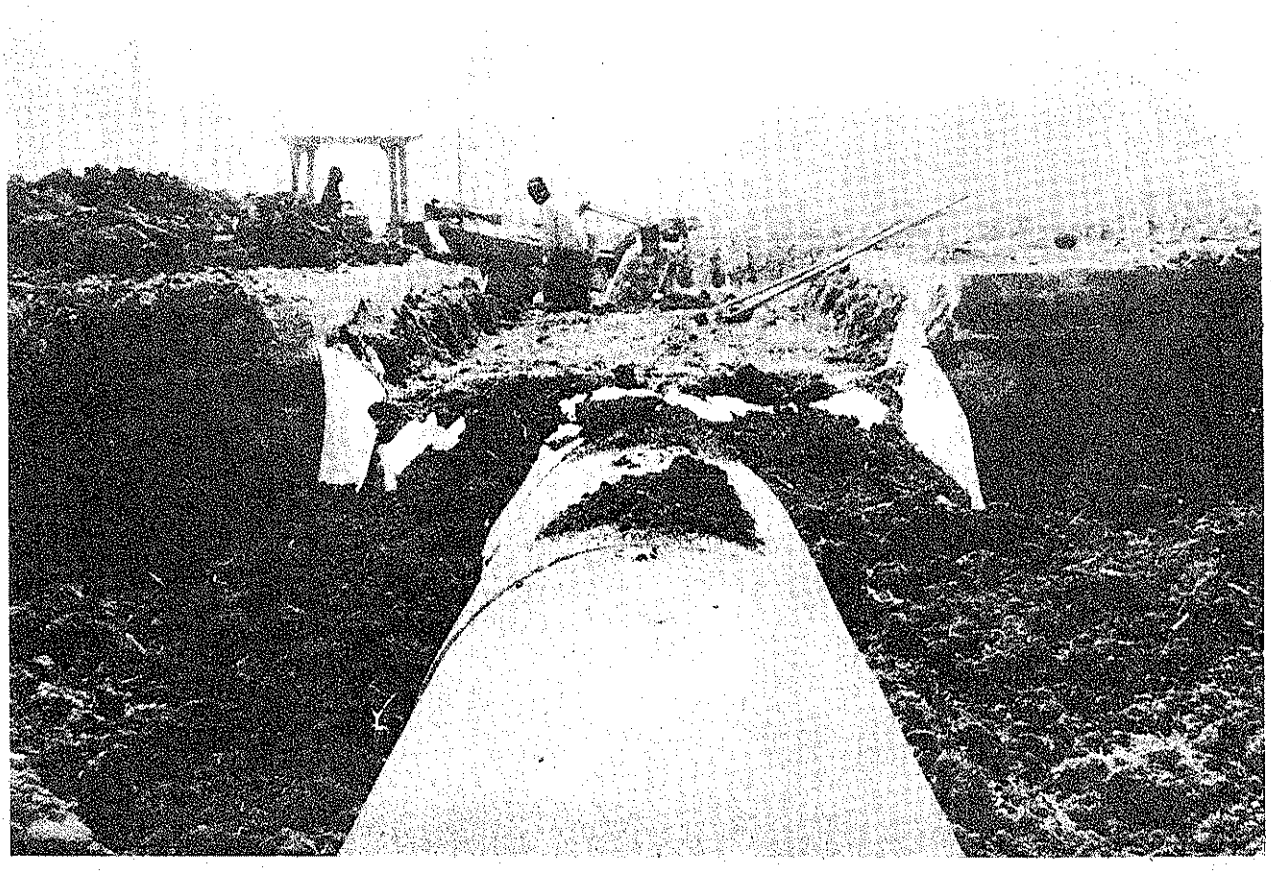


Figure 4 - Filter fabric encapsulation of the granular backfill.

INSTALLATION WITH CLASS "B" BEDDING

At station 1041+85 the plans show the concrete pipe location at Station 1041+40 with the removal of an 18" x 36' CMP at Station 1041+85. The new concrete pipe culvert was installed at the removal location (Station 1041+85) because of a conflict with an entrance location. This installation involved Class "B" bedding (granular material) and backfill with the excavated material. Since the replacement pipe was only 24" diameter, the flow line was not monitored. However, the surface was checked at the proposed intervals (Fig. 5).

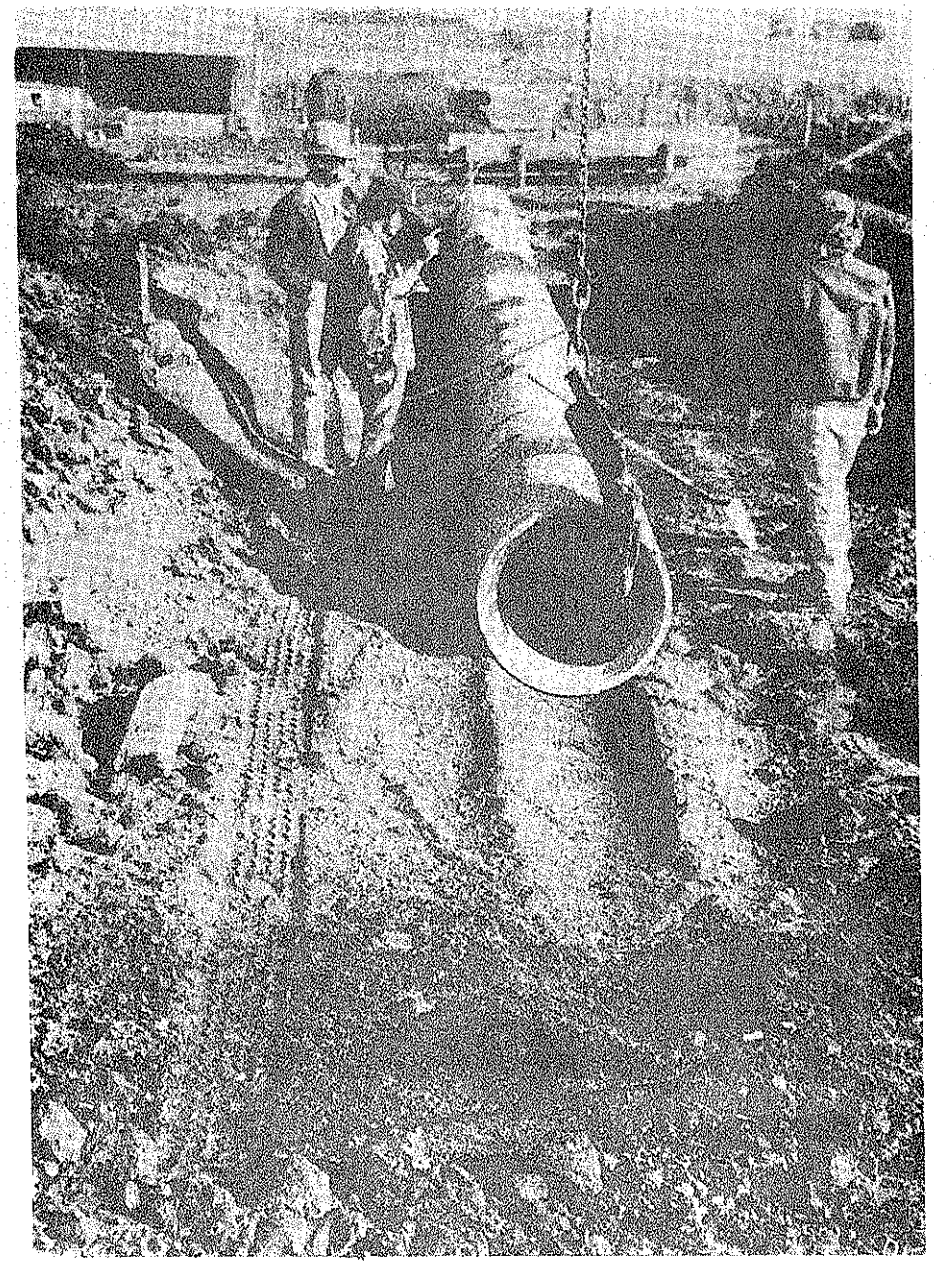


Figure 5 - Installation of a 24" R.C. pipe on Class "B" bedding.

At Station 1008+00 the installation was with Class "B" bedding and with soil backfill using moisture control. The moisture limits were plus or minus 2 percentage points from optimum as determined by the standard proctor method.

INSTALLATION WITH CLASS "C" BEDDING

At Station 952+80 and Station 1094+64 the installations were with Class "C" Bedding using moisture control on the soil used for backfill. The moisture limits were plus or minus 2 percentage points from optimum as determined by the standard proctor method.

At Station 1094+64 the soil at bedding elevation was not stable, therefore the poor soil was excavated 2'± below grade and replaced with dry soil. A firm bedding was obtained by compaction with a sheepsfoot roller. Due to the poor soil condition of the excavated soil, it was wasted and replaced with better quality soil from the backslope cut just east of the culvert location.

EQUIPMENT

The equipment used by the subcontractor for installing the concrete pipe culverts was:

1 Caterpillar Model 235 backhoe

1 Andrew bedding machine

1 Caterpillar Model 851 track loader

1 Case Model 450B dozer with blade

1 Wacker Model GVR-100 backfill tamper

PERSONNEL

The subcontractor's personnel included a foreman and four operators. The four operators were also used to complete crews to install culverts when their equipment was not being used in the placement of the concrete pipe culverts.

METHOD OF MONITORING

A string line was erected through the pipe culvert with a reference to the flow line of the culvert at the inlet and outlet. The tension on the string was controlled by a weight and pulley system so the tension was consistent for all measurements (Fig. 6). Measurements were taken from the flow line of the culvert to the stringline at each joint in the pipe.

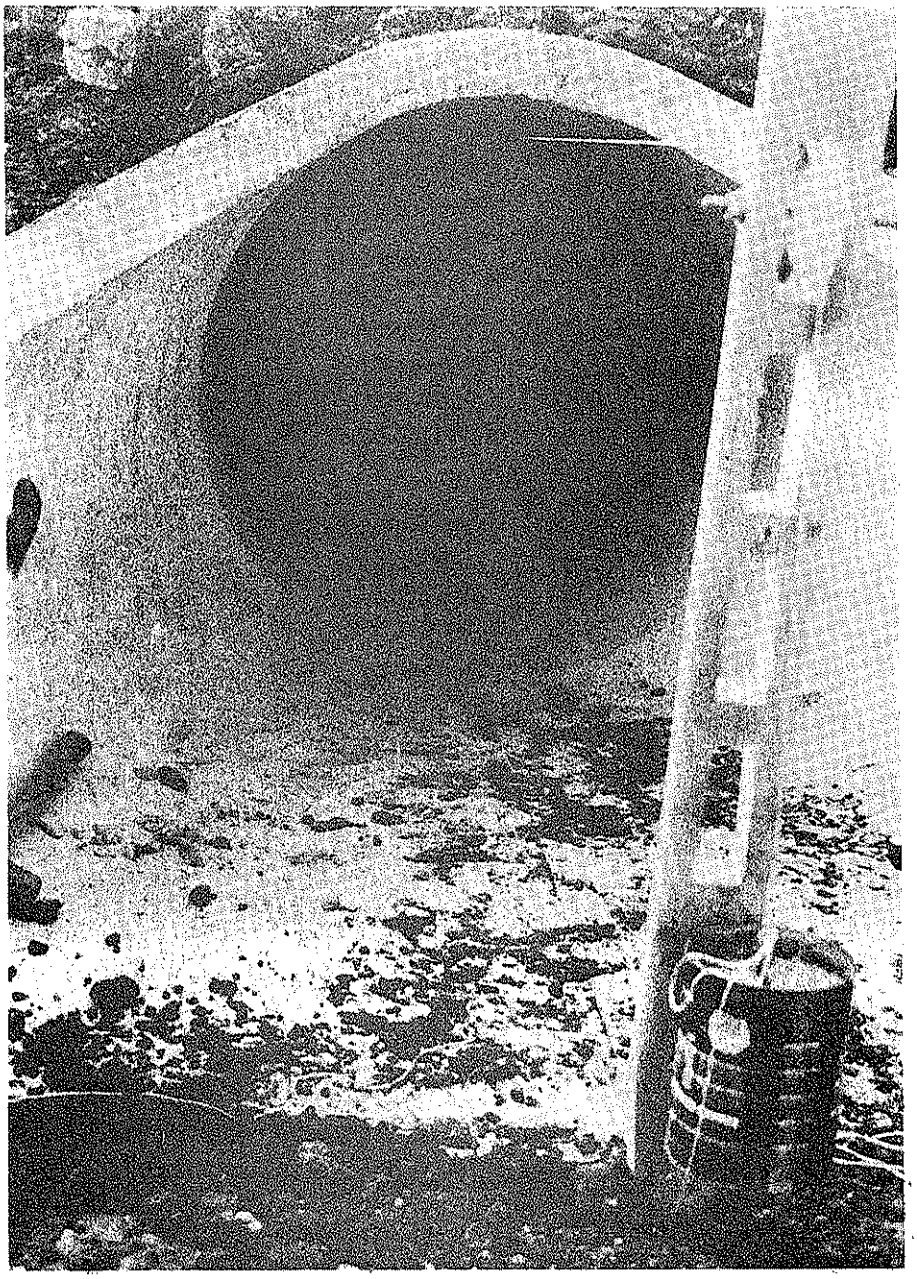


Figure 6 - Stringline for monitoring flowlines of culverts.

OBSERVATIONS

The culverts were installed in September of 1980 and the full depth patch placed in October of 1980. The installations were in areas to be widened and resurfaced with asphaltic cement concrete. The resurfacing was not completed until June of 1981. During the winter of 1980-1981, Iowa 44 was open to local traffic resulting in loads which caused settlement in the full depth patch areas over the culverts. In March of 1981, the settlements were:

Installation Type	Settlement (Inches)
Flowable Mortar	0 to 1/4
Class "B" Bedding	0 to 3/8
Class "C" Stone	0 *
Class "C" Bedding Moisture Control Backfill	1/4 to 3/4

The A.C.C. resurfacing was completed in June of 1981 and since that time very little settlement has occurred. Some cracks have radiated through the A.C.C. resurfacing indicating some movement of the full depth patching. Apparently the initial settlement had taken place prior to the completion of the A.C.C. resurfacing. Because of this there was no monitoring during the fall of 1981.

* One of the Class "C" stone backfill and bedding locations (Sta. 1226+74) had the binder course of A.C.C. resurfacing completed at the time of this check.

PAVEMENT SETTLEMENT

On November 17, 1982 and April 6, 1984 the pavement surface was checked to determine the settlement at the culverts on this project. This information is given in Appendix D "SUMMARY TABLE FINAL REPORT". This Table identifies the condition of the A.C.C. pavement over the culvert excavation at four different times.

The following chart shows the changes in settlement at each inspection:

SETTLEMENT COMPARISON
(inches)

Date	"C" Bedding w/M.C.		"B" Bedding w/o M.C.	"B"Bedding w/M.C.	Backfill Class "C" Stone		Flowable Mortar	
3-13-81	1/2-3/4	1/4-5/8	0	1/8 - 3/8	0	0	1/8-1/4	0
12-18-81	0	0	0	0	0	0	0	0
11-17-82	1/4-7/16	1/8	0	1/8 - 3/16	0	0	1/4-3/16	0
4-06-84	1/4-7/16	1/8-3/8	0	1/8 - 1/4	0	0	1/4	0

Notes: Class "C" Bedding consists of a concave saddle shaped in compacted soil to such a depth that 10% of the height of the pipe rests below the adjacent ground line.

Class "B" Bedding consists of a 2-inch cushion of sand shaped to a concave saddle in compacted soil to such a depth that 15% of the height of the pipe rests on the sand cushion below the adjacent ground line.

M.C. is moisture control. The backfill moisture content is brought to within 2 percentage points of standard optimum of standard proctor density.

The pipe culverts installed with Class "C" bedding settled more than the other methods of installation. The settlements on March 13, 1981 were taken before the A.C.C. surface course was placed. The total settlement of this installation varied from 3/4 inch to 1 3/16 inch. At the present time the settlement varies from 1/8 inch to 7/16 inch. The surface of the A.C.C. pavement has minor cracks but not wide enough to require sealing.

The pipe culverts installed with Class "B" bedding and soil backfill without moisture control had no settlement, while the culvert backfilled with moisture control has a total settlement of between 1/4 inch and 5/8 inch. No apparent explanation exists for this difference.

The backfill using flowable mortar did not settle at one location and settled a total of 3/8 inch to 1/2 inch in the other location. At the present time, the settlement is only 1/4 inch on the installation that did settle.

The best method of installation was at the locations which used the Class "C" stone. In both installations there has been no settlement to date.

SUMMARY OF TOTAL SETTLEMENT

Type of Backfill	Class "C" Bedding w/ M.C.	Class "B" Bedding w/o M.C.	Class "B" Bedding w/ M.C.	Flowable Mortar	Class "C" Stone Backfill
Total	3/4"-1 3/16"	0	1/4"-5/8"	1/4"	0

CONSTRUCTION COSTS

Preparation construction costs have been assumed to be approximately the same for all installations.

Cost of Flowable Mortar (Sta. 955+60) after the pipe culvert was placed:

Material		
Flowable Mortar	5.5 Cu. Yds. @ $30.00	165.00
Class 10	4.7 Cu. Yds. @ $ 1.70	8.00
Total Material		173.00
Labor		
Foreman	4 hrs. @ $10.09	40.36
Equipment Operator	2 hrs. @ $ 9.59	19.18
Labor	8 hrs. @ $ 6.97	55.76
Total Labor		115.30
Equipment		
Backhoe	2 hrs. @ $190.50	381.00
Loader	2 hrs. @ $58.50	117.00
Total Equipment		498.00
Total cost of Flowable Mortar		$786.30

Cost of Granular Backfill (Class "C" Stone) (Sta. 1226+74) :

Material		
Granular Backfill	33 Tons @ $3.90	128.70
Filter Fabric	18 Sq.yds. @ $1.43	25.74
Total Material		154.44
Labor		
Foreman	6 hrs. @ $10.09	60.54
Equipment Operator	6 hrs. @ $ 9.59	57.54
Labor	12 hrs. @ $ 6.97	83.64
Total Labor		201.72
Equipment		
Backhoe	6 hrs. @ $190.45	1,142.70
Loader	6 hrs. @ $ 58.37	350.22
Compactor	6 hrs. @ $ 4.50	27.00
Total Equipment		1,519.92
Total cost of Granular Backfill		$1,876.08

Cost of Soil with Moisture Control:

Material		
Soil (Class 10)	27 cu.yds. @ $1.70	45.90
Total Material		45.90
Labor		
Foreman	6 hrs. @ $10.09	60.54
Equipment Operator	7 hrs. @ $ 9.54	66.78
Labor	12 hrs. @ $ 6.97	83.64
Total Labor		210.96
Equipment		
Backhoe	6 hrs. @ $190.45	1,142.70
Loader	1 hr. @ $ 58.37	58.37
Total Equipment		1,201.07
Total cost of Soil Backfill		$1,790.42

SUMMARY OF TOTAL COST

Flowable Mortar	786.30
Class "C" Stone	1,876.08
Soil Backfill	1,457.93

Time was the main factor when comparing the various methods of backfill. At one flowable mortar installation the placement of 9 cu.yds. of mortar took only 2 hours. For this location the total cost was $326.00 which did not include the construction of the soil shoulder to contain the flowable mortar. The costs mentioned above include all costs after the pipe culvert was in place and required a total of 6 hours of labor.

SUMMARY

Since the ACC surface course was not placed in the fall of 1981, there was an opportunity to restore the initial settlement at these culverts with the ACC surface in 1982. Because of this, there has been no need for maintenance leveling at any of the culverts. Of all five methods of backfill, the Class "C" Bedding with Moisture Control is the only location which would have required any maintenance leveling. Of all methods of backfill, the backfill with the excavated soil was the most expensive method used.

The Class "C" Stone Backfill had the least settlement of the backfill methods. When considering the cost of material and time used, the total cost of the Class "C" Stone Backfill was nearly the same as the soil backfill.

The most cost effective method with a minor amount of total settlement was the flowable mortar backfill. In fact, the contractor who installed these culverts indicated that he would suggest flowable mortar backfill in similar situations on future projects.

On this research project, more continuous Iowa DOT inspection was provided than is normally available for other culvert pipe installations. This forced the contractor to follow specifications and plans more rigidly than if an inspector was only periodically checking the operation.

CONCLUSIONS

This research on settlement at culverts supports the following conclusions:

1. More extensive or continuous inspection may result in reduced pavement settlement over culvert replacements.
2. The Class "C" Bedding resulted in the greatest settlement.
3. The Class "C" Stone backfill yielded the least settlement.
4. The least expensive method of culvert replacement backfilling was flowable mortar.
5. Flowable mortar is a very cost effective, viable method of backfilling.

EXPANDED USE OF FLOWABLE MORTAR

Based on the experience from this research the Iowa DOT has used flowable mortar for filling voids between reinforced concrete box culverts in which a corrugated metal culvert liner has been installed.

Also, where a bridge was replaced with a culvert, flowable mortar, sand and soil were used to fill in the area between the culvert and the bottom of the bridge deck.

IOWA DEPARTMENT OF TRANSPORTATION
Ames, Iowa

Special Provisions
for

INSTALLATION AND BACKFILL OF CULVERT PIPE

Dallas County EACF-44-5(15)--2K-25

July 15, 1980

321.01 GENERAL. This Special Provision covers the installation and backfill of culvert pipe on this project. This work is to be done using several methods and materials as described on the plans and as required herein.

Certain aspects of this project are of a research nature, and requirements may be changed by the engineer in order to make these aspects more meaningful.

321.02 MATERIALS. Materials to be used are as follows:

A. Culvert Pipe. Culvert pipe shall be of the type and size shown on the plans.

B. Filter Fabric shall be one of the following, or approved equal:

Bidim C-22, Monsanto Textiles Co.
Mirafi 140S, Celanese Fibers Marketing Co.
Supac 4-P, Phillips Fibers, Inc.
True-Tex MG-76, Railway Appliance Div., True Temper Corp.
Typar 3401, DuPont Co., Textile Fibers Dept.

C. Aggregate for Class B Bedding shall be granular material for bedding or a sand.

D. Granular Material for Bedding shall meet requirements of Section 4132, excluding 4132.04, or Section 4120, excluding 4120.06. Though the plans may indicate Class A or C crushed stone for this material, the intention is to allow the contractor the options described in this paragraph.

E. Flowable Mortar shall be a mixture meeting the following requirements:

1. Proportions shall be as follows:

ABSOLUTE VOLUME (Percent)

Cement	Fly Ash	Sand	Water	Air
0.040	0.125	0.500	0.260	0.075

APPROXIMATE QUANTITIES (Pounds/Cu.Yd.)

212	505	2232	438	-

2. Cement shall be Type I cement described in Section 4101.

3. Fly ash shall comply with requirements of ASTM C 618, Class F, and the following additional requirements:

Loss on ignition	5.0% Max.
Available Alkalies, as Na_2O	1.5% Max.
Silicon Dioxide plus Aluminum Oxide plus Iron Oxide	65% Min.

Fly ash shall be from a source approved by the engineer.

4. Sand shall be a mortar or plaster sand or other fine sand similar to that described in Section 4112.

5. Air entraining agent shall meet requirements of Section 4103.

6. Proportioning and mixing shall be according to 2001.20 and 2001.21. The mixture shall be under continuous agitation until discharged.

Other flowable mortars having similar properties may be used. The mix design should be submitted to the engineer for approval.

321.03 CONSTRUCTION. Culvert pipe shall be installed and the backfill shall be placed as described for each location.

A. Station 748+51.0. The pavement shall be removed, and the embankment shall be excavated. Excavation under the pavement shall be to the width shown on the plans. The trench sides shall be maintained as vertical as is practicable. The excavation under the pavement shall be to the depth shown on the plans, intended to allow placement of granular material for bedding 6 inches below the bottom of the pipe in the area within 17.5 feet of the centerline. Granular material for bedding shall be placed and compacted to a depth of 6 inches. The pipe shall be placed in accord with 2416.04C on this flat surface; outside the area of granular materials, the pipe shall be placed on a Class C bedding.

Backfilling shall be as shown on the plans and as follows: Granular material used for bedding shall be placed and compacted in 6 inch lifts with a moisture content suitable for compaction. Compaction shall be an approved, vibratory compactor. Care shall be used to place and compact the material so as not to disturb joints, alignment, and grade line of pipe. Backfilling shall be done simultaneously on both sides of the pipe and shall continue to the elevation of the subgrade. The slope of the granular material shall be controlled as shown on the plans.

Filter fabric shall be installed on the surface of the sloping granular material as shown on the plans. The filter fabric shall be placed to avoid direct contact between the granular material for bedding and the soil. It shall be in contact with the natural soil on the bottom of the pipe and the sides of the trench and the backfilled soil on the entire periphery of the pipe. Where the fabric is lapped during placement, the laps shall be at least 12 inches. Wire staples may be necessary to hold the fabric in place against the granular material.

Backfilling of the shoulder areas shall be done according to the Standard Specifications. Material excavated from the trench may be used. This may be done in conjunction with normal Class 10 Excavation.

B. Station 952+80 (OR). The pavement shall be removed, and the embankment shall be excavated to the depth necessary to place the pipe at the required flow line. The entire trench bottom shall be shaped to allow placement with a Class C bedding as provided in the Standard Specifications. The pipe shall be placed as provided in 2416.04C.

Material from the trench excavation shall be placed and compacted in the backfill according to requirements of 2416.04D, except the material shall be compacted by a pneumatic tamper or other suitable compactor and backfill material shall be compacted with moisture control. The moisture at the time of compaction shall be the optimum moisture shown on the plans for that soil, within a tolerance of plus or minus 2.0 percentage points. Backfilling shall continue to the elevations of the subgrade and shoulders and may be in conjunction with normal Class 10 excavation.

C. Station 955+60.0 (OR). The pavement shall be removed, and the embankment shall be excavated to the width shown on the plans. The trench sides below the top of the pipe shall be maintained as vertical as is practicable; above this, the trench sides shall be sloped as shown on the plans. The excavation shall be to the depth shown on the plans, suitable for the intended flow line. The pipe shall be placed in accord with 2416.04C, but on a flat surface of the existing soil within 9 feet of the center line, and on a Class C bedding in the shoulder area.

Backfilling of the shoulder areas shall be done in accordance with 2416.04D. Material excavated from the trench may be used. The interior slopes shall be maintained during and after backfilling.

The interior area shall be filled with flowable mortar to the top of the pipe. This mortar shall be placed at a rate slow enough to provide for as continuous an operation as is practicable, bringing the mortar backfill up simultaneously on both sides of the pipe.

The remainder of the backfill shall be placed as required for Class 10 Excavation except that portion placed within approximately 13 feet of the center line shall be placed and compacted with moisture control. The moisture at the time of compaction shall be the optimum moisture shown on the plans for that soil within a tolerance of plus or minus 2.0 percentage points. Backfilling shall continue to the subgrade and shoulder elevations and may be in conjunction with normal Class 10 Excavation. Backfill shall not be placed over flowable mortar the same day the flowable mortar is placed.

D. Station 1008+00 (OR). The pavement shall be removed, and the embankment shall be excavated to the depth necessary to place the entire pipe at the required flow line with a Class B bedding as provided in the Standard Specifications. The pipe shall be placed as provided in 2416.04C. Bedding shall be prepared with the granular material for bedding or sand.

Material from the trench excavation shall be placed and compacted in the backfill according to requirements of 2416.04D except the material shall be compacted by a pneumatic tamper or

ther suitable compactor and backfill material shall be compacted with moisture control. The moisture at the time of compaction shall be the optimum moisture shown on the plans for that soil within the tolerance of plus or minus 2.0 percentage points. Backfilling shall continue to the elevations of the shoulder and subgrade and may be in conjunction with normal Class 10 excavation.

E. Station 1041+40 (OR). The pavement shall be removed, and the embankment shall be excavated to the depth necessary to place the entire pipe at the required flow line with a Class B bedding as provided in the Standard Specifications. The pipe shall be placed as provided in 2416.04C. Bedding shall be prepared with the granular material for bedding or sand. Material from the trench excavation shall be placed and compacted in the backfill according to requirements of 2416.04D. Backfill shall continue to the elevations of the shoulder and subgrade and may be in conjunction with normal Class 10 excavation.

F. Station 1041+85 (OR). The pavement shall be removed and the embankment shall be excavated to the depth necessary to remove the existing pipe, and the pipe shall be removed. Material excavated from the trench may be used for backfill. Backfilling shall be according to requirements of 2416.04D and may be in conjunction with Class 10 excavation.

G. Station 1081+75.0 (OR). The pavement shall be removed, and the embankment shall be excavated. Excavation under the pavement shall be to the width shown on the plans. The trench sides in the lower 5 feet of trench shall be maintained as vertical as is practicable; above this, the trench sides shall be sloped as shown on the plans. The excavation under the pavement shall be to the depth shown on the plans, suitable for the intended flow line. The pipe shall be placed in accord with 2416.04C, but on a flat surface of the existing soil within 9 feet of the center line; outside the area, the pipe shall be placed on a Class C bedding.

Backfilling of the shoulder areas shall be done in accordance with 2416.04D and in a manner normal for Class 10 excavation. Material excavated from the trench may be used. Interior slopes shall be maintained during and after backfilling.

The interior area shall be filled with flowable mortar to a depth of 5 feet. The mortar shall be placed at a rate slow enough to provide for as continuous an operation as is practicable, bringing the mortar backfill up simultaneously on both sides of the pipe. The remainder of the backfill within the shoulder lines shall be placed as required for normal Class 10 excavation except it shall be placed and compacted with moisture control. The moisture at the time of compaction shall be the optimum moisture shown on the plans for that soil within a tolerance of plus or minus 2.0 percentage points. Backfilling shall continue to the subgrade elevation and may be in conjunction with normal Class 10 excavation. Backfill shall not be placed over flowable mortar the same day the flowable mortar is placed.

H. Station 1094+64 (OR). The pavement shall be removed, and the embankment shall be excavated to the depth necessary to place the pipe at the required flow line. The entire trench bottom shall be shaped to allow placement on a Class C bedding as provided in the Standard Specifications. The pipe shall be placed as provided in 2416.04C.

Material from the trench excavation shall be placed and compacted in the backfill according to requirements of 2416.04D except the material shall be compacted by a pneumatic tamper or other suitable compactor and backfill material shall be compacted with moisture control. The moisture at the time of compaction shall be the optimum moisture shown on the plans for that soil within a tolerance of plus or minus 2.0 percentage points. Backfilling shall continue to the elevations of the shoulders and the subgrade and may be in conjunction with normal Class 10 excavation.

I. Station 1215+50. The pavement shall be removed, and the embankment shall be excavated to the width shown on the plans. The trench sides shall be maintained as vertical as is practicable. The excavation shall be to the depth shown on the plans, suitable for the intended flow line. Backfilling of the shoulder areas shall be done in accordance with 2416.04D and in a manner normal to Class 10 excavation, using material excavated from the trench. The interior slopes shall be maintained as vertical as practicable during and after backfilling.

The interior area shall be filled with flowable mortar to the subgrade elevation. This mortar shall be placed at a rate slow enough to provide for as continuous an operation as is practicable, bringing the mortar backfill up simultaneously on both sides of the pipe and to the subgrade elevation. Vehicles or construction activities shall not be allowed over flowable mortar the same day the flowable mortar is placed.

J. Station 1226+74 (OR). The pavement shall be removed, and the embankment shall be excavated. Excavation under the pavement shall be to the width shown on the plans. The trench sides shall be maintained as vertical as is practicable. The excavation under the pavement shall be to the depth shown on the plans, intended to allow placement of granular material for bedding 2 inches below the bottom of the pipe in the area within 16 feet of the center line. Granular material for bedding shall be placed to a depth of 2 inches. The pipe shall be placed in accord with 2416.04C on this flat surface; outside the area of granular material, the pipe shall be placed on a Class C bedding.

4

Backfilling shall be as shown on the plans and as follows: Granular material used for bedding shall be placed and compacted in 6-inch lifts with a moisture content suitable for compaction. Compaction shall be by an approved vibratory compactor. Care shall be used to place and compact the material so as not to disturb joints, alignment, and grade line of the pipe. Backfilling shall be done simultaneously on both sides of the pipe and shall continue to the elevation of the subgrade. The slope of the granular material shall be controlled as shown on the plans.

Filter fabric shall be installed on the surface of the sloping granular material as shown on the plans. The filter fabric shall be placed to avoid direct contact between the granular material for bedding and the soil. It shall be in contact with the natural soil on the bottom of the pipe and the sides of the trench and the backfilled soil on the entire periphery of the pipe. Where the fabric is lapped during placement, the laps shall be at least 12 inches. Wire staples may be necessary to hold the fabric in place against the granular material.

Backfilling of the shoulder areas shall be done according to the Standard Specifications. Material excavated from the trench may be used. This may be done in conjunction with normal Class 10 excavation.

321.03 MEASUREMENT AND PAYMENT. The work described in this specification will be measured and paid for in accordance with 2416.05 and 2416.06. In addition, payment will be made as follows:

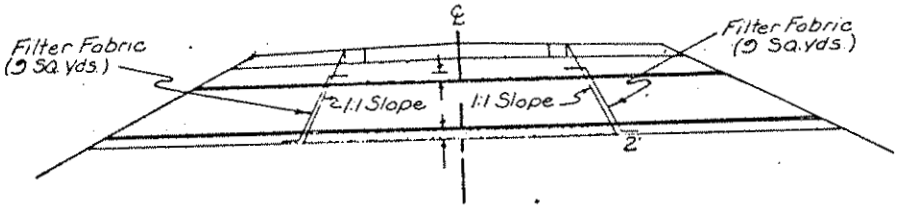
A. Filter Fabric. Payment will be made at the contract price per square yard for the quantity of filter fabric shown on the plans.

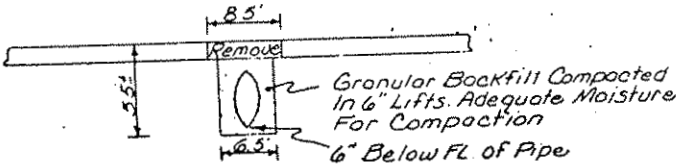
B. Flowable Mortar. Payment will be made at the contract price per cubic yard for the quantity of flowable mortar shown on the plans.

C. Granular Material for Bedding. Payment will be made at the contract price per cubic yard for the quantity of granular material for bedding shown on the plans. This quantity will be included in the quantity required elsewhere on the project for backfilling around storm sewers. Payment in accord with Section 2416 and this additional payment will be considered full compensation for furnishing all materials, equipment, and labor necessary to complete the work specified herein and as shown on the plans, including special compaction procedures, adjustment of moisture, and moisture control not covered by other items in the contract.

APPENDIX B

LOCATION STATION ~~748+51.0~~ INSTALL 36"Ø RF-1

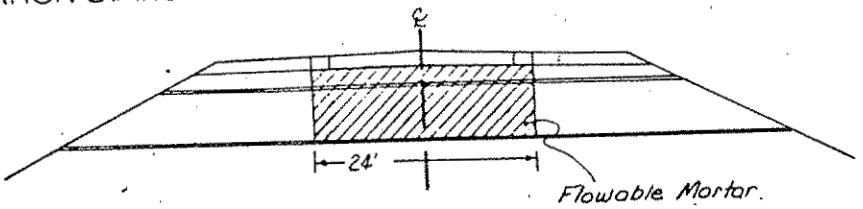


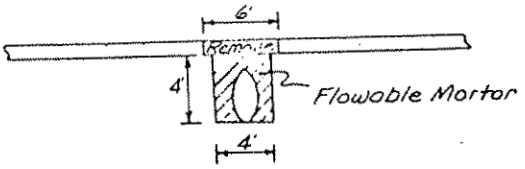


Material Required

Filter Fabric	= 18 Sq. Yds
* Granular Backfill	= 45 tons
Full Depth Patch	= 23 Sq.yds.

LOCATION STATION 1215+500(O.R.) INSTALL 30" Ø RF-1

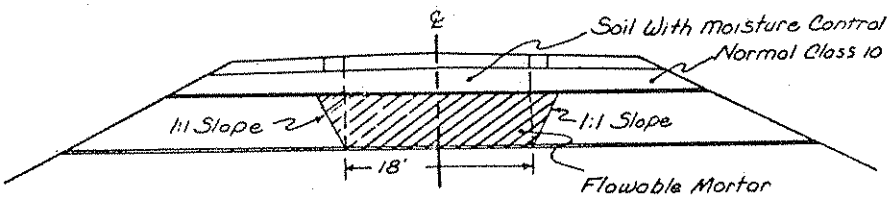


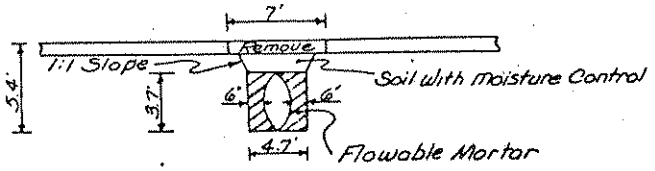


Material Required

Flowable Mortar	= 8.7 Cu.yds.
Full Depth Patch	= 16 Sq.yds.

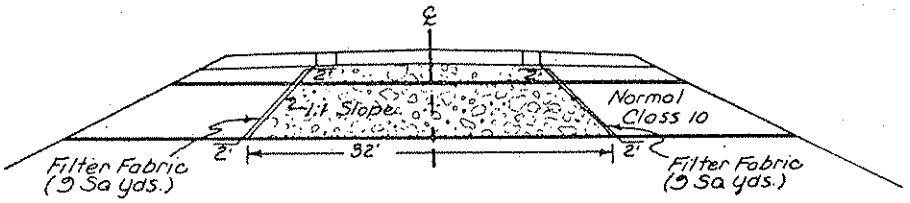
LOCATION STATION 955+60.0(O.R) INSTALL 36"Ø RF-1

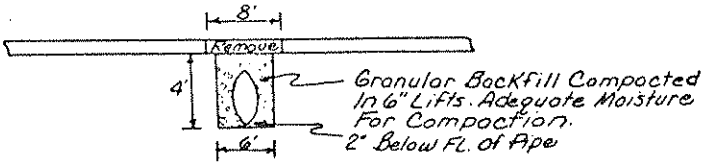




Material Required
Flowable Mortar = 5.5 Cu. yds.
Full Depth Patch = 19 Sq. yds.

LOCATION STATION 1226+74.0 (O.R.) INSTALL 30" O RF-1





Material Required
Filter Fabric = 18 Sq yds.
*Granular Backfill = 33 [illegible]
Full Depth Patch = 21.5 Sq. yds.

APPENDIX C

List of Contract Items Involved.

Item No.	Description	Quantity	Unit Price	Amount
4	Excavation Class 20 for Roadway Pipe Culv.	2,035 cu.yd.	4.00	8,140.00
82	Patches, Full Depth	1,229 sq.yd.	60.00	73,740.00
85	Compaction w/moisture control	8,918 cu.yd.	.50	4,459.00
89	Granular Material for Bedding	2,947 cu.yd.	15.00	44,205.00
91	Filter Fabric	36 sq.yd.	1.50	54.00
92	Flowable Mortar	25.4 cu.yd.	50.00	1,270.00

APPENDIX D

SUMMARY TABLE FINAL REPORT

CONCRETE PIPE CULVERT BACKFILL ----- EACF-44-5(15) DALLAS COUNTY

Culvert Location	748+51.0	952+80	955+60	1008+00	1041+85	1081+75	1094+64	1215+50	1226+74
Diameter	36"	36"	36"	36"	24"	30"	30"	30"	30"
Backfill Method	Class "C" Stone	"C" Bedding Moisture Control Soil	Flowable Mortar	"B" Bedding Moisture Control Soil	"B" Bedding Normal Backfill	Flowable Mortar	"C" Bedding Moisture Control Soil	Flowable Mortar	Class "C" Stone
Date Installed	9-26-80	9-22-80	9-24-80	9-19-80	9-18-80	9-16-80	9-10-80	9-10-80	9-09-80
Date of Full Depth Patch	10-17-80	9-25-80	9-28-80	9-25-80	9-22-80	9-18-80	9-18-80	9-22-80	9-22-80
Date of Initial Stringline	9-29-80	9-25-80	9-29-80	9-25-80	-------	9-19-80	9-17-80	9-17-80	9-17-80
Settlement of Surface 3-13-81	0	1/2" to 3/4"	1/8" to 1/4"	1/8" to 3/8"	0	0 to 1/8"	1/4" to 5/8"	0 to 1/8" A.C. Resurf.	0
Condition * 12-18-81	0 settlement 1 crack	0 settlement 0 cracks	0 settlement 1 crack	0 settlement 0 cracks	0 settlement 1 crack	0 settlement 0 cracks	0 settlement 0 cracks	0 settlement 0 cracks	0 settlement 0 cracks
Condition of Surface 11-17-82	Settlement 0 1 hairline crack 11' E. of center line of culv.	Settlement 7/16"N,1/4"S. Hairline cracks at both sides of culv. from center line north	Settlement 1/4"N,3/16"S. Hairline cracks partial width both sides of culv. center line	Settlement 1/8"N, 3/16"S. 1 hairline crack E. of culv. 2' long at center line of pavement	Settlement 0 1 Hairline crack W. of center line of culv. 6' long in North lane	Settlement 1/8" both edges. 1 hairline crack E. of center line of culv.	Settlement 1/8" both edges. No cracks.	Settlement 0 1 hairline crack 4' E. of center line of culv.	Settlement 0 1 hairline crack 6' E. of center line of culv. from S. edge of pavement. N. 6'
Condition of Surface 4-6-84	Settlement 0 1 hairline crack 11' E. of center line of culvert	Settlement 7/16"N, 3/8"centerline 1/4"S.Hairline cracks both sides from center line north	Settlement 1/4"N, 1/4"centerline 1/4"S.Hairline cracks center line NW of culv. Crack full width E. of culvert	Settlement 1/8"N, 1/8"centerline 1/4"S.Hairline crack full width W. of culvert	Settlement 0 1 hairline crack W. of culvert in N. lane only	Settlement N 1/4", E 1/8",S.O. 1 hairline crack E. of culvert only	Settlement 3/8"N, 1/4"centerline 1/8"S. No cracks	Settlement 0 1 hairline crack E. of culvert	Settlement 0 1 hairline crack E. of culvert in S. lane only

* After ACC Resurfacing Spring and Summer, 1981