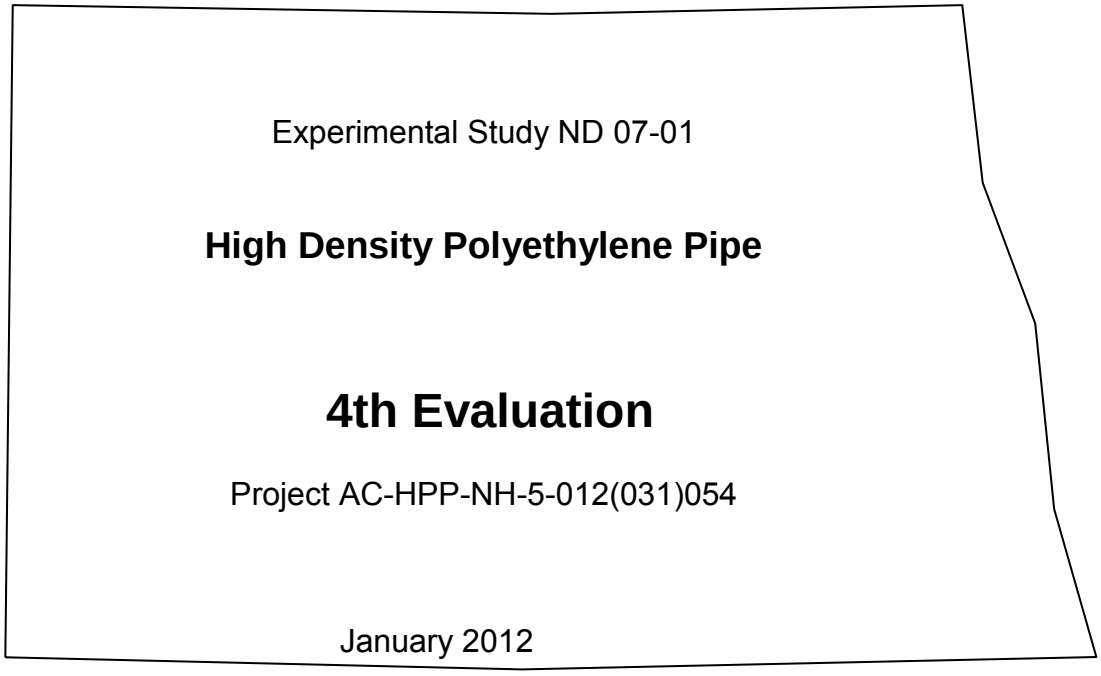
NORTH DAKOTA
DEPARTMENT OF TRANSPORTATION

MATERIALS AND RESEARCH DIVISION



Experimental Study ND 07-01

High Density Polyethylene Pipe

4th Evaluation

Project AC-HPP-NH-5-012(031)054

January 2012

Prepared by

NORTH DAKOTA DEPARTMENT OF TRANSPORTATION
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Written by
Andrew Mastel

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Disclaimer

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U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

EXPERIMENTAL PROJECT REPORT

EXPERIMENTAL PROJECT

EXPERIMENTAL PROJECT NO. (1)
STATE: ND | YEAR: 2007 | NUMBER: 01 | SUFF:

CONSTRUCTION PROJ NO (8): AC-HPP-NH-5-012(031)054

LOCATION: Adams (28 County)

EVALUATION FUNDING (48)
1 HP&R
2 x CONSTRUCTION
3 DEMONSTRATION
4 IMPLEMENTATION

NEEP NO. (49):

PROPRIETARY FEATURE? (51)
Yes
X No

SHORT TITLE

TITLE (52): High Density Polyethylene Pipe

THIS FORM

DATE (140): MO. January -- YR. 2012

REPORTING: 1 INITIAL 2 X ANNUAL 3 FINAL

KEY WORDS

KEY WORD 1 (145): HDPE
KEY WORD 2 (167): Pipe
KEY WORD 3 (189):
KEY WORD 4 (211):
UNIQUE WORD (233):
PROPRIETARY FEATURE NAME (255):

CHRONOLOGY

Date Work Plan Approved (277)	Date Feature Constructed: (281)	Evaluation Scheduled Until: (285)	Evaluation Extended Until: (289)	Date Evaluation Terminated: (293)
6/2006	Summer 2007	Summer 2012		

QUANTITY AND COST

QUANTITY OF UNITS (ROUNDED TO WHOLE NUMBERS) (297):
24" - $33.06
18" - $29.67
30" - $46.50

UNITS (305):
1 X LIN. FT
2 SY
3 SY-IN
4 CY
5 TON
6 LBS
7 EACH
8 LUMP SUM

UNIT COST (*Dollars, Cents*) (306):

AVAILABLE EVALUATION REPORTS

CONSTRUCTION (315)	PERFORMANCE	FINAL
X	X	

EVALUATION

CONSTRUCTION PROBLEMS (318)
1 NONE
2 SLIGHT
3 x MODERATE
4 SIGNIFICANT
5 SEVERE

PERFORMANCE (319)
1 EXCELLENT
2 GOOD
3 X SATISFACTORY
4 MARGINAL
5 UNSATISFACTORY

APPLICATION (320)

1 ADOPTED AS PRIMARY STD.
2 PERMITTED ALTERNATIVE
3 ADOPTED CONDITIONALLY
4 X PENDING
5 REJECTED
6 NOT CONSTRUCTED

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

REMARKS (321)

Mandrel testing to determine if the HDPE pipes are deflecting was performed several times. The HDPE pipes were tested for construction acceptance on 10/20/07 and for evaluation reasons on 7/23/08, ,08/31/09 ,9/29/10, and 10/05/11. This test is to determine if the pipe is deflecting 5% or greater at any point within each pipeline. The results from the latest testing was; The 5% mandrel could pass through one of the 18" approach pipes, both centerline 24" pipes, and one of the 30" centerline pipes. The 7.5% mandrel was able to pass through all pipelines tested.

Form FHWA 1461

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4th Evaluation
High Density Polyethylene Pipe
ND 07-01

Purpose and Need

Due to the rising construction costs and a high demand for construction materials, the North Dakota Department of Transportation (NDDOT) has been looking for alternatives to current culvert materials. The NDDOT has not used HDPE pipe extensively in the past for this type of application. With continued improvements in material properties, high density polyethylene (HDPE) pipe may be a viable alternative for culvert applications. This experimental study will be used to evaluate the installation and monitor the performance of HDPE pipe for approach and centerline drainage.

Objective

Previous research conducted by Ohio Research Institute for Transportation and the Environment (ORITE) studied 18 thermoplastic pipes. In their study the 18 thermoplastic pipes were instrumented and monitored beneath roadway embankment in Ohio Universitys research facility in Athens, Ohio.

They found that deflections in all of the pipes stabilized within 45 days after completion of construction, except for one pipe, which stabilized in 100 days because it was subjected to additional load from heavy equipment during construction. The change in diameter for each pipe was less than 30.5 mm (1.2 in.) over a period of eight months.

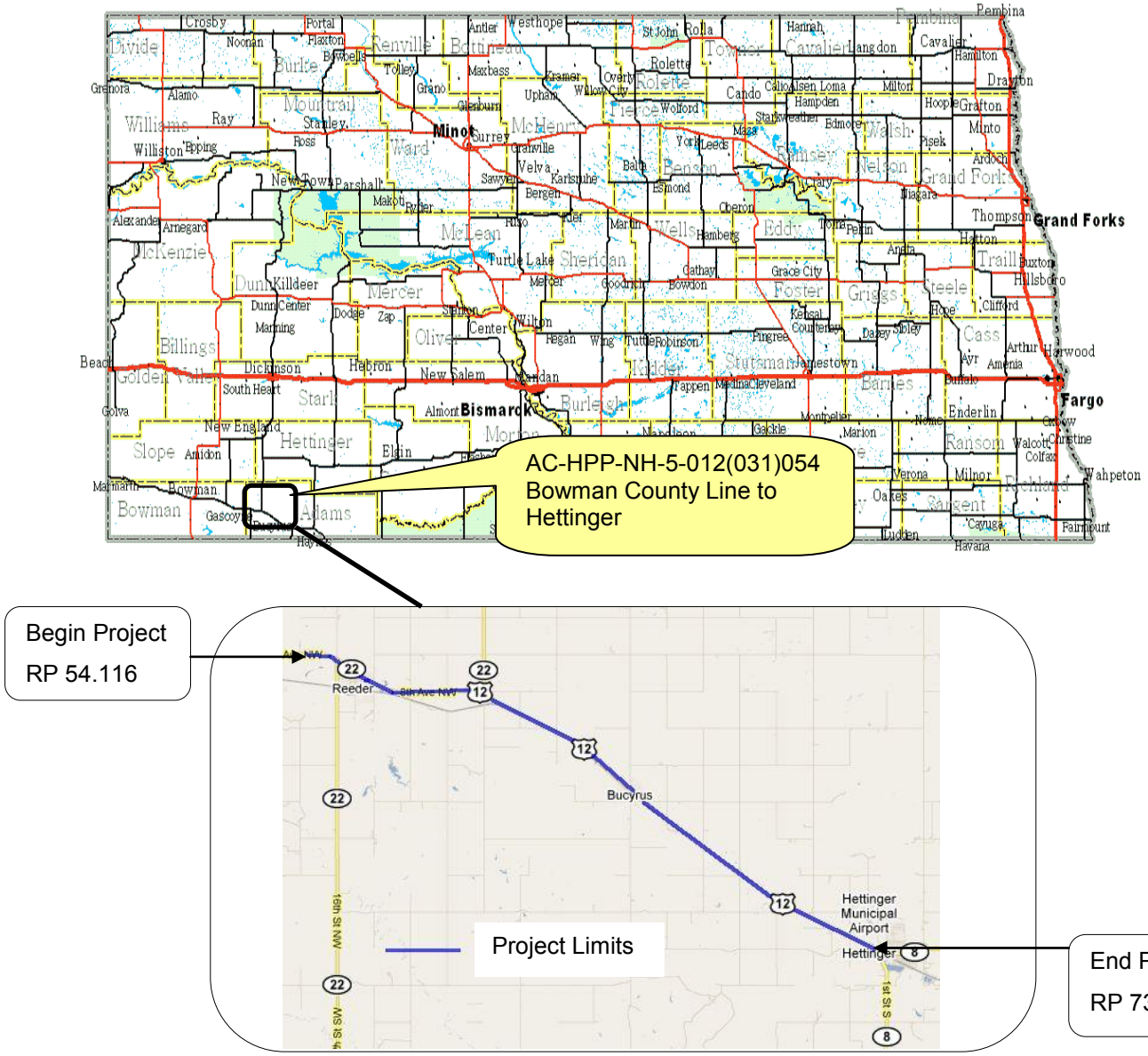
The objective of this research is to determine if HDPE has the structural capacity and durability to perform as an alternative to corrugated steel pipe (CSP) and reinforced concrete pipe (RCP) for culvert applications. This research will also evaluate the proposed installation detail for HDPE pipe.

Scope

For the evaluation of HDPE, four centerline culverts and four approach culverts are specified as HDPE pipe for project AC-HPP-NH-5-012(031)054, to be constructed in 2007. The installation of the eight HDPE pipes will be monitored, and the performance of the pipe will be evaluated and documented. Deflection testing will be performed by the contractor on the installed HDPE pipe as required in the NDDOT Standard Specifications.

Location

The project is located in Adams County from the Adams County line to Hettinger. The project is on US Highway 12 from reference points 54.116 to 73.455. The project length is 19.339 miles.



Design Summary

The design for HDPE pipe for this project was based on the manufacturer's recommendations, state DOTs' current practices, and various other research. The structural design of the corrugated polyethylene pipe required for this project meets AASHTO's *LRFD Bridge Design Specifications*, Section 12, and also conforms to AASHTO M 294 standard specification for corrugated polyethylene pipe.

Evaluation

The HDPE pipes on the NDDOT project will be evaluated annually for a period of 5 years. A report will be written biannually. The performance evaluation will be based on the results of the mandrel testing and visual condition of the pipes. Mandrel testing will be conducted with the assistance of the pipe manufacturer, who will provide the proper size mandrels. Pavement profile data will also be collected during the annual evaluations.

Construction Summary

Project AC-HPP-NH-5-012(031)054 was constructed in the summer of 2007. The prime contractor was Border States Paving Co. of Fargo, ND. The sub-contractor that installed the pipe was Harold H. Schwartz Construction, Inc. of New England, ND. On September 25, 2007 Scott Middaugh and Steven Henrichs of the NDDOT Materials & Research Division along with Jeff Hammer, Territory Manager of the HDPE pipe manufacturer, ADS, Inc. observed the installation of a 24" HDPE centerline pipe. The project engineer was Jason Fischer and the district engineer was Larry Gangl.

Design of the pipes called for centerline and approach pipes to be installed with aggregate backfill. The approach pipes were not installed with aggregate backfill. Ordinary dirt was used to install the four HDPE approach pipes. The left approach pipe at RP 68+1506 was removed and reinstalled in June 2008 due to excess deflection. Aggregate backfill was used. The backfill detail D-714-14 for HDPE pipe at the time of construction is included in Appendix A.

The HDPE pipes that were installed are as follows:

HDPE Pipe Location			Pipe Description	Pipe Length (ft.)
Location #	Reference Point	Station		
1	68+1506	3605 +58	18" South approach pipe	60 ft.
2	68+5472	3645 +24	18" South approach pipe	60 ft.
3	71+1646	3764 +02	24" centerline pipe	86 ft.
4	71+2457	3772 +13	30" centerline pipe	85 ft.
5	71+3060	3778 +16	24"centerline pipe	92 ft.
6	71+3843	3785 +99	30" centerline pipe	84 ft.
7	72+3385	3835 +59	18" South approach pipe	60 ft.
8	72+3385	3835 +59	18" North approach pipe	78 ft.

Table 1 - Pipe location, size, and length

Photo 1: Centerline HDPE pipe being installed

Photo 2: metal end section of HDPE pipe.

Cost

Included in the cost comparison below is the pipe, trench excavation, disposal of unsuitable excavated material on inslope, backfill of suitable excavated material, and corrugated steel end section. The cost comparison of the HDPE pipe to RCP is shown in Table 2:

Pipe Diameter	HDPE Pipe Price		RCP Price	
	Pipe (LF)	End Section (ea.)	Pipe (LF)	End Section (ea.)
18"	$29.67	incidental	$62.09	$655.09
24"	$33.06	$279.13	$100.21	$702.59
30"	$46.50	$417.61	$110.67	$794.24

Table 2 - Cost comparison of HDPE pipe to RCP

Mandrel Testing

Photo 3: Mandrel at the end of an 18" HDPE Pipe

The HDPE pipes were mandrel tested in accordance with section 714.03.A.9 of the NDDOT Standard Specifications. The specification requires a maximum deflection of less than 5% of the inside diameter of the pipe. Below in table 3 is the pipe diameters along with the mandrel size diameters used to test for deflection. A mandrel measuring 28.5" was not available. A lath cut to 28.5" was used to test for deflection in the 30" pipes. Locations of the pipes are listed in tables 1 and 4. Testing was performed in 2007,2008, 2009, 2010, and 2011. The field notes are in the evaluation sections and a summarized table of the results are in the most current evaluation sections.

Pipe Diameter	Mandrel Diameter (5% less than Pipe D)	Mandrel Diameter (7.5% less than Pipe D)
18"	17.1"	16.65"
24"	22.8"	22.2"
30"	28.5"	27.75"

Table 3: Pipe Diameters along with the mandrel diameter used to test for deflection.

Pavement Profile Testing

Materials and Research used their Ames Lightweight Profiler to collect pavement surface IRI data shortly after construction in the fall of 2007 and in June of 2008. In 2009 the IRI data was collected with their Ames High Speed Profiler. Materials and Research broke down the data in the eastbound direction into 25 foot lots to show a comparison of the 2007, 2008, and 2009 Mean Roughness Index (MRI) data. The MRI is the IRI mean of the right and left laser of the profiler.

Shown in the most current evaluation is the MRI comparison of the 25 foot interval that the pipe is in along with the interval before and after the pipe.

Post Construction Evaluation

Mandrel Testing

The initial mandrel testing on this project was performed for construction acceptance. Jason Fisher and other Dickinson District personnel along with the pipe manufacturer (ADS Hancor) representative mandrel tested the HDPE pipes on 10/20/2007. Included are the mandrel testing field notes from 2007 and Table 4 has the overall results of all of the mandrel testing.

18” approach pipes (locations 1,2,7, and 8)

The four 18” approach pipes were not installed in accordance with standard drawing D-714-14. Ordinary dirt was used instead of aggregate. At location 1 the 18” approach pipe failed the mandrel test at approximately 15 feet from the ends on both sides. This pipe was scheduled to be reset in 2008. The other three pipes passed and will be left in place without aggregate backfill.

24” Centerline Pipes (locations 3 and 5)

Both 24” centerline pipes passed the mandrel test.

30” Centerline Pipes (locations 4 and 6)

The mandrel supplied by the contractor for the 30” pipes was too heavy and difficult to

pull through the pipes. Instead the Project Engineer cut a lath to 28.5" (30" less 5%) and crawled into the pipe. The lath did not pass through the pipe at location 4. This pipe was deflected to approximately 27.5", six feet in from the south end, where a 1.5" opening was present between seams. This pipe was excavated and the pipe returned to its original shape. It was then relaid and passed inspection. At location 6 a deflection was located approximately 6'-10' from the south end of the pipe. The deflection measured 28.5" which is still passing.

Pavement Profile Testing

Materials and Research collected profile data in the fall of 2007 with their Ames Lightweight Profiler. This data is located in Table 5.

1st Evaluation

Mandrel Testing

Materials and Research personnel, Dickinson District personnel and, the pipe manufacturer representative Roger Baldwin from ADS Hancor, mandrel tested the HDPE pipes on 07/23/2008. The pipe manufacturer representative brought an adjustable mandrel. This mandrel was used in the 18" and 24" HDPE pipes to test for deflection. The mandrel was adjustable to two sizes, 5% less than nominal, and 8% less than nominal. A lath (cut to 5% less than nominal) was used to evaluate the 30" HDPE pipes. Included is the mandrel testing field notes from 2008. Table 4 has the summarized results of all of the mandrel testing.

The areas where the mandrel did not pass through were usually near a pipe joint.

18" approach pipes (locations 1,2,7, and 8)

The pipe at location 1 was reinstalled in late May or early June of 2008 due to deflection issues during initial construction. Once the pipe was removed it returned to its original shape and was reinstalled. The approach pipe detail D-714-14 in Appendix A was used. The 5% mandrel was able to pass through this pipe.

At location 2 the 5% mandrel was unable to pass through approximately 20 ft. in

from the east and west end of the pipe. The 8% mandrel was able to pass through the pipes. The pipe at location 7 did not pass through at approximately 20 ft. in from the east end of the pipe using the 5% mandrel. The pipe at location 8 did not pass through at approximately 19 ft. in from the east and west ends of the pipe using the 5% mandrel.

24” Centerline Pipes (locations 3 and 5)

The 5% mandrel was able to pass through both 24” pipes.

30” Centerline Pipes (locations 4 and 6)

The 30” pipe at location 4 was too muddy to crawl through to properly inspect for deflection. The pipe at location 6 passed inspection using a lath cut to 28.5”.

Pavement Profile Testing

Materials and Research collected profile data in June of 2008. The pavement profile over the pipes is significantly worse. This is probably due to embankment settlement. Table 5, located in the most current evaluation, has the most current profile data.

2nd Evaluation

Mandrel Testing

Materials and Research personnel, along with the pipe manufacturer's representative, mandrel tested the HDPE pipes on 08/31/2009. The representative provided three mandrels sized 5% less than the nominal diameter of the 18", 24", and 30" pipes. A lath (cut to 5% less than nominal diameter) was used to evaluate the 30" HDPE pipes because the 30" mandrel measured 27.11" which was less than the required 28.5 in. Included is the mandrel testing field notes from 2009. Table 4 has the summarized results of all of the mandrel testing.

The areas where the mandrel did not pass through were usually near a pipe joint.

18" approach pipes (locations 1,2,7, and 8)

The 5% mandrel was able to pass through the pipe at location 1. It was unable to pass through the pipe at location 2, approximately 20 ft. in from the east end and 13.5 ft. in from the west end of the pipe.

At location 7 the mandrel passed through when pulling from west to east. When

performing the mandrel test from east to west it does not pass through at 18 ft. in from the east side end of the pipe. At location 8 the mandrel did not pass through at 17 ft. in from the east end and 17 ft. in from west end. Water was standing in the pipe 17 ft. in from the west end.

24" Centerline Pipes (locations 3 and 5)

The 5% mandrel was able to pass through both 24" pipes at locations 3 and 5. The pipe at location 5 had water standing in the bottom of the pipe at the north end.

30" Centerline Pipes (locations 4 and 6)

The 30" pipe at location 4 did not pass the lath test at 8 ft. in from the south end of the pipe. The 30" pipe at location 6 passed inspection using a lath cut to 5% (28.5").

3rd Evaluation

Mandrel Testing

Materials and Research personnel, along with the pipe manufacturer's representative, mandrel tested the HDPE pipes on 09/29/10. The representative provided two mandrels sized 5% less than the nominal diameter of the 18"and 24" pipes. A lath (cut to 5% less than nominal diameter) was used to evaluate the 30" HDPE pipes. Included is a table that summarizes all of the mandrel tests.

The areas where the mandrel did not pass through were usually near a pipe joint.

18" approach pipes (locations 1,2,7, and 8)

The 5% mandrel was able to pass through the pipe at location 1. It was unable to pass through the pipe at location 2, approximately 4.5 ft. in from the east end and 12.5 ft. in from the west end of the pipe.

When performing the mandrel test at location 7 it did not pass through at 16.5 ft. in from the east and 16 ft. in from the west end of the pipe. At location 8 the mandrel did not pass through at 13.5 ft. in from the east end..

24" Centerline Pipes (locations 3 and 5)

The 5% mandrel was able to pass through both 24” pipes at locations 3 and 5.

30” Centerline Pipes (locations 4 and 6)

The 30” pipe at location 4 did not pass the lath test at 8 ft. in from the south end of the pipe. The 30” pipe at location 6 passed inspection using a lath cut to 5% (28.5”).

4th Evaluation

Materials and Research personnel, along with the pipe manufacturer’s representative, mandrel tested the HDPE pipes on 10/05/11. The representative provided several mandrels sized 5% and 7.5% less than the nominal diameter of the 18”, 24” and 30” pipes. In 2011 if a 5% mandrel could not pass through the pipeline a 7.5% mandrel was then used to get a better understanding of how much deflection was occurring in the pipelines. Included is a table that summarizes all of the mandrel tests.

The areas where the mandrel did not pass through were usually near a pipe joint.

Summary of Mandrel Testing Results

HDPE Pipe Location			Pipe Description	Pipe Length	Mandrel Testing Results (Deflection= ≤ 5%,>5%, or ≤7.5%)					
Location #	Reference Point	Station			2007	2008	2009	2010	2011	2011 Comments
1	68+1506	3605 +58	18" North AP	60 ft.	>5%	≤ 5%	≤ 5%	≤ 5%	≤ 5%	In 2008 pipe was reinstalled with granular backfill.
2	68+5472	3645 +24	18" North AP	60 ft.	≤ 5%	>5%	>5%	>5%	>5% but ≤7.5%	5% Mandrel failed 14.0’ in from the east and 14.0’ in from the west.
3	71+1646	3764 +02	24" CL	86 ft.	≤ 5%	≤ 5%	≤ 5%	≤ 5%	≤ 5%	
4	71+2457	3772 +13	30" CL	85 ft.	≤ 5%	N/A	>5%	>5%	>5% but ≤7.5%	5% Mandrel failed 8.0’ in from the south end of the pipe.
5	71+3060	3778 +16	24"CL	92 ft.	≤ 5%	≤ 5%	≤ 5%	≤ 5%	≤ 5%	
6	71+3843	3785 +99	30" CL	84 ft.	≤ 5%	≤ 5%	≤ 5%	≤ 5%	≤ 5%	
7	72+3385	3835 +59	18" South AP	60 ft.	≤ 5%	>5%	≤ 5%	>5%	>5% but ≤7.5%	5% Mandrel failed 18.5’ in from the east end.
8	72+3385	3835 +59	18" North AP	78 ft.	≤ 5%	>5%	>5%	>5%	>5% but ≤7.5%	5% Mandrel failed 16.5’ in from the east and 16.5 in from the west.

Table 4: Pipe locations and mandrel testing results

Pavement Profile Testing

In June of 2009 the Dickinson District maintenance personnel placed cold mix asphalt to fill the dips above the pipes. A 28 foot wide slurry seal was also applied in 2009. The dips above pipes were not isolated to the HDPE pipe locations.

Below are the results of the pavement profile data collected over the centerline HDPE pipes.

	Average MRI over three 25 ft lots					
Pipe	**RP**	**Station**	**2007 MRI**	**2008 MRI**	**2009 MRI**	**2011 MRI**
24" RCP*	70+4404	3740+22	34.90	69.47	40.65	N/A
Box Culvert*	71+0904	3756+60	41.17	51.83	75.47	243.22
24" HDPE	71+1646	3764+02	55.87	88.20	110.17	160.68
30" HDPE	71+2457	3772+13	54.53	132.10	155.10	193.91
24" HDPE	71+3060	3778+16	52.63	129.87	181.10	176.81
30" HDPE	71+3843	3785+99	61.23	189.13	184.53	191.97
24" RCP*	72+0285	3804+59	61.70	193.30	218.53	231.60
Box Culvert*	72+1558	3817+32	41.27	36.77	271.70	373.14

Table 5: IRI data over HDPE and RCP pipes

***These pipes are within the limits where profile testing has been done and are for ride comparison reasons only.**

Summary

The four 18” approach pipes were not installed in accordance with standard drawing D-714-14. Ordinary dirt was used instead of aggregate.

After construction, in the fall of 2007, three of the four 18” approach HDPE pipes passed the 5% (17.1”) mandrel test. The 18” approach pipe at location 1 did not pass the 5% mandrel test after construction. This pipe was reinstalled using D-714-14 standard drawing. The other approach pipes were left in place.

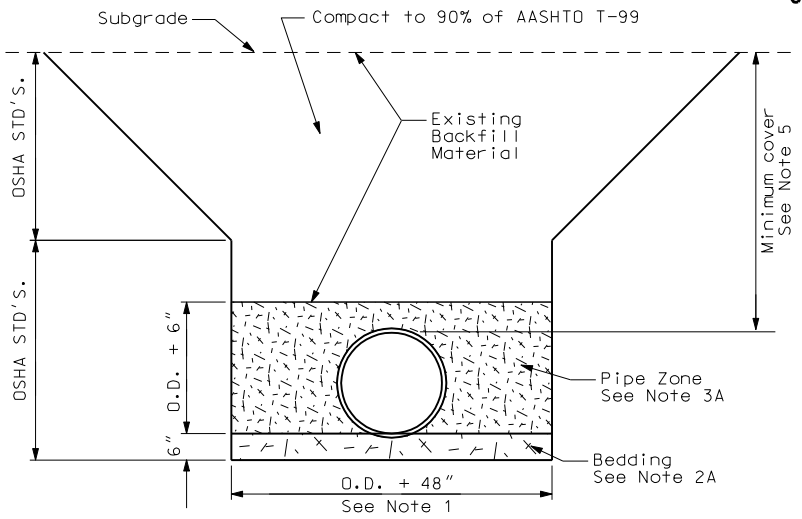
Mandrel testing, performed to determine if the HDPE pipes were deflecting, was performed several times. The HDPE pipes were tested for construction acceptance on 10/20/07 and for evaluation reasons on 7/23/08, 08/31/09, 09/29/10, and 10/05/11. This test was conducted to determine if the pipe was deflecting 5% or greater at any point within each pipeline. In 2011 if a 5% mandrel could not pass through the pipeline a 7.5% mandrel was then used to get a better understanding of how much deflection was occurring in the pipelines. The results from the latest testing were: One of the 18” approach pipes had ≤ 5% deflection at location 1. Three 18” approach pipes had > 5% but ≤ 7.5% deflections at locations 2, 7 and 8. At locations 3 and 5 both centerline 24” pipes had deflections ≤ 5%. The centerline 30” at location 6 had a deflection ≤ 5% and the centerline 30” at location 4 had a deflection > 5% but ≤7.5%.

In 2008, dips in the roadway appearing at pipe locations (HDPE, RCP, and Box culverts) were thought to be the result of embankment settlement. In June of 2009, the Dickinson District maintenance employees filled the dips above the pipes and box culverts with cold mix asphalt, followed by a slurry seal. Pavement profile data was collected prior to and after the 2009 repairs. The profile data collected in 2011 shows continued deterioration in pavement profile over the centerline pipes and box culverts in most locations. The evaluation of the centerline HDPE pipes has not shown a change in pipe deflections since 2009.

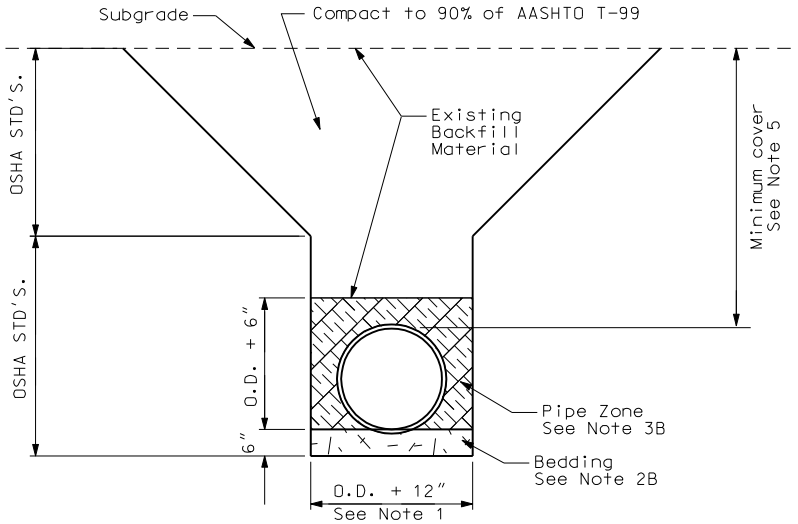
Appendix A: Standard Drawing D-714-14

CORRUGATED POLYETHYLENE PIPE INSTALLATION

D-714-14



CORRUGATED POLYETHYLENE PIPE DETAIL
Alternative A: Aggregate in Pipe Zone



CORRUGATED POLYETHYLENE PIPE DETAIL
Alternative B: Controlled Density Fill in Pipe Zone

Notes:

1. The polyethylene pipe requires a trench installation. Embankment shall be placed prior to installing the polyethylene pipe if necessary. The minimum height of the embankment shall be to the top of the Pipe Zone. The contractor shall not be permitted to drive over the pipe until the pipe has minimum cover. Minimum trench width shall be as recommended by the pipe manufacturer or as shown on the drawing, whichever is greater.

2. Bedding material shall be Aggregate Base Course Class 3M or Class 5.

   A. Alternative A: The aggregate shall be loosely compacted to allow for pipe seating.

   B. Alternative B: The aggregate shall be graded to uniformly support the pipe, and the trench bottom recessed to fit the bell and spigot.

3. The pipe shall be laid to line and grade and secured to prevent floating or shifting of the pipe during placement of material in the Pipe Zone. Backfill material in Pipe Zone shall be Alternative A or B unless otherwise specified.

   A. Alternative A: Aggregate Base Course Class 3M or Class 5. The aggregate shall be compacted in layers not to exceed six inches using a hand-held vibratory plate compactor or a hand-held mechanical tamper.

   B. Alternative B: Controlled Density Backfill.

   The properties of the controlled density backfill shall be a blend of cement, water, pozzolanic materials, and fillers. The material shall be fluid on placement to flow around and fill the voids around pipe in the backfill area. The material shall be able to support normal loads after six hours and have a compressive strength in the range of 75 psi to 125 psi at 28 days. The material shall be such that it lends itself to easy removal with a tractor backhoe. If the mix design shown is used, no further testing will be required. The mix design yields approximately one cubic yard of flowable mortar.

MIX DESIGN	
Cement	100 lbs
Fly Ash	300 lbs
Fine Aggr	2600 lbs
Water	70 gals

   No material shall be placed over the controlled density backfill for at least 8 hours after placement.

4. Material delivered to the site shall be inspected for dimensions and condition. The pipe shall be free from visible defects and not exhibit cracking or splitting. Pipe damaged by crushing or stretching shall not be used.

5. Minimum cover shall be 24 inches or as determined by the manufacturer's recommendations, whichever is greater. Any pipe damaged due to live load shall be replaced at the contractor's expense.

6. Use Corrugated Steel End Sections.

7. Notify Materials and Research at least 72 hours in advance of installing the pipe. Call 701-328-6915

Included in Pay Item
1) Pipe
2) Trench excavation
3) Disposal of unsuitable excavated material and placement of suitable excavated material on inslope.
4) Backfill of suitable excavated material
5) Aggregate Base Course Cl 3M or Cl 5
6) Control Density Fill
7) Corrugated Steel End Sections

Pay Items
1) Pipe Conduit

NORTH DAKOTA DEPARTMENT OF TRANSPORTATION	
08/03/87	
REVISIONS	
DATE	CHANGE
06-21-00	Major revision
12-01-04	PE Stamp added
11-06-06	Major revisions
12-13-06	Add note 7

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