Evaluation of High Density Polyethylene (HDPE) Pipe
SD96-11
Final Report

Prepared by
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ACKNOWLEDGMENTS

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The assistance of the Martin, SD SDDOT Maintenance Unit is gratefully acknowledged.
This report presents the findings and recommendations on the evaluation of High Density Polyethylene (HDPE) Pipe resulting from a 1996 Transportation Enhancement/Hazard Elimination Project in Martin, South Dakota. This was the first project where HDPE pipe was allowed to be installed under a state highway in South Dakota.

Department researchers installed instrumentation and conducted deflection testing on a 760 mm (30 in) HDPE pipe installed under US Highway 18 in Martin, South Dakota. A horizontal inclinometer probe was used to determine vertical heave or settlement. Surface profiles were monitored with a Dipstick® Floor Profiler. Thirteen separate sets of measurements were taken between August 1996 and June 1997.

Costs were determined for installation and delivery of both HDPE pipes and reinforced concrete pipes (RCP). Neighboring states were surveyed to determine their costs for storm sewer pipes as well as specifications for installing HDPE pipes.

Recommendations were made to allow the installation of HDPE pipe based on information received from the state survey, literature reviews, and the results of the Martin, South Dakota Project.
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Executive Summary

This report presents the findings and recommendations on the Evaluation of High Density Polyethylene (HDPE) Pipe resulting from a 1996 Transportation Enhancement/Hazard Elimination Project in Martin, South Dakota. Because the SDDOT had never used HDPE for any mainline drainage application, a research team was directed to investigate the suitability and cost effectiveness of using HDPE pipe as storm sewer with shallow cover at the Martin, South Dakota project.

Research Objectives

The technical panel overseeing Research Project SD96-11 “Evaluation of High Density Polyethylene Pipe (HDPE)”, defined the following objectives for the study:

1) Determine the suitability of High Density Polyethylene Pipe (HDPE) as storm sewer pipe.
2) Determine the cost effectiveness of using High Density Polyethylene Pipe.
3) Develop specifications for using HDPE for use on mainline applications.

Project Design

The plans for the 1996 project specified a 915 mm (36 in) HDPE pipe which was to replace a 455 mm (18 in) storm sewer pipe under US Highway 18 just west of its intersection with SD 73 in Martin. The plans were revised to specify a 760 mm (30 in) and a 610 mm (24 in) HDPE pipe so that a minimum of 305 mm (12 in) of cover could be placed over the pipes.

Installation

The contractors excavated the trench and prepared the pipe bedding to conform to the requirements of Class B bedding. After the bedding material was compacted, SDDOT staff dug a shallow trench and placed a 85.8 mm (3.38 in) acrylonitrile-butadiene-styrene (ABS) plastic
inclinometer pipe at the centerline for the 760 mm (30 in) HDPE pipe. Two 6.1 m (20 ft) sections of the 760 mm (30 in) HDPE pipe were connected together and placed on top of the inclinometer pipe. Plastic straps were attached to hold the inclinometer pipe in place during the fill operations.

An additional 3.05 m (10 ft) of HDPE pipe was cut with a gas powered hand saw from one of the HDPE sections which had been stockpiled adjacent to the trench. It was then lowered into the trench by hand. No heavy equipment was needed, since the 760 mm (30 in) HDPE pipe only weighs 23.1 kg/m (15.4 lb/ft), as compared to 576 kg/m (384 lb/ft) for 760 mm (30 in) concrete pipe. An additional 85.8 mm (3.38 in) ABS plastic inclinometer pipe was attached to the top of the 760 mm (30 in) HDPE pipe so that deflection measurements could be taken from both the top and the bottom of the HDPE pipe.

Sandy fill was placed and compacted in 152.5 mm (6 in) lifts until 152.5 mm (6 in) of sand covered the 760 mm (30 in) HDPE pipe. An additional 305 mm (12 in) of base course material was then placed over the pipes and compacted. Four 50 mm (2 in) lifts of asphalt completed the trench fill, resulting in a total of 650 mm (26 in) of cover over the 760 mm (30 in) HDPE storm sewer pipe. The 650 mm (26 in) depth of cover was the result of an apparent bust in the survey, as the plans had called for a minimum of 305 mm (12 in) cover.

**Project Monitoring**

Immediately upon completion of the final 50 mm (2 in) asphalt lift, inclinometer readings and surface profile readings were taken to establish a base set of data for monitoring. A horizontal inclinometer probe was used to determine vertical heave or settlement. Surface profile readings were taken with a Dipstick® Floor Profiler. A grid was measured and marked on the asphalt pavement so that a profile could be established and monitored throughout the project study period. Between August 14, 1996 and June 26, 1997 eleven separate dipstick profiles were taken on each of the nine grid sections covering the storm sewer pipes.
The final check of the 760 mm (30 in) HDPE storm sewer was completed visually. During each visit to the site, research staff climbed into the storm sewer to assess its condition. Visual checks were also made on the attached 915 mm (36 in) HDPE storm sewer pipes and the parallel 610 mm (24 in) storm sewer pipe.

**Project Evaluation**

An evaluation of the surface profiles indicated that very little movement occurred throughout the monitoring period. Sections one through seven had maximum changes in elevation ranging from 4.65 mm (.186 in) to 5.8 mm (.232 in). Section eight had a maximum elevation change of 11.2 mm (.45 in). Section nine, which was located directly over the entire length of the 760 mm (30 in) pipe had a maximum elevation change of 4.5 mm (.18 in). All of the elevation changes were lower than the original profile. (A diagram of the test sections is located under task 7 of the full report.)

The horizontal inclinometer probe recordings were analyzed to determine maximum point deflections and average pipe deflections on both the top and bottom of the 760 mm (30 in) HDPE storm sewer pipe. Eight total recordings were made on the bottom of the pipe and thirteen recordings were taken on the top of the pipe. The difference in the number of recordings was due to water, sand, and ice covering the bottom inclinometer pipe.

Based on eight separate recordings between August 14, 1996 and May 20, 1997 the bottom inclinometer pipe had a maximum point deflection of 0.77 mm (.0308 in) or .10%. The average pipe deflection was 0.035 mm (.0014 in) or .005%.

Based on the thirteen recordings which were taken between August 14, 1996 and June 26, 1997, the top inclinometer pipe had a maximum point deflection of 2.278 mm (.0911 in) or .30%. The average top pipe deflection was 0.105 mm (.0042 in) or .01%. All of the deflection measurements were well within the established five percent deflection threshold established by the technical panel.
Project Costs

An evaluation of the HDPE pipe bids and the corresponding RCP pipe bids for the Martin project showed that the 1996 HDPE pipe bid price was 39% of the cost of the 1995 Martin RCP bid price. Both the installation cost and the HDPE unit bid price averaged 39% of the cost of the 1995 RCP bid. These costs were for the pipe and installation only, and did not include tees, wyes, bends or other connectors.

The installation and unit costs of over 550 M (1,800 ft) of assorted sizes of HDPE pipes bid in the 1996 Martin project were compared with the 1997 statewide average costs for the same amount of RCP round pipe and installation costs. The results showed the Martin project HDPE unit and installation costs were 52% of the 1997 statewide average cost of RCP furnished round pipe and installation. The actual Martin HDPE installation bid costs were 71% of the average statewide cost of RCP installation, while the furnished unit HDPE pipe bid costs were 43% of the average statewide cost of furnished RCP pipe. It should be noted that the 1997 RCP unit and installation costs were a statewide average for all projects, while the HDPE costs were for the Martin project only, because no other project using HDPE pipe had been let.

Conclusions and Recommendations

Numerous studies have been completed which address the use of HDPE pipes for storm sewer and culvert applications. While some neighboring states have not used HDPE pipe for either application, most will allow its use if requested by a municipality, county or contractor. The Iowa DOT has used HDPE for over ten years under driveways, field entrances and unclassified roads. The Nebraska Department of Roads has recently adopted a new policy (DES97-01) which allows HDPE to be considered as an alternative when designing and constructing highways.

Research from the University of Nebraska-Lincoln (1996) indicates that when polyethylene pipe is included in the construction plans as an alternate to reinforced concrete pipe or corrugated
metal pipe, bid prices for each type of pipe are generally lower. In many cases the unit cost of polyethylene is less than either reinforced concrete or corrugated metal pipe.

Based on the extensive literature review completed for this research project, and the favorable results obtained during the Martin, South Dakota Transportation Enhancement/Hazard Elimination Project, the following recommendations are offered for consideration by the South Dakota Department of Transportation Research Review Board:

1. **Corrugated high density polyethylene pipe should be specified as an alternative for storm sewer and culvert installations on all South Dakota roadways where pipe sizes 305 mm (12 in) to 915 mm (36 in) are used.** Literature indicates that HDPE is an acceptable alternative to both reinforced concrete pipe and corrugated metal pipe if proper installation procedures and materials are used. The Martin project and other studies also show that the costs for installation of storm sewer and culverts are generally lower when polyethylene pipe is specified as an alternative.

2. **The 1998 Standard Specifications for Roads and Bridges, South Dakota Department of Transportation, Section 990.1 F. Corrugated Polyethylene Pipe should be retained as it is currently written “Corrugated polyethylene pipe, couplings, and fittings shall conform to the requirements of AASHTO M 294”.** Extensive research studies and national surveys of states indicate that AASHTO M 294 is the standard that is currently specified and widely used.

3. **A 5% deflection criterion should apply to the pipe when HDPE is installed on any South Dakota maintained highway.** The deflection testing can be conducted as per procedures identified in ASTM Designation D 2321-89 (Reapproved 1995) Section X1.13 and X1.13.1 “Deflection testing”.

4. **The 1998 Standard Specifications for Roads and Bridges, South Dakota Department of Transportation, Section 450.3 C, Corrugated Polyethylene Pipe Culverts: “Corrugated polyethylene pipe culverts shall be installed according to manufacturer instructions”,**
should be modified to require that “corrugated polyethylene pipe be installed according
to standards specified in ASTM D 2321 - 89 Standard Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications”. This modification addresses storm sewer installations as well as culvert installations. The use of the ASTM D 2321 standard provides a reliable guideline for the installation of all polyethylene pipe. While manufacturers’ instructions are important, the installation decisions should be made by SDDOT engineers based on consistent national standards.

5. The minimum cover for corrugated polyethylene pipes should be established as 457 mm (18 in) for all South Dakota Department of Transportation arterial highway drainage applications. The 1997 Iowa “Investigation of Plastic Pipes for Highway Applications: Phase II” report suggested that 305 mm (12 in) was an acceptable minimum cover for all roadways. Specifications from other states varied from 305 mm (12 in) of cover to 610 mm (24 in) of cover. While research studies indicate the 305 mm (12 in) minimum cover requirement is acceptable, South Dakota does not have much experience with the installation of polyethylene pipe, therefore it is better to be more conservative until additional installation experience is gained.

6. The minimum cover for corrugated polyethylene pipes should be established as 305 mm (12 in) for all collectors, secondary roadways and private driveways where truck or other heavy vehicle traffic is minimal. Research conducted in Iowa in 1997 indicated that a cover thickness less than 610 mm (24 in) is acceptable provided the backfill is well compacted.

7. The maximum fill height for corrugated polyethylene pipes should be established as 6.1 m (20 ft) with a 90 percent Standard Proctor Density compaction. Although this is a conservative figure when compared with manufacturers’ literature and studies completed by the College of Engineering and Technology, University of Nebraska - Lincoln and the Engineering Research Institute, Iowa State University, it is compatible with the current
practices of the Minnesota Department of Transportation and provides a reasonable starting point for future HDPE installations by the SDDOT.

8. **The South Dakota Department of Transportation should allow the option of using polyethylene end sections in municipal settings.** This would require that the Plan Note for Approach Pipe currently used in rural areas be modified accordingly.

9. **Inspection procedures should be rigorously followed to insure the installation and compaction specifications defined in ASTM D 2321 are maintained.** Available literature indicates that most failures of polyethylene and other types of drainage pipe are caused by poor installation and compaction. Concerted inspections of drainage projects will allow Department engineers and contractors to share their expertise and provide our tax paying citizens with good quality drainage projects at competitive prices.
Introduction

Until the summer of 1996, the South Dakota Department of Transportation (SDDOT) had not evaluated the use of High Density Polyethylene Pipe (HDPE) for mainline drainage applications. Historically, the Department has typically used reinforced concrete pipe (RCP) for mainline drainage applications including sanitary sewer, storm sewer, and culverts. While the Department uses a plan note allowing HDPE pipe to be installed as culvert drains in crossovers, field entrances and approaches, there have not been any HDPE pipe installations since the plan note was approved in the early 1990’s.

Background

In the summer of 1995, the SDDOT assisted the City of Martin, South Dakota with the development of a Transportation Enhancement/Hazard Elimination Project which included the installation of storm sewer, bike paths, and the reconstruction of a portion of S.D. Highway 365 and its intersection with U.S. Highway 18. Project P8004 and P-PHOENH(32) were originally let in August of 1995 but the bids came in higher than the available funding causing all bids to be rejected. During the following year, a number of cost cutting steps were taken to reduce the overall cost of the project. The use of HDPE pipe provided one cost saving method and helped enable the project to be rebid in June, 1996.

The revised project plans called for HDPE pipe to be installed across Highway 18 by trench excavation with a 250 mm (10 in) minimum cover not including the asphalt thickness. The project was designed for a 915 mm (36 in) inside diameter round pipe which was to replace an existing 455 mm (18 in) corrugated metal drainage pipe (CMP). Prior to the construction of the storm sewer project, the design firm “The Alliance of Architects and Engineers” noted a possible elevation error on the plan sheets. Following meetings with the City of Martin and the SDDOT, it was decided to replace the 915 mm (36 in) pipe crossing U.S. Highway 18 with a 760 mm (30 in) and a 610 mm (24 in) drainage pipe. This would allow a minimum cover of 305 mm (12 in) of fill to be placed over both pipes in the roadway area.
While the intent of the research project was to evaluate the use of HDPE pipe with minimum cover, a bust in the survey resulted in a final cover of 650 mm (26 in) over the 760 mm (30 in) HDPE pipe.
Research Objectives

The technical panel overseeing Research Project SD96-11 “Evaluation of High Density Polyethylene Pipe (HDPE)”, defined the following objectives for the study:

1) Determine the suitability of High Density Polyethylene Pipe (HDPE) as storm sewer pipe.
2) Determine the cost effectiveness of using HDPE.
3) Develop specifications for using HDPE for use on mainline applications.

Since the SDDOT had never used HDPE for any mainline drainage application, a research team was directed to investigate the suitability and cost effectiveness of using HDPE pipe as storm sewer with shallow cover at the Martin, South Dakota project. Contact with other State DOTs and HDPE pipe manufacturers indicated that HDPE pipe was a more cost effective option than the alternative reinforced concrete pipe. It was estimated that the rebidding of the Martin storm sewer project would save approximately $20,000 by using HDPE pipe instead of the standard reinforced concrete pipe which was in the original construction plans for this project.

The South Dakota Department of Transportation “Standard Specifications for Roads and Bridges” Sections 450 and 990 specify that corrugated polyethylene pipe, couplings and fittings shall conform to the requirements of AASHTO M 294 and the pipe culverts shall be installed according to the manufacturers’ instructions (1). Since the Department had limited experience with HDPE pipe, this research project was designed to monitor installation techniques, deflection, roadway surface profiles, and determine which specifications could be used on future projects using HDPE pipe.
Research Tasks

The technical panel defined the following research tasks:

**Task 1: Meet with the technical panel**

*Meet with the technical panel to review the project scope and work plan.* Research staff and the project monitor met with the technical panel to develop the scope of work for this project. The technical panel was kept informed on all activities through the use of personal contact and electronic mail updates.

**Task 2: Review and summarize literature**

*Review and summarize literature regarding design and installation of High Density Polyethylene Pipe (HDPE).* A literature search was conducted using the Transportation Research Information Service (TRIS). In addition, manufacturers and other DOTs were contacted and asked to provide specifications and costs for HDPE pipe applications.

An extensive amount of literature discusses both the design and installation of High Density Polyethylene Pipe. Several excellent articles on experimental and analytical studies have been produced at numerous universities such as Utah State University, University of Massachusetts, College of Engineering and Technology University of Nebraska-Lincoln, and the Engineering Research Institute, Iowa State University.

Two manufacturers were contacted to get information on installation techniques for HDPE. Hancor, Incorporated and Advanced Drainage Systems, Incorporated provided recommendations for installation, backfill, and compaction. With very few modifications, the recommended installation techniques followed the requirements established in the American Society for Testing and Materials (ASTM) Designation D 2321-89 (Reapproved 1995) “Standard Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications”.

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The scope of ASTM D 2321-89 is as follows:

1.1 “This practice provides recommendations for the installation of buried thermoplastic pipe used in sewers and other gravity-flow applications. These recommendations are intended to ensure a stable underground environment for thermoplastic pipe under a wide range of service conditions. However, because of the numerous flexible plastic pipe products available and the inherent variability of natural ground conditions, achieving satisfactory performance of any one product may require modification to provisions contained herein to meet specific product requirements”. (2)

The standard covers material classifications, trench excavation, backfill techniques, compaction requirements and minimum cover necessary before traffic or construction equipment crosses the pipe. Depending on the size of the pipe that is installed, the manufacturers may recommend modifications to the standard. Generally, the modifications suggested in the manufacturers’ specification manuals are more conservative than the ASTM standard. The exception to this is minimum cover requirements, where the manufacturers suggest a minimum cover of 305 mm (12 in) and the ASTM standards recommend a minimum cover of 610 mm (24 in) or one pipe diameter, whichever is larger. Several articles recommended that the manufacturer be contacted for specific information concerning design and installation of HDPE.

While ASTM D 2321 provides guidance for trench installations, South Dakota also uses embankment fill and modified embankment installations. This research report focuses on trench installations and researchers did not complete field analysis of embankment installations. However, literature provided by HDPE manufacturers indicates that embankment installations generally require a soil envelope adequate to support all the loads on the pipe. This envelope has size requirements that are similar to the cover requirements specified in ASTM D 2321.

AASHTO “Standard Specifications for Highway Bridges” Sixteenth Edition, 1996, Section 18 “Soil-Thermoplastic Pipe Interaction Systems” 18.1.6.1, Soil Parameters, provides the following information on embankment installations: “the minimum width of the soil envelope shall be
sufficient to ensure lateral restraint for the buried structure. The combined width of the soil envelope and embankment beyond shall be adequate to support all the loads on the pipe. As a guide, the width of the soil envelope on each side of the pipe should be the pipe diameter or 610 mm (24 in), whichever is less. The minimum upper limit of the soil envelope is 305 mm (12 in) above the culvert”. (“The minimum cover shall be measured from the top of a rigid pavement or the bottom of a flexible pavement”).

HDPE manufacturers provide a wide range of connectors and fittings for corrugated pipe sizes including 305 mm (12 in) to 915 mm (36 in). Typical fittings, including coupling bands, standard tees, and elbows of various degrees are readily available. Specially fabricated fittings are available on a case by case basis. All of the fittings must conform to AASHTO M 294 and are fully described in the manufacturers’ product literature.

Studies completed by the College of Engineering, Iowa State University and the University of Nebraska - Lincoln address concerns about the long term effects of ultraviolet (UV) degradation on HDPE pipe stored in direct sunlight for extended periods of time, and its effect on the exposed ends after installation. Unprotected plastics will lose impact strength over time when exposed to UV radiation. To help counter this, manufacturers have incorporated carbon black, which is UV absorbent, into the material. According to manufacturers, the UV absorbent will prevent any substantial loss of strength in the pipe by limiting the effects of UV degradation to a small fraction of the pipe wall thickness. The damaged outer layer then provides protection to the remaining wall thickness.

The Division of Materials and Tests of the Department of Transportation in Tennessee performed laboratory studies to determine the effects of ultraviolet rays on HDPE pipe. Pipe samples were placed on the roof of the facility from December 1988 to February 1990. No deterioration was reported. In addition, a performance review of a 610 mm (24 in) diameter culvert in Ohio indicated that after 14 years of UV exposure, the pipe sample experienced only slight discoloration of the exposed pipe ends.
A number of studies have been completed which address corrosion and abrasion in polyethylene pipes. Literature provided by Hancor, Inc., states that pipe materials react differently under chemically corrosive environments. Individual states often make recommendations on environments where specific products can be used based on their past performance. Soil environments fluctuate widely making it impossible to offer blanket statements about product suitability throughout the country.

Aluminum pipe is acceptable for near neutral (pH 7.0) soil and effluent conditions. Depending on the particular installation, some means of protecting the material may be required. Aluminum is usually not acceptable for use in saline or brackish waters.

Concrete is affected by a combination of low pH, sulfates, and chlorides. Additional protection should be considered in acidic or mildly acidic conditions. Alkaline conditions (high pH) in combination with sulfates tend to create an environment that will adversely affect concrete.

Low pH conditions, in the range of 4.5 or less, may not be suitable for steel pipe. Chlorides, sulfates, and the soil environment will also affect the corrosion rate. Coatings are available to delay the effects of acids, salts, and other aggressive chemicals although the life of the coating may be limited.

HDPE manufacturers’ literature indicates that high density polyethylene is a stable material. Polyethylene has been extensively tested with many potentially corrosive chemicals with few chemicals having any effect on the pipe. It is unaffected by soils or effluents with pH ranges from 1 to 14. HDPE’s ductility and molecular structure result in excellent resistance to abrasion. Polyethylene pipe shows less than 20% of the material loss of concrete pipe in abrasive environments, and is often specified for harsh mine slurries and as a slip liner for deteriorated metal culverts.

In addition to the HDPE manufacturers’ literature described above, several other corrosion studies have been completed. A 1986 review of 16 culvert installations (3 years after installation) in western Pennsylvania by Casner, Cochrane, and Bryan led to the recommendation that
corrugated polyethylene pipe be used in maintenance operations and be included on new design projects. At one particular site, due to acidic water conditions, corrugated steel pipe had to be replaced approximately every 6 months due to corrosion. All polyethylene culverts performed well, and there was no evidence of attack by the acidic waters in the area.

A study completed in 1985 by John O. Hurd and published in Transportation Research Record 1087 reviewed a total of 172 corrugated polyethylene pipe culverts 305 mm (12 in) through 610 mm (24 in) in diameter which were installed in Ohio. The pipes ranged in age from 0-4 years and showed no visible signs of loss of materials. Water pH ranged from 3.5 to 8.3 and flows ranged from non-abrasive to extremely abrasive. A review of the worst case installation identified a 610 mm (24 in) corrugated polyethylene culvert where there is a constant acidic flow at the site, and storm waters carry a bed load of abrasive cobbles. After four years this culvert is in good condition. The invert of the polymeric-coated galvanized corrugated steel pipe previously at that location completely deteriorated in less than one year.

Finally, a study completed by the University of Nebraska - Lincoln, discusses abrasion concerns in the State of Nebraska. The Nebraska Department of Roads (NDOR) has prepared a map of all soil and abrasive conditions, which it uses to determine where a particular type of pipe can be installed. Because abrasion does affect the performance of the pipe material, it is an important issue that should be addressed when specifying a product. However, because there are relatively few areas of moderate and severe abrasion in Nebraska, abrasion concerns have little impact on material selections by the NDOR.

Due to a wide range of environmental and other factors, determining the expected service life of HDPE and other types of pipes can be fairly complicated. Product life is dependent on many factors including wall thickness and exact material composition; size, shape, frequency, and velocity of abrasives; soil and effluent pH and composition; and the ability of the soil, effluent, and pipe to support galvanic corrosion. Design variables include the pipe diameter, compaction density, aggregate class, existing soil type, design height of fill and geographic location.
Literature indicates that as a general guideline, the service life expectancy of HDPE pipes can be considered equivalent to that of RCP. HDPE manufacturers suggest that the minimum design life expectancy is 50 to 75 years. Advanced Drainage Systems, Inc., product literature indicates that HDPE and Reinforced Concrete both have an anticipated service life of 75 years, while corrugated steel pipe with a protective coating has an anticipated service life of 40 years.

These generalized service life figures must be tempered with the dependent factors listed above. Engineering expertise and knowledge of the installation site are very important when determining which product to use. For HDPE, AASHTO Standard Specifications for Highway Bridges Section 18 “Soil Thermoplastic Pipe Interaction Systems” provides guidelines for determining fifty-year design lives for plastic pipes.

**Task 3: Develop deflection criteria**

*Develop deflection criteria for the design and acceptance of HDPE pipe.* ASTM D 2321 indicates that “pipe deflection is the diametral change in the pipe-soil system resulting from the process of installing the pipe (construction deflection), static and live loads applied to the pipe (load-induced deflection), and time dependent soil response (deflection lag). Construction and load-induced deflections together constitute initial pipe deflection. Additional time dependent deflections are attributed primarily to changes in embedment and in-situ soils and trench settlement. The sum of initial and time dependent deflections constitutes total deflection”.

ASTM D 2321 goes on to say “…to ensure specified deflection limits are not exceeded, the engineer may require deflection testing of the pipe using specified measuring devices. To allow for stabilization of the pipe soil system, deflection tests should be performed at least 30 days after installation. However, as a quality control measure, periodic checks of deflection may be made during installation”.

The Hancor, Inc. Drainage Handbook states that deflection is the change in diameter that results when a load is applied to a flexible pipe. When deflections are small, as in most pipe
installations, the reduction in vertical diameter is approximately the same as the increase in horizontal diameter. In pipe design, the vertical dimension is usually of more concern. Vertical deflection is usually limited to 7.5% of the base inside diameter; the base inside diameter is the nominal diameter less manufacturing and out-of-roundness tolerances inherent to the manufacturing process. This level of deflection is highly conservative and is also used in the design of other thermoplastic pipe (3).

A University of Nebraska - Lincoln Report “Comparative Study of Highway Pipe Materials for the Establishment of a Design Selection Policy”, completed in 1996 identifies several studies which address the deflection thresholds. The report uses a maximum deflection of 5% to calculate fill values. This value correlates with the maximum joint deflection allowed by Advanced Drainage Systems, Inc. and Hancor, Inc. to ensure soil tightness. Although the pipe may be capable of withstanding deflections exceeding 5%, the joint may fail with respect to the allowable soil infiltration requirements (4).

An April 1997 survey of neighboring States revealed the following with respect to deflection criteria: Iowa has not established deflection criteria (5); Montana has not established deflection criteria (6); Wyoming uses a maximum of 7% deflection (7); North Dakota does not design any projects using plastic pipe larger than 305 mm (12 in) and did not report any deflection criteria (8); Nebraska did not report any deflection criteria in their survey response (9), however, Nebraska has approved a new policy (DES97-01) which allows the use of HDPE for projects to be let after July 1, 1998 (10); and Minnesota states that the pipe must be deflection tested with a maximum allowable deflection of 5% nominal diameter (11).

Based on a review of the available literature, discussions with representatives from Advanced Drainage Systems, Inc., and discussions with members of the research technical panel, a deflection criterion of 5% was established for the Martin, South Dakota storm sewer project.
Task 4: Provide a preliminary design

Provide a preliminary design to be included in the plans for the Martin, South Dakota project. The plans for the Martin, South Dakota project were completed by the Alliance of Architects and Engineers, Rapid City, South Dakota in cooperation with the SDDOT Office of Local Government Assistance, and the SDDOT Office of Research. The plans specified that the HDPE pipe: conform to AASHTO M 294 Type S for use in gravity flow drainage installations. The pipe shall have a smooth interior and annular corrugated exterior. The installation shall be in accordance with ASTM D 2321 with the exception that minimum cover in trafficked areas shall be 305 mm (12 in) (12). The 305 mm (12 in) minimum cover was recommended in literature provided by Hancor, Incorporated and Advanced Drainage Systems, Incorporated.

Task 5: Consult with the pipe supplier

Consult with the pipe supplier during the development of the final design for the installation of the HDPE pipe. Two manufacturers were contacted to provide input on the design and installation of the HDPE pipe. The project plans specified that the pipe be HANCOR Hi-Q by Hancor, Incorporated or, N-12 by Advanced Drainage Systems, Incorporated or an approved equal. The project plans also required that the pipe manufacturer provide a trained representative to assist and advise the contractor for a minimum of two (2) days during the initial installation of the pipe to insure the proper procedures for the pipeline construction.
Task 6: Monitor the construction and install instrumentation

Monitor the construction and install instrumentation for short- and long-term deflection testing. The testing should cover at least one freeze-thaw period. Two representatives from Advanced Drainage Systems, Incorporated provided technical assistance and advice for three days during the initial installation of the HDPE storm sewer pipe. Representatives from the SDDOT Office of Local Government Assistance, Office of Materials and Surfacing and the Office of Research monitored the installation to insure that the provisions of ASTM D 2321 were followed.
The plans for the project specified a 915 mm (36 in) HDPE pipe, which was to replace an 455 mm (18 in) storm sewer pipe under US Highway 18 just west of its intersection with SD 73 in Martin. However, due to a suspected survey error, the plans were revised to specify a 760 mm (30 in) and a 610 mm (24 in) HDPE pipe so that a minimum of 305 mm (12 in) of cover could be placed over the pipes. The entire storm sewer project required over 550 m (1,800 ft) of HDPE pipe. However, researchers only provided instrumentation to monitor the 15.25 m (50 ft) section of 760 mm (30 in) pipe placed under US Highway 18.

The contractors excavated the trench and prepared the pipe bedding to conform to the requirements of Class B bedding. Class B bedding consisted of a bed of granular material having a thickness of 100 mm to 152.5 mm (4 to 6 in) below the bottom of the
pipe. The bedding material was a sandy material, all of which passed a 9.5 mm (3/8 in) sieve and not more than 10 percent of which passed a 75µm (No. 200) sieve (13).

![Figure 3 Using A Gas Powered Hand Saw To Cut The HDPE Pipe To Size.](image)

After the bedding material was compacted, SDDOT staff dug a shallow trench and placed a 85.8 mm (3.38 in) acrylonitrile-butadiene-styrene (ABS) plastic inclinometer pipe at the centerline for the 760 mm (30 in) HDPE pipe. Two 6.1 m (20 ft) sections of the 760 mm (30 in) HDPE pipe were connected together and placed on top on the inclinometer pipe. Plastic straps were attached to hold the inclinometer pipe in place during the fill operations. An additional 3.05 m (10 ft) of HDPE pipe was needed to complete the storm sewer installation. This 3.05 m (10 ft) section was cut from one of the standard 6.1 m (20 ft) sections which had been stockpiled adjacent to the trench. A gas powered hand saw was used to cut the pipe to the correct size. The 3.05 m (10 ft) section was then lowered into the trench by hand. No heavy equipment was needed, since the 760 mm (30 in) HDPE pipe only weighs 23.1 kg/m (15.4 lb/ft), as compared to 576 kg/m (384
lb/ft) for 760 mm (30 in) concrete pipe (14). An additional 85.8 mm (3.38 in) ABS plastic inclinometer pipe was attached to the top of the 760 mm (30 in) HDPE pipe so that deflection measurements could be taken from both the top and the bottom of the HDPE pipe.

Figure 4 Compacting The Sandy Fill Over The HDPE Pipes. Note The Inclinometer Tubing Strapped To The Top Of The 760 Mm (30 In) Pipe

The 610 mm (24 in) HDPE pipe was installed parallel to the 760 mm (30 in) HDPE pipe with a distance between them of 610 mm (24 in). This spacing was necessary to insure that good compaction could be obtained with the equipment on hand. Approximately 406 mm (16 in) separated the trench wall from the HDPE pipes on both sides. These distances are consistent with requirements for both HDPE pipe and reinforced concrete pipe.
Sand was placed over the HDPE storm sewer pipes in 152.5 mm (6 in) lifts. The initial lift of sand was hand tamped and compacted with vibrator equipment to make sure that the haunch area was completely filled. The sand was gradually dumped over the pipes to insure that the pipes did not rise during the haunching operations. Additional sandy fill was placed and compacted in 152.5 mm (6 in) lifts until 152.5 mm (6 in) of sand covered the 760 mm (30 in) HDPE pipe. An additional 305 mm (12 in) of base coarse material was then placed over the pipes and compacted. A nuclear testing gauge was used to determine the amount of compaction. The gauge measured 96% compaction at each of the testing sites. Four 50 mm (2 in) lifts of asphalt completed the trench fill, resulting in a total of 650 mm (26 in) of compacted material over the 760 mm (30 in) HDPE storm sewer pipe.
Specially modified 1.98 m (6.5 ft) deep drop inlets were installed at each end of the HDPE pipe. The inlets were an additional 152.5 mm (6 in) deep to allow a horizontal inclinometer to be used in the ABS inclinometer pipe under the 760 mm (30 in) instrumented HDPE storm sewer pipe. During the coarse of the monitoring, this proved to be a challenge since the additional 152.5 mm (6 in) constantly filled up with sand and other material and needed to be cleaned out by hand in order to take the inclinometer measurements. After the concrete tops were placed on the inlets, metal grates were installed to keep large material from entering the storm sewer system.

Prior to completing the asphalt lifts, a 915 mm (36 in) section of PCCP concrete was sawed and removed from the highway adjacent to the west side of the storm sewer trench. It was felt that this would reduce impact to the pipe from vehicles moving from the PCCP roadway on to the newly constructed asphalt covering the storm sewer.

**Task 7: Conduct deflection testing**

*Conduct deflection testing using loadings from H10 up to H20.* Immediately upon completion of the final 50 mm (2 in) asphalt lift, inclinometer readings and surface profile readings were taken to establish a base set of data for monitoring. A horizontal inclinometer probe was used to determine vertical heave or settlement. This sensor operates in a 85.8 mm (3.38 in) outside diameter casing which was attached to the bottom and top of the 760 mm (30 in) HDPE storm sewer pipe.

Data from the horizontal inclinometer was recorded for two opposite directions to eliminate bias caused by either the sensor or the indicator. To read the opposite direction, the sensor had to be turned end for end. This was accomplished by attaching a rope to one end of the sensor and pulling the sensor through the inclinometer casing to the inlet on the opposite side of the highway. The sensor was then turned 180 degrees, reattached to the portable computer, which was also moved to the drop inlet on the opposite side of the highway, and pulled back to its starting point by the use of the attached computer cable. Readings were taken at 305 mm (12 in)
intervals. The rope was left in the inclinometer casing so it could be used for future readings. Upon completion of the readings, each inclinometer pipe was covered and sealed so water and dirt could not enter when the storm sewer and inlets filled with runoff water.

Figure 6 HDPE Surface Profile Grid Sections (Not to Scale)

Surface profile readings were taken with a Dipstick® Floor Profiler. A grid was measured and marked on the asphalt pavement so a profile could be established and monitored throughout the project study period. Eight separate longitudinal readings were taken from west to east, and a ninth transverse reading was taken from north to south. Reading number one was measured 915 mm (36 in) from the gutter pan on the south side of the highway. Reading number two was measured 2.75 m (9 ft) from the gutter pan on the south side of the highway. Each of the
remaining longitudinal measurements were completed at 1.8 m (6 ft) intervals, south to north, in an attempt to duplicate the existing wheel paths of the highway. The ninth transverse measurement was taken over the top of the 760 mm (30 in) HDPE pipe from north to south.

The final check of the 760 mm (30 in) HDPE storm sewer was completed visually. During each visit to the site, research staff climbed into the storm sewer to assess its condition. Visual checks were also made on the attached 915 mm (36 in) HDPE storm sewer pipes and the parallel 610 mm (24 in) storm sewer pipe.

![Figure 7 South Dakota Department of Transportation Dump Truck From The Martin Maintenance Shop, Which Was Used For The Load Tests](image)

The asphalt surfacing and baseline measurements were completed on August 16, 1996. Prior to opening the roadway to traffic, load tests were conducted on August 20, 1996 to determine any
potential deflection or rutting. The tests were conducted using a SDDOT maintenance two axle dump truck which was loaded with sand and weighed at the Martin grain elevator. The rear axle weight was 9100 kg (20,200 lb).

Inclinometer and Dipstick ® surface profile measurements were taken prior to placing the load on the storm sewer pipe. The dump truck was slowly backed onto the asphalt surface over the pipe at monitoring sections five and six, which corresponded to the west-bound driving lanes. Inclinometer readings were taken while the vehicle was positioned over the pipe. The dump truck was then moved to sections three and four, which correspond to the east-bound driving lanes and additional inclinometer readings were taken. After the load test inclinometer readings were completed, the truck was removed from the site and additional inclinometer readings were taken.

During and upon completion of the inclinometer tests, visual inspections were made on the HDPE storm sewer pipe. Dipstick ® profile measurements were taken after the truck was removed from sections three and four as well as sections five and six. A final transverse Dipstick ® profile measurement was then taken for section nine covering the entire length of the HDPE storm sewer pipe.

Inclinometer, Dipstick ® surface profile and visual inspections were again taken on August 28th, September 4th, and September 12th, 1996. Discussions with Advanced Drainage Systems, Inc. engineers, and literature reviews had indicated that most deflections could be expected within the first thirty days after the installation was completed. Between September 1996 and June 1997 an additional five sets of measurements were completed. This allowed the researchers to evaluate any changes due to freeze thaw cycles.

**Task 8: Evaluate the results of the deflection testing**

Evaluate the results of the deflection testing to determine if HDPE storm sewer pipe meets the deflection criteria. Visual inspections of each of the storm sewer pipes were completed during
each of the site visits. The HDPE pipes were also visually monitored during each of the load tests. No movement was noted during any of the site visits or during the load tests. Additional visual checks were completed on the adjacent connecting storm sewer pipes whenever weather conditions allowed. It was not practical to climb into the storm sewers when there was a threat of water entering the storm sewer system. No noticeable joint separations or deflections were noted on the adjacent 915 mm (36 in) storm sewer sections, even though these sections had approximately 305 mm (12 in) of gravel cover and were subjected to truck traffic servicing the commercial businesses in the area.

Figure 8 Inside View Of The 760 Mm (30 In) HDPE Pipe 9 Months After Installation
Figure 9 Pavement Elevation Changes For Section 5. The 760 Mm (30 In) HDPE Pipe Is Located Directly Under The Number 9

Between August 14, 1996 and June 26, 1997 eleven separate Dipstick ® profiles were taken on each of the nine grid sections covering the storm sewer pipes. The Dipstick ® displays elevation differences up to 1.999 inches in increments of .001 inches (15). All of the measurements were charted on an Excel spreadsheet and reviewed for consistency and surface movement. Figure 9 shows the profile from section five which is the westbound driving lane adjacent to the centerline. The 760 mm (30 in) pipe is located directly under number 9. As can be seen, there was virtually no movement during the eleven site visits. The remaining graphs for each section are displayed in Appendix A.
An evaluation of the profiles indicated that very little movement occurred throughout the monitoring period. Sections one through seven had maximum changes in elevation ranging from 4.65 mm (.186 in) to 5.8 mm (.232 in). Section eight had a maximum elevation change of 11.2 mm (.45 in). Section nine, which was located directly over the entire length of the 760 mm (30 in) pipe had a maximum elevation change of 4.5 mm (.18 in). The vast majority of the readings on each test section showed little if any movement. The greatest movement appeared adjacent to the area where the asphalt connected to the portland concrete cement pavement and gutter surfaces.
A 2.5 mm (.10 in) movement was noted west of the 760 mm (30 in) storm sewer pipe during the December 12, 1996 site visit. The slight heave was probably due to frost action and had completely settled to its previous elevation when new measurements were taken on March 17, 1997. No additional movement was noted during any of the other site visits.

The horizontal inclinometer recordings were analyzed to determine maximum point deflections and average pipe deflections on both the top and bottom of the 760 mm (30 in ) HDPE storm sewer pipe. Eight recordings were made on the bottom of the pipe and thirteen recordings were taken on the top of the pipe. The difference in the number of recordings was due to water, sand, and ice covering the bottom inclinometer pipe. During several of the site visits readings could only be taken on the top inclinometer pipe due to a continuous flow of water into the storm
sewer. At other times, ice and sand covered the bottom pipe and could not be effectively removed to take measurements.

All of the inclinometer recordings were compared to the base recordings that were taken on August 14, 1996, prior to the asphalt overlay, which was completed on August 16, 1996. No significant differences were noted in the inclinometer readings between August 14, 1996 and August 16, 1996; therefore it was decided to utilize the earlier recordings as the base data.

Based on eight separate recordings between August 14, 1996 and May 20, 1997 the bottom inclinometer pipe had a maximum point deflection of 0.77 mm (.0308 in) or .10%. The average pipe deflection was 0.035 mm (.0014 in) or .005%.

Based on the thirteen recordings which were taken between August 14, 1996 and June 26, 1997, the top inclinometer pipe had a maximum point deflection of 2.28 mm (.0911 in) or .30%. The average top pipe deflection was 0.105 mm (.0042 in) or .01%.

All of the deflection measurements were well within the established five percent deflection threshold established by the technical panel. In fact, throughout the entire recording period there was little if any pipe movement noted.

**Task 9: Determine the costs of the installation**

*Determine the costs of the installation of the HDPE pipe and compare them to the cost of installing round reinforced concrete pipe. Include the backfill and other associated costs.*

A considerable amount of data exists comparing the costs of reinforced concrete pipe and HDPE pipe. While manufacturers of both products can provide extensive literature expounding the benefits and savings of their individual products, it must be noted that various circumstances and site conditions can favor either product.

Manufacturers' material prices are generally quoted as a delivered product. Cost of the product itself as well as handling charges will be incorporated to cover the loading at the factory and
unloading at the job site. The more difficult the handling of the material, the greater the handling cost. Heavy pipe, such as reinforced concrete products, are more difficult to handle than most other materials, especially lightweight plastics. Additionally, damage resulting from the handling of coated products (e.g., polymer-coated steel) may need to be repaired before installation can proceed.

Hauling charges are also included in the material costs. This figure is affected by the distance between the manufacturing plant and the job site, and the quantity of material that can be hauled at one time. Lightweight corrugated pipes can easily be nested allowing the number of trips to the job site to be markedly reduced.

Equipment and manpower necessary for trenching are the same for nearly all products. However, the equipment and manpower required to handle the pipe is closely linked to its weight. Even small diameter concrete pipe requires equipment to help lower it into the trench. Several laborers are needed to guide it into place to form the joints. With the equipment necessarily come operators which add to the cost of installation.

Rough terrain, vegetation, or a requirement to preserve the environment may make it impossible for equipment to be brought adjacent to the trench. It then becomes a necessity for the pipe to be handled solely by workers (16).

A recent survey of State Departments of Transportation revealed that reductions in installed cost for HDPE pipe were 12 to 38 percent of concrete, and 5 to 28 percent of corrugated steel (17). Information provided from New York, South Carolina and Colorado indicate that the price of corrugated metal pipe and reinforced concrete pipe prices generally dropped when polyethylene pipe was specified as an alternative. Ohio studies indicate that “...when projects are bid as reinforced concrete only, installed costs are an average of 29.2 percent higher on 305 mm to 915 mm (12 to 36 in) drain pipe than when polyethylene is allowed as an alternative”. (18)
A 1994 Tennessee “Report on the Use of High Density Polyethylene Pipe in Roadway Drainage Applications” prepared by Fiscal Review Committee Staff indicated that 42 states allow the use of polyethylene pipe 305 mm (12 in) in diameter and greater in highway drainage applications. The report goes on to say that available cost data suggest that when the use of polyethylene pipe is allowed, the cost of concrete pipe goes down, and the cost of polyethylene pipe is generally less than the cost of either metal or concrete pipe. In comparing the experience of other states and some local governments, cost savings were realized not only because polyethylene pipe was a less expensive product, but also because the equipment and labor costs were less. Polyethylene pipe installation also reportedly results in fewer injuries to employees (19).

A review of information supplied by neighboring DOTs indicated varying degrees of use and cost information. The Montana DOT will allow the use of HDPE pipe as an option to RCP, Corrugated Steel Pipe (CSP), and Corrugated Aluminum Pipe (CAP). The contractor is then allowed to select which material he intends to use (for farm field or local approach roads only). To date, Montana has not used HDPE pipe, and excludes the use of HDPE on major and minor collectors and arterial approach roads.

The Wyoming DOT has not completed any installations of HDPE pipe on State projects. The use of HDPE is only specified for “off system” roadways when requested by a municipality or county.

The North Dakota DOT currently does not design any highway projects using plastic pipe larger than 305 mm (12 in) for highway drainage.

The Iowa DOT has used large diameter (305 mm or larger) plastic materials for highway drainage for approximately ten years under driveways, field entrances and unclassified roads. The engineer who responded to the survey was not aware of any cost savings using HDPE pipe. However, other information reviewed during the course of this research indicated that Iowa cost information does show that HDPE pipe is less expensive than RCP.
The Nebraska Department of Roads Materials and Tests Engineer indicated that Nebraska has not had the experience necessary with plastic pipe to provide answers to the survey, which was sent in April, 1997. It should be noted that the Nebraska DOR has co-sponsored studies with the University of Nebraska-Lincoln which resulted in the Nebraska DOR approving a new Policy DES97-01. That policy states that the designers will select the allowable pipe materials for each installation, and the contractor will chose the final pipe material from the list of options provided (which include HDPE).

The Minnesota DOT has used dual-wall corrugated polyethylene pipe since 1989. For storm sewer they allow use of 305 mm to 915 mm (12 to 36 in) diameter pipe with a minimum cover of 610 mm (24 in) and a maximum cover of 6.1 m (20 ft). The pipe must be installed according to their specifications. The pipe must be deflection tested with a maximum allowable deflection of 5% nominal diameter. Polyethylene pipe is included in the construction plans as an alternate to reinforced concrete pipe.

For culvert use, the Minnesota DOT will allow the use of 305 mm to 610 mm (12 to 24 in) diameter dual wall corrugated polyethylene pipe under side roads with a minimum cover of 305 mm (12 in) for private driveways, 610 mm (24 in) for public roads and a maximum cover of 6.1 m (20 ft). They include polyethylene pipe as an alternate to corrugated steel pipe and reinforced concrete pipe for culverts under side roads.

The Minnesota DOT survey response indicated that they have had no significant construction problems or any pipe reported to be damaged by fire. No formal studies have been done to document cost or construction time savings, but their review of the year-end construction costs indicates that providing pipe alternates in the plan leads to lower installed pipe costs.

Prior to the HDPE storm sewer installation in Martin, South Dakota, there had been limited use of HDPE in South Dakota. The City of Sioux Falls had installed HDPE pipe on a project located at 18th Street and Elmwood Avenue. Discussions with city representatives indicated that a
failure had occurred on that project due to bad backfill and improper construction installation. The HDPE storm sewer pipe was replaced with the same product and installed with a granular backfill rather than the clay fill utilized on the first installation. The supplier provided inspection support during the replacement installation. City staff emphasized the need for adequate supervision during the installation of HDPE pipe to make sure that the manufacturers’ guidelines are followed. The replaced HDPE storm sewer section continues to be monitored by city personnel and has not had any additional problems to date.

An evaluation of the HDPE pipe bids and the corresponding RCP pipe bids for the Martin project showed that the 1996 HDPE pipe bid price was 39% of the cost of the 1995 Martin RCP bid price. Both the installation cost and the HDPE unit bid price averaged 39% of the cost of the 1995 RCP bid. These costs were for the pipe and installation only, and did not include tees, wyes, bends or other connectors.

The installation and unit costs of over 550 M (1,800 ft) of assorted sizes of HDPE pipes bid in the 1996 Martin project were compared with the 1997 average costs of the same amount of RCP round pipe and installation costs. The results showed the 1996 Martin project HDPE unit and installation costs were 52% of the 1996 statewide average cost of RCP furnished round pipe and installation. The actual Martin HDPE installation bid costs were 71% of the average statewide cost of RCP installation, while the furnished unit HDPE pipe bid costs were 43% of the average statewide cost of furnished RCP pipe. It should be noted that the RCP unit and installation costs were a statewide average for all projects, while the HDPE costs were for the Martin project only. The SDDOT did not have any other HDPE cost comparisons since no other project using HDPE pipe had been let.

When a comparison was done with the HDPE pipe list price supplied by a major HDPE distributor, it was noted that the Martin HDPE unit bid prices were lower than the actual 1995-96 HDPE unit list prices. This may be due to the fact that distributors will often discount unit list prices if sufficient quantities are ordered. In the case of the Martin project, over 550 m (1,800 ft) of HDPE pipe was installed. Since this was the first HDPE project in South Dakota, it may also
be due to the increased competition generated by allowing HDPE pipe distributors to directly compete with RCP pipe distributors.

![Graph showing Martin Project Bid Comparisons]

**Figure 12 Martin Project HDPE, RCP, And Statewide RCP Average Cost Comparisons For Over 550 M (1,800 Ft) Of Pipe Installed. Costs Include Furnished Pipe And Installation Costs For All Sizes Of Pipe Used In The Project**

Finally, when reviewing the overall cost of the use of HDPE pipe, the cost estimator must consider the cost of the granular fill, which provides the protective envelope around the installed HDPE pipe. This is important since some areas of the state do not have good quality granular fill readily available for use in storm sewer projects. The Sioux Falls experience highlights the need for quality granular fill as well as proper installation procedures. On the same note, the Martin project and other literature/research projects demonstrate that HDPE pipe is an acceptable alternative to RCP pipe and CMP pipe when proper installation procedures and materials are utilized.
Task 10: Recommend specifications for using HDPE

Recommend specifications for using HDPE as storm sewer and mainline drainage pipe. The 1998 Standard Specifications for Roads and Bridges, South Dakota Department of Transportation Section 990.1 F. Corrugated Polyethylene Pipe specifies that “corrugated polyethylene pipe, couplings, and fittings shall conform to the requirements of AASHTO M 294”. This specification is consistent with the requirements found in the manufacturers’ literature as well as polyethylene pipe specifications reviewed from other states and research studies. It is recommended that the SDDOT continue to utilize the current AASHTO M 294 specification.

The SDDOT 1998 Standard Specifications for Roads and Bridges Section 450.3 C. Corrugated Polyethylene Pipe Culverts specifies “Corrugated polyethylene pipe culverts shall be installed according to manufacturer instructions”. Research indicates HDPE pipe manufacturers recommend that ASTM Designation D 2321 be followed with some modifications. The modifications generally relate to the amount of cover required before traffic is allowed over the culvert or storm sewer pipe. The ASTM Designation generally requires a minimum cover of 610 mm (24 in) before vehicles are allowed over the pipe. The Designation goes on to say that the minimum depth of cover should be established by the engineer based on an evaluation of specific project conditions.

The Martin, South Dakota research project focused on trench installations with minimum cover, however, the SDDOT also allows embankment installations. As previously mentioned, AASHTO Section 18 provides recommendations on embankment installations. These recommendations are similar to the cover depth and compaction requirements specified in ASTM D 2321. The Nebraska Department of Roads also allows embankment installations for HDPE. For information purposes, a copy of their specifications are attached as Appendix B.
The April 1996 College of Engineering and Technology, University of Nebraska - Lincoln “Comparative Study of Highway Materials for the Establishment of a Design Selection Policy” states that “the most important parameters influencing the deformation of culverts are quality of installation and compaction methods, suitable backfill material, and height of cover. Failure to provide uniform backfill material and compaction may result in upward deflection exceeding the maximum limit of 5%, distorted pipe barrels, and the delamination of pipe joints. Installation failure may be avoided with strict adherence to the recommendations and installation procedures provided by the manufacturer”.

Advanced Drainage Systems Recommendations (Goddard, 1992) recommends following the provisions of ASTM D 2321. Additionally, Advanced Drainage Systems gives recommendations for the minimum trench width as the outside diameter plus 406 mm (16 in) or the outside diameter times 1.25 plus 305 mm (12 in), which ever is greater. Poor in situ soil conditions will require substantially wider backfill as well as deeper foundation and bedding. Trench width and foundation should be based on a thorough site investigation. They note that recent development of flowable, low strength cement or fly ash backfill provides the ability to reduce trench width and still get adequate backfill support. This can be particularly helpful in municipal street installations (20). The cost of flowable fill varies from area to area. Designers and cost estimators should include the cost of the flowable fill when making estimates to determine if the HDPE pipe with a flowable fill base is the most cost effective option.

Hancor, Inc. “Drainage Handbook Overview of Installation Considerations” states that installation of Hancor polyethylene pipe is in most respects very much like that of any quality pipe installation. The strength of a pipe system should be considered a combination of the pipe itself and the backfill envelope. Proper construction maximizes the drainage capabilities designed into the pipe by maintaining alignment and load carrying ability.

Recommendations for proper backfill and installation for Hancor products are based primarily on the requirements of ASTM D 2321 “Recommended Practice for Underground Installation of Flexible Thermoplastic Sewer Pipe” with few exceptions.
The width of the trench depends on the pipe diameter, backfill material, and the method of compaction. Trenches that are too narrow will not allow for proper pipe installation and compaction, whereas trenches that are overly wide are unnecessarily costly.

Backfill construction should be evaluated as part of the structural design of polyethylene pipe like it is for other materials. ASTM D 2321 serves as the basis for installation recommendations in trafficked installations. Acceptable backfill materials and construction methods are very similar or, in many cases, identical to those required for other types of pipe material.

The primary purpose of the backfill envelope is to provide long-term support to the pipe. In a properly constructed backfill envelope, the loads are distributed across the crown of the pipe to the material along the sides and then to the pipe bedding and foundation. This load arching effect means that most of the load is carried by the backfill; only a small portion of the total load is applied to the pipe.

MINIMUM COVER

Hancor recommends achieving a backfill modulus of at least 1000 psi in installations involving AASHTO H20 loads under minimum cover of 305 mm (12 in) conditions or in deep installations (21). The Hancor recommended minimum cover of 305 mm (12 in) is the most notable difference from the ASTM D 2321 minimum cover specification of 610 mm (24 in) or one pipe diameter which ever is larger.

In a 1990 Transportation Research Record article, Katona stated that the guideline for minimum cover of plastic pipe, as suggested by the AASHTO Flexible Culvert Committee, is taken directly from the metal culvert industry, the American Iron and Steel Institute (AISI). The AISI specification for corrugated metal culverts requires a minimum of 305 mm (12 in) of soil cover for all pipe diameters up to 2.44 m (96 in). Paving material, if any, is not permitted to be included in the 305 mm (12 in) minimum cover due to the concern of construction loads prior to
paving. This requirement is based on long-time observations by the corrugated steel pipe industry of structural performance under live loads (22).

Katona’s report goes on to say that a 305 mm (12 in) minimum cover is applicable to all corrugated pipes including polyethylene. He also notes that the larger diameter pipes generally require less cover depth than that of a smaller pipe with the same loading. However, a 305 mm (12 in) cover is specified as the absolute minimum for corrugated pipes.

A November 1997 Report “Investigation of Plastic Pipes for Highway Applications: Phase II” prepared by Iowa State University states that deflections are reduced dramatically when the soil cover is increased from 305 mm (12 in) to 610 mm (24 in). However, the rate of deflection reduction decreases when the soil cover height is greater than 610 mm (24 in). Furthermore, both 915 mm (36 in) and 1220 mm (48 in) HDPE pipes with a soil cover height of 610 mm (24 in) or higher and under any of the six backfill conditions researched in the Iowa study meet the 5% deflection criteria (23).

The report goes on to say that it is generally accepted that high density polyethylene pipe performs well under live loads with shallow cover, provided the backfill is well compacted. Although industry standards require carefully compacted backfill, poor inspection and/or faulty construction may result in soils that provided inadequate restraint at the springlines of the pipes thereby causing failure. The report states the minimum soil cover height is 305 mm (12 in) as determined from a Culvert Analysis and Design (CANDE) analysis and controlled by a 5% deflection criteria. Pipes with poor silt and clay backfills with less than 85% compaction require a minimum soil height of 610 mm (24 in).

MAXIMUM COVER

Several studies have been completed which evaluate allowable fill heights for HDPE pipe. In 1993, Moser and Kellog (1993) tested four 1220 mm (48 in) diameter smooth lined corrugated HDPE pipes for Hancor, Inc. to determine structural performance characteristics as a function of depth of cover. Variables investigated included type of soil, compaction of soil, and vertical soil
loading (simulating depth of soil cover). In this investigation it was concluded that structurally, there are no reasons why HDPE pipes cannot perform well. Clearly, pipes deflect more in loose soil than in dense soil because loose soil compresses more. If the pipe is buried under high soil cover, or large surface loads, the backfill around the pipe should be granular and carefully compacted.

Dr. A. P. Moser and the College of Engineering, Utah State University, completed another study in 1994. Three 1220 mm (48 in) diameter high density profile-wall (Honeycomb Wall Design) polyethylene pipes from Advanced Drainage Systems, Inc. were evaluated to determine the structural characteristics as a function of depth of cover. The dependent variables were ring deflection, any visual evidence of distress, and structural performance limits. The independent variables were soil type, soil density (compaction), and the vertical soil load simulating height of soil cover.

The basic soil type was silty sand and is designated as a Class III soil by ASTM D 2321. This soil is classified as SM according to the Unified Soil Classification System. SM soil was used because it is common, it is of lesser quality than most soils specified as backfill (worst case test), and it can be compacted over a wide range of soil densities.

The results of the tests indicated that high-density polyethylene pipes should perform well. The soil should be granular and carefully compacted if the pipe is buried under high soil cover, or under heavy surface loads. Granular backfill material at moderate to high densities assures that the pipes will perform well even at high earth covers. Initial dimpling occurred at equivalent depths of cover in the range of 28 feet to 120 feet. This incipient dimpling load is a function of soil density. Dimpling is not a structural performance limit.

The load at which a formation of a hinge line (crease) takes place is a function of the soil density. For a relatively poor installation (75 percent Standard Proctor) the hinge line begins to form at about 34 feet of cover. For a good installation (85 percent Standard Proctor Density) the hinge line begins to form at about 60 feet of cover. For an excellent installation (96.5 percent Standard Proctor) the hinge line starts to form at about 180 feet of cover.
HDPE manufacturers recommend achieving a backfill modulus of at least 1000 psi in installations involving AASHTO H20 loads under minimum cover (305 mm) conditions or in deep installations. Maximum cover would typically be 15 to 18 m (50-60 ft) but will vary depending on the application and engineering design. Manufacturers note that the cover heights are measured from the top of the pipe; calculations are based on load factor design as per AASHTO procedures; assume loose sand, earth or gravel soil density of 100 lbs./cu. ft.; and 120 lbs./cu. ft. for compacted sand, earth, gravel or ballast.

The April 1997 survey of neighboring states showed that the Minnesota Department of Transportation has recently increased its maximum fill allowed. Technical Memorandum No. 95-14-B-02 now allows the use of 760 mm and 915 mm (30 and 36 in) diameter pipe and increased the allowable overfill from 3 to 6 m (10 to 20 ft). HDPE dual wall corrugated pipe and reinforced concrete pipe shall normally be provided in plans as alternates and may be used on all state trunk highways.

Based on the literature review, and the survey of other DOT practices, it is recommended that the SDDOT set the HDPE maximum fill height at 6.1 m (20 ft) with a 90 percent Standard Proctor Density compaction. This will allow the use of HDPE for most applications and will provide engineers and contractors the opportunity to evaluate its use on a continuing basis. The maximum and minimum fill heights issue should be re-evaluated after the SDDOT acquires additional experience with HDPE installation techniques.

POTENTIAL FOR DAMAGE BY FIRE

The susceptibility of polyethylene pipe to fires is an important issue that has been addressed by various testing facilities including studies conducted in Florida and Texas. Texas DOT officials conducted ten different scenarios, testing two twenty foot sections of HDPE pipe. After attempting to ignite the pipe with combustible materials, Texas DOT engineers attending the test felt the polyethylene material was not a fire concern for culvert installations (24).
A study performed by the Florida Department of Transportation concluded that “the heat gain of the pipe cross section was not sufficient to cause softening or subsequent weakening of the pipe during burn tests”. Out of the 41 states responding to the Florida study survey, only four reported incidents of fire and the total number of fires was reported as eight. The computed rate at which fires affecting HDPE pipe have occurred is one fire per state every 48 years. However, it should be noted that mitered polyethylene end sections are “...subject to fire damage and destruction when exposed to expected grass fire intensities.” The Florida DOT recommends that the polyethylene pipe terminate in a concrete headwall, drainage structure, or non-plastic mitered end concrete apron (25).

In November 1991 a routine fuel reduction burn destroyed 60 lineal feet of 760 mm (30 in) polyethylene pipe culvert in the Badlands National Park in South Dakota. While this event has been highly publicized, it remains an isolated incident. The author is not aware of any other fire causing damage to HDPE pipe in South Dakota.

The South Dakota Department of Transportation uses an Approach Pipe Plan Note that specifies “Class II Reinforced Concrete Pipe with Safety Ends and Polyethylene Pipe with CMP end sections may be substituted for Corrugated Metal Pipe at approaches on a per site basis at no additional cost to the State. Acceptance of polyethylene pipe will be by certification. The end sections for the polyethylene pipe shall be metal and conform to the details for CMP end sections, and shall be compatible to the polyethylene pipe”. While the use of concrete or metal end sections is recommended for those areas where the possibility of grass fires exist, it is recommended that the SDDOT allow the option of using plastic end sections in municipal settings.
Conclusions and Recommendations

Numerous studies have been completed which address the use of HDPE pipes for storm sewer and culvert applications. While some neighboring states have not used HDPE pipe for either application, most will allow its use if requested by a municipality, county or contractor. Both the Iowa and Nebraska Transportation Departments have sponsored extensive studies focusing on HDPE applications. The Iowa DOT has used HDPE for over ten years under driveways, field entrances and unclassified roads. The Nebraska Department of Roads has recently adopted a new policy (DES97-01) which allows HDPE to be considered as an alternative when designing and constructing highways.

Research from the University of Nebraska-Lincoln (1996) indicates that when polyethylene pipe is included in the construction plans as an alternate to reinforced concrete pipe or corrugated metal pipe, bid prices for each type of pipe are generally lower. In many cases the unit cost of polyethylene is less than either reinforced concrete or corrugated metal pipe. A comparison of the 1996 Martin HDPE project bid price with the 1997 SDDOT average costs for RCP round pipe and installation resulted in the Martin project HDPE unit and installation costs to be 52% of the 1997 statewide average cost of RCP pipe and installation.

Based on the extensive literature review completed for this research project, and the favorable results obtained during the Martin, South Dakota Transportation Enhancement/Hazard Elimination Project, the following recommendations are offered for consideration by the South Dakota Department of Transportation Research Review Board:

1. Corrugated high density polyethylene pipe should be specified as an alternative for storm sewer and culvert installations on all South Dakota roadways where pipe sizes 305 mm (12 in) to 915 mm (36 in) are used. Literature indicates that HDPE is an acceptable alternative to both reinforced concrete pipe and corrugated metal pipe if proper installation procedures and materials are used. The Martin project and other studies also show that the
costs for installation of storm sewer and culverts are generally lower when polyethylene pipe is specified as an alternative.

2. **The 1998 Standard Specifications for Roads and Bridges, South Dakota Department of Transportation, Section 990.1 F. Corrugated Polyethylene Pipe should be retained as it is currently written “Corrugated polyethylene pipe, couplings, and fittings shall conform to the requirements of AASHTO M 294”.** Extensive research studies and national surveys of states indicate that AASHTO M 294 is the standard that is currently specified and widely used.

3. **A 5% deflection criterion should apply to the pipe when HDPE is installed on any South Dakota maintained highway.** The deflection testing can be conducted as per procedures identified in ASTM Designation D 2321-89 (Reapproved 1995) Section X1.13 and X1.13.1 “Deflection testing”.

4. **The 1998 Standard Specifications for Roads and Bridges, South Dakota Department of Transportation, Section 450.3 C, Corrugated Polyethylene Pipe Culverts: “Corrugated polyethylene pipe culverts shall be installed according to manufacturer instructions”, should be modified to require that “corrugated polyethylene pipe be installed according to standards specified in ASTM D 2321 - 89 Standard Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity- Flow Applications”.** This modification addresses storm sewer installations as well as culvert installations. The use of the ASTM D 2321 standard provides a reliable guideline for the installation of all polyethylene pipe. While manufacturers’ instructions are important, the installation decisions should be made by SDDOT engineers based on consistent national standards.

5. **The minimum cover for corrugated polyethylene pipes should be established as 457 mm (18 in) for all South Dakota Department of Transportation arterial highway drainage applications.** The 1997 Iowa “Investigation of Plastic Pipes for Highway Applications: Phase II” report suggested that 305 mm (12 in) was an acceptable minimum cover for all
roadways. Specifications from other states varied from 305 mm (12 in) of cover to 610 mm (24 in) of cover. While research studies indicate the 305mm (12 in) minimum cover requirement is acceptable, South Dakota does not have much experience with the installation of polyethylene pipe, therefore it is better to be more conservative until additional installation experience is gained.

6. The minimum cover for corrugated polyethylene pipes should be established as 305 mm (12 in) for all collectors, secondary roadways and private driveways where truck or other heavy vehicle traffic is minimal. Research conducted in Iowa in 1997 indicated that a cover thickness less than 610 mm (24 in) is acceptable provided the backfill is well compacted.

7. The maximum fill height for corrugated polyethylene pipes should be established as 6.1 m (20 ft) with a 90 percent Standard Proctor Density compaction. Although this is a conservative figure when compared with manufacturers’ literature and studies completed by the University of Nebraska-Lincoln and the Engineering Research Institute, Iowa State University, it is compatible with the current practices of the Minnesota Department of Transportation and provides a reasonable starting point for future HDPE installations by the SDDOT.

8. The South Dakota Department of Transportation should allow the option of using polyethylene end sections in municipal settings. This would require that the Plan Note for Approach Pipe currently used in rural areas be modified accordingly.

9. Inspection procedures should be rigorously followed to insure the installation and compaction specifications defined in ASTM D 2321 are maintained. Available literature indicates that most failures of polyethylene and other types of drainage pipe are caused by poor installation and compaction. Concerted inspections of drainage projects will allow Department engineers and contractors to share their expertise and provide our tax paying citizens with good quality drainage projects at competitive prices.
References

10. Nebraska Department of Roads, Roadway Design Division, Policy Letter.
18. Comparative Study of Highway Pipe Materials for the Establishment of a Design Selection
   Policy, Final Report, College of Engineering and Technology, University of Nebraska-
   Lincoln, April 5, 1996, page 63.
19. Report on the Use of High Density Polyethylene Pipe in Roadway Drainage Applications,
   September 22, 1994, Fiscal Review Committee Staff, Nashville, Tennessee.
20. Investigation of High Density Polyethylene Pipe for Highway Applications, January 1996,
   College of Engineering, Iowa State University, page 34-42.
22. Transportation Research Record No 1288, Geotechnical Engineering 1990, Minimum Cover
    Heights for Corrugated Plastic Pipe Under Vehicle Loading, Michael G. Katona.
    State University, R.A. Loknes.
24. Special Report, Texas Department of Transportation Flame Resistance Test, Hancor, Inc.
    July 7, 1994
25. Special Report, High Density Polyethylene Pipe Fire Risk Evaluation, Report No. 94-74,
    Florida Department of Transportation, July 15, 1994.
Appendix A Pavement Evaluation Changes
8-16-98 through 6-26-97

Pavement Elevation Changes 8-16-96 Through 6-26-97
Section 1, 3 ft From South Gutter Pan
Transverse Profile

Section 2, 9 ft From South Gutter Pan
Transverse Profile
Pavement Elevation Changes 8-16-96 Through 6-26-97
Section 5, 27 ft From South Gutter Pan
Transverse Profile

Distance East of PCC Pavement (ft)

HDPE Pipe

Pavement Elevation Changes 8-16-96 Through 6-26-97
Section 6, 33 ft From South Gutter Pan
Transverse Profile

Distance East of PCC Pavement (ft)
Pavement Elevation Changes 8-16-96 Through 6-26-97
Section 7, 39 ft From South Gutter Pan
Transverse Profile

Distance East of PCC Pavement (ft)

Pavement Elevation Changes 8-16-96 Through 6-26-97
Section 8, 45 ft From South Gutter Pan
Transverse Profile

Distance East of PCC Pavement (ft)
Pavement Elevation Changes 8-16-96 Through 6-26-97

Section 9, Located Longitudinally Over Centerline of 30 Inch HDPE Pipe

Distance South of North Gutter Pan (ft)
## Appendix B Nebraska Department of Roads Typical Installation Instructions

### Typical Trench Installation

**Table 1: Soil Classification for Granular Fill Material**

<table>
<thead>
<tr>
<th>Soil Group</th>
<th>Description</th>
<th>N, m (lb/ft²)</th>
<th>R, m (lb/ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CF</td>
<td>Fine-grained</td>
<td>60%</td>
<td>80%</td>
</tr>
<tr>
<td>SF</td>
<td>Silt-grained</td>
<td>50%</td>
<td>60%</td>
</tr>
<tr>
<td>GP</td>
<td>Gravelly</td>
<td>40%</td>
<td>50%</td>
</tr>
<tr>
<td>SP</td>
<td>Sand-grained</td>
<td>30%</td>
<td>40%</td>
</tr>
<tr>
<td>GP</td>
<td>Gravelly</td>
<td>20%</td>
<td>30%</td>
</tr>
</tbody>
</table>

### TYPICAL EMBANKMENT INSTALLATION

**Table 2: Minimum d (in.)**

<table>
<thead>
<tr>
<th>Pipe Size</th>
<th>Minimum d (in.)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

Notes:
- Installations as shown are required under all surfaced roadways. Bedding and backfill for drive pipe or other pipe outside the roadway plus 5 feet on each side for urban projects may be installed using suitable existing soil, placed and compacted in accordance with the Standard Specifications.
- Where in-place soil is not acceptable e.g. peat, muck, or highly expansive soil, embankment shall be placed and compacted in accordance with the Standard Specifications.
- Where in-place soil is not acceptable e.g. peat, muck, or highly expansive soil, embankment shall be placed and compacted in accordance with the Standard Specifications.
- To prevent the pipe and backfill from straining, provide a minimum of 30° of compacted fill material over the top of the pipe before allowing any heavy equipment to traverse over the pipe. Extremely heavy equipment may require larger cover as determined by the contractor.
- Pipe volume should not be subtracted from the volume of excavation.
- These design standards are minimum. If a more restrictive design is required by the Engineer or the civil engineer, the design engineer shall be consulted. Changes in pipe size quantities due to unknown site conditions shall be calculated and incorporated into the contract by a change order.
- Exposed ends of the pipe shall be sealed with cohesive soil (sand and gravel mix) to protect against infiltration and erosion.
- Granular fill material may be used for structural backfill and concrete.”

### Bedding and Backfill Requirements for MCCMP, PCCP, and Plastic Pipe

**SPECIAL PLAN C**

**Bedding and Backfill Requirements**

- Bedding shall consist of clean, coarse-grained sand or gravel with a maximum particle size of 0.25 inches. The bedding shall be placed and compacted to the required thickness.
- The backfill shall consist of compacted soil with a maximum dry density of 95% of the Standard Proctor.

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**Bedding and Backfill Diagram**

![Diagram of Bedding and Backfill](image)
Appendix C: Project Evaluation & Implementation Recommendations

This Appendix lists the evaluation of the project by the technical panel that defined and monitored the work. In addition, it lists the implementation recommendations of the researcher, the technical panel, and the Research Review Board of the South Dakota Department of Transportation.

Technical Panel Evaluation and Recommendations

SD96-11 Evaluation of High Density Polyethylene (HDPE) Pipe
June 3, 1998

Researcher: Anselem H. Rumpca
Organization: South Dakota Department of Transportation
Office of Research
Pierre, South Dakota 57501-2586

Study Duration: February 1996 - April 1998

Study Evaluation

The principal investigator on this project was Anselem H. Rumpca from the Office of Research, South Dakota Department of Transportation.

The study evaluated the use of High Density Polyethylene (HDPE) pipe for use as storm sewer installed under state maintained highway US18 in Martin, South Dakota. Many issues concerning the strength, durability, construction and cost of using HDPE pipe under a state highway were addressed.

The soils in Martin were excellent for this type of installation and are not typical for South Dakota. The original design was to have minimal cover of approximately one foot. However, a surveying error placed the top of the HDPE pipe approximately twenty-six (26) inches below the pavement surface. The pipe performed satisfactorily with no visible or measurable deviations.

Research Objectives

1) Determine the suitability of High Density Polyethylene (HDPE) pipe as storm sewer pipe.

2) Determine the cost effectiveness of using High Density Polyethylene (HDPE).

3) Develop specifications for using HDPE for use on mainline applications.

Panel Comments

The HDPE pipe was installed and monitored to determine if any deviations in the pipe could be noted over time. A load test was also conducted on the pipe after it was installed with minimal movement noted.

The cost of concrete and HDPE pipe were compared based on bid prices and interviews with other states and agencies.

Recommendations were developed to allow the use of HDPE pipe for storm sewer applications under a state highway.
<table>
<thead>
<tr>
<th>Research Tasks</th>
<th>Panel Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Meet with the technical panel to review project scope and work plan.</td>
<td>The researcher met with the technical panel to review the proposal and address any concerns the panel had.</td>
</tr>
<tr>
<td>2) Review and summarize literature regarding design and installation of High Density Polyethylene (HDPE) pipe.</td>
<td>A significant amount of literature was reviewed concerning the use of HDPE pipe. Manufacturers and other transportation departments were contacted concerning specifications and costs of using HDPE pipe.</td>
</tr>
<tr>
<td>3) Develop deflection criteria for the design and acceptance of HDPE pipe.</td>
<td>The range of maximum deflection allowed by many states and agencies ranges from 5 to 7.5 percent. For this study a maximum deflection of 5 percent was used.</td>
</tr>
<tr>
<td>4) Provide a preliminary design to be included in the plans for the Martin, SD project.</td>
<td>Assistance was given to the Alliance of Architects and Engineers in Rapid City, South Dakota, concerning pipe and installation specifications.</td>
</tr>
<tr>
<td>5) Consult with the pipe supplier during the development of the final design for the installation of the HDPE pipe.</td>
<td>The pipe manufacturers were willing to provide technical assistance to the project. The selected manufacturer provided a trained representative for onsite technical assistance.</td>
</tr>
<tr>
<td>6) Monitor the construction and install instrumentation for short and long term deflection testing. The testing should cover at least one freeze thaw period.</td>
<td>A horizontal slope inclinometer tubing was placed on the top and bottom of the pipe to monitor deflections of the pipe. The pavement surface was monitored for movement with a dipstick floor profiler. The instrumentation provided adequate accuracy to monitor any deflections that may have occurred.</td>
</tr>
<tr>
<td>7) Conduct deflection testing using loading from H10 up to H20.</td>
<td>A SDDOT maintenance two-axle dump truck was loaded to simulate H20 loading. The rear axle was placed over the pipe and deflections were measured. No appreciable deflections of the pipe or the road surface was observed.</td>
</tr>
<tr>
<td>8) Evaluate results of deflection testing to determine if HDPE meets deflection criteria.</td>
<td>Deflection tests were evaluated and indicated a maximum deflection of 0.10 percent and an average deflection of 0.005 percent. Deflections were well within the 5 percent maximum deflection used for this project.</td>
</tr>
<tr>
<td>9) Determine costs of installation of HDPE pipe and compare to the cost of installing round reinforced concrete pipe. Include backfill and other associated costs.</td>
<td>The cost of concrete and HDPE pipe were compared based on bid prices and interviews with other states and agencies.</td>
</tr>
<tr>
<td>10) Recommend specifications for using HDPE as storm sewer and mainline drainage pipe.</td>
<td>Recommendations were made for specifying and installing HDPE pipe.</td>
</tr>
</tbody>
</table>
11) Prepare a final report and executive summary of the literature review, research methodology, findings, conclusions, and recommendations.

The researcher provided a well written and accurate report fulfilling the requirements of the project.

12) Make an executive presentation to the SDDOT Research Review Board at conclusion of the project.

An executive presentation was made to the Research Review Board at the conclusion of the project.

<table>
<thead>
<tr>
<th>Researcher’s Recommendations</th>
<th>Technical Panel’s Recommendations</th>
<th>Research Review Board’s Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Corrugated high density polyethylene pipe should be specified as an alternative for storm sewer and culvert installations on all South Dakota roadways where pipe sizes 305 mm (12 in) to 915 mm (36 in) are used.</td>
<td>The panel recommends that the offices of Road Design and Materials &amp; Surfacing should evaluate individual projects and include HDPE pipe as an alternate when appropriate on all South Dakota roadways except interstate.</td>
<td></td>
</tr>
<tr>
<td>2) The 1998 Standard Specifications for Roads and Bridges, South Dakota Department of Transportation, Section 990.1 F. Corrugated Polyethylene Pipe should be retained as it is currently written “Corrugated polyethylene pipe, couplings, and fittings shall conform to the requirements of AASHTO M 294”.</td>
<td>The panel agrees with this recommendation that no changes be made to the 1998 Standard Specifications for Roads and Bridges, Section 990.1 F referring to AASHTO M 294 as a standard.</td>
<td></td>
</tr>
<tr>
<td>3) A 5% deflection criterion should apply to the pipe when HDPE is installed on any South Dakota maintained highways.</td>
<td>The panel agrees with the 5% deflection criterion and recommends that the offices of Materials &amp; Surfacing and Operations Support should include as a installation specification that any HDPE pipe showing obvious distress be tested and removed if the deflection exceeds 5%. The panel also recommends that the offices of Materials &amp; Surfacing and Operations Support should evaluate the need to test HDPE pipe according to the 5% deflection criteria.</td>
<td></td>
</tr>
</tbody>
</table>
4) The 1998 Standard Specifications for Roads and Bridges, South Dakota Department of Transportation, Section 450.3 C, Corrugated Polyethylene Pipe Culverts: “Corrugated polyethylene pipe culverts shall be installed according to manufacturer instructions”, should be modified to require that “corrugated polyethylene pipe be installed according to standards specified in ASTM D 2321 - 89 Standard Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications”.

The panel recommends that the Office of Operations Support should modify the 1998 Standard Specifications for Roads and Bridges, Section 450.3 C, Corrugated Polyethylene Pipe Culverts: “Corrugated Polyethylene pipe culverts shall be installed according to manufacturer instructions”, to require that “corrugated polyethylene pipe be installed according to standards specified in ASTM D 2321 - 89 Standard Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications”.

5) The minimum cover for corrugated polyethylene pipes should be established as 457 mm (18 in) for all South Dakota Department of Transportation arterial highway drainage applications.

The panel agrees that the Office of Materials & Surfacing should establish the minimum cover for corrugated polyethylene pipes as 457 mm (18”) for all SDDOT arterial highway drainage applications.

6) A minimum cover for corrugated polyethylene pipes should be established as 305 mm (12 in) for all collectors, secondary roadways and private driveways where truck or other heavy vehicle traffic is minimal.

The panel recommends that the Office of Roadway Design should include as a plan note or specification that the minimum cover for corrugated polyethylene pipes should be 305 mm (12 in) for all collectors, secondary roadways and private driveways where truck or other heavy vehicle traffic is minimal.

7) The maximum fill height for corrugated polyethylene pipes should be established as 6.1 m (20 ft) with a 90 percent Standard Proctor Density compaction.

The Office of Materials & Surfacing should specify that the maximum fill height for corrugated polyethylene pipes be established as 6.1 m (20 ft) with a 90 percent minimum Standard Proctor Density.

8) The South Dakota Department of Transportation should allow
the option of using polyethylene end sections in municipal settings.

Materials & Surfacing should change the current plan note for Approach Pipe to allow the use of polyethylene end sections in municipal settings.

9) Inspection procedures should be rigorously followed to insure the installation and compaction specifications defined in ASTM D 2321 are maintained.

The panel recommends the office of Materials & Surfacing should review ASTM D 2321 and make appropriate changes to current policies and procedures as necessary.

Technical Panel

Vernon Bump ...................... Materials & Surfacing
Wayne Cramer ................................. Huron Area
Hadley Eisenbeisz ......................... Bridge Design
Jim Holzwarth ......................... Operations Support
                          Daris Ormesher ........................................ Research
                          Scott Rabern ......................................... Roadway Design
                          Leon Schochenmaier ........................ Pierre Region
                          Jay Tople ........................................ Materials & Surfacing