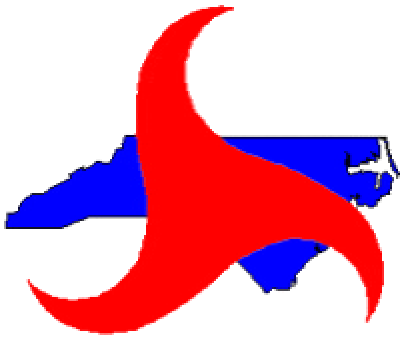
# DRAINAGE USERS MANUAL

**January 1, 2003**



## N. C. DEPARTMENT OF TRANSPORTATION
## DIVISION OF HIGHWAYS

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# Acknowledgements

This manual was developed by the North Carolina Department of Transportation to service the need for having as much pertinent information on the proper usage of pipe materials consolidated into one source. Many people were involved in the preparation of this manual and it has taken concerted efforts and coordination beyond their normal work assignments.

Special thanks is given to the following individuals for their dedication and hard work in making this manual possible:

| | |
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| Paul D. Bryant , P.E. | Bridge Maintenance Unit |
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The Drainage Users Manual has been edited by the Materials and Tests Unit of the North Carolina Department of Transportation. The contact person within the Materials and Tests Unit is the Field Operations Engineer.

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# Introduction

Stormwater pipe culverts may consist of concrete, metal, plastic, or a combination of these or similar materials. The pipe culvert structure, regardless of the pipe material used, is made up of the pipe, the foundation, the bedding materials, and the backfill materials that work in conjunction to support the loads imposed on the culvert.

Proper installation of pipe culverts is crucial to the overall performance of the culvert structure. Various problems associated with pipe installation can occur early on in the process. If the trench width is either too narrow or too wide, improper placement and compaction may result in a failure of the pipeline. If sections of pipe are not properly jointed or joints are not properly sealed, exfiltration or infiltration may result in a reduction of the pipe's capacity and voids may occur within the embankment. Damage to pipe during handling and installation may result in premature deterioration of the pipe and the pipe being unable to support design loads leading to failure during its service life. In addition, crossing pipe culverts with heavy construction equipment before adequate cover has been placed can lead to damage of the culvert. These and other problems associated with improper installation of pipe will increase maintenance costs and otherwise limit the design life of a culvert.

This manual is devoted to the proper materials selection, storage, handling, installation, and inspection of pipe culverts. It is intended to serve as a tool to aid NCDOT personnel in performing their duties during construction and maintenance activities. It is also intended to serve as a general guide for private industry involved in construction of roadways that may receive future acceptance onto the North Carolina Highway System.

This manual is not intended to serve as a design guide for pipe culverts used by NCDOT. Although several design references are contained herein, they are used only for clarification purposes.

The information contained within this document is not intended to alter or replace the Standard Specifications, but is to serve as a reference guide to fulfill the requirements set forth by the Specifications.

# References to Specifications

Transportation Improvement Program (TIP) projects should reference the version of the N. C. Department of Transportation's Standard Specifications for Roads and Structures indicated on the plan title sheet. All other work (maintenance activities, subdivision roads for future acceptance onto the state system, encroachment work within the right of way, etc.) should reference the version of the Standard Specifications in effect when the work is reviewed for approval.

Subdivisions and encroachments are to be reviewed prior to beginning work on these projects as stated in the Subdivision Roads Minimum Construction Standards and the Municipal/Developer Submittals Guidelines for Plan Reviews and Encroachments.

Any deviations from this Manual, the cited references herein, or the Standard Specifications, must have prior approval from the responsible NCDOT Engineer.

# Types of Pipe

The material types described below are ones currently allowed by the Standard Specifications, Standard Special Provisions, or New Products Approved Listing. Other specific material types not listed must receive prior approval through the New Products Committee.

## A. SITE SELECTION FOR MATERIAL TYPES

Several factors must be considered in determining the size and material of a pipe used for a particular application. The following table shows where specific material types may be used according to NCDOT policy.

| Pipe Material Type | Locations Allowed for Usage |
|---|---|
| Reinforced Concrete | All locations with invert slopes less than 10%. |
| Corrugated High Density Polyethylene | - As alternate on contract projects for driveways.<br>- By Special Provision on contract projects for side drains.<br>- Subdivision cross drains and side drains.<br>- Maintenance installation at Engineer's discretion. |
| Corrugated Polyvinyl Chloride | - As alternate on contract projects for driveways.<br>- By Special Provision on contract projects for side drains.<br>- Subdivision cross drains and side drains.<br>- Maintenance installation at Engineer's discretion. |
| Corrugated Steel | - As alternate on contract projects for driveways.<br>- By Special Provision on contract projects for side drains.<br>- Subdivision cross drains and side drains.<br>- Maintenance installation at Engineer's discretion. |
| Corrugated Aluminum | - As alternate on contract projects for driveways.<br>- By Special Provision on contract projects for side drains.<br>- Subdivision cross drains and side drains.<br>- Maintenance installation at Engineer's discretion. |
| Corrugated Steel Plate | - By Special Provision for contract cross drains.<br>- Maintenance installation at Engineer's discretion. |
| Corrugated Aluminum Plate | - By Special Provision for contract cross drains.<br>- Maintenance installation at Engineer's discretion. |
| NOTE: Other site or project specific factors such as: corrosive conditions, accessibility, environmental requirements, and handling may dictate the use of a particular material. | |

## B. CONCRETE PIPE CULVERTS

### 1. Basic Materials Properties

Concrete pipe is available as either Plain, meeting the requirements of AASHTO M 86, or Reinforced, meeting the requirements of AASHTO M 170. Reinforced concrete pipe uses a cage of reinforcing steel within the pipe. Concrete pipe is specified based on its inside diameter and one of five different strength classes: Class I, II, III, IV, or V. The higher the class number, the higher the strength of the pipe and the higher the external forces it can withstand. Another designation used for concrete pipe is for wall thickness. The letters A, B, and C are used to identify the different thicknesses, with a Wall Thickness C being the thickest. Most concrete pipe uses a "tongue and groove" (also called "bell and spigot") connection that allows for the placement of sections end to end.

### 2. Specific Acceptance Requirements

Materials for concrete pipe must meet the requirements of Section 1032-9 of the Standard Specifications.

All acceptable concrete pipe is stamped approved by Materials and Tests technicians prior to shipment from the producer's facility. The stamp should be located on the inside wall within the first foot of the end of the pipe. The stamp will include the type and class of pipe.

An example of the stamp:

The "3" represents the class (Class III) of pipe and the "B" is the wall thickness designation.


Only material coming from an approved pipe producer should be accepted for use on NCDOT right of way. The current listing of approved concrete pipe producers can be found on the Department's Vendor System and web page at: http://apps02.dot.state.nc.us/MTtracking/IntroPage.asp.

The producer should not ship any pipe not stamped to a NCDOT job site. If any pipe arrives on the job site without an approved stamp,

the pipe should be immediately rejected and returned to the producer.

When concrete pipe arrives on a job site, it must be visually inspected by NCDOT personnel. The NCDOT personnel will insure that the pipe has not been damaged during shipment. NCDOT personnel can reject any material damaged in shipment.

If questions do arise concerning the acceptability of materials, please notify your local Section Materials Specialist for assistance.

### 3. Joint Materials

There are two main types of materials required for concrete pipe:

a. Mortar - materials used in the mortar mix for joining pipe: Portland cement must meet the requirements of Article 1024-1. Sand must meet the requirements of Article 1014-1 for fine aggregate or Article 1040-6 for mortar sand. Hydrated lime must meet the requirements of Article 1040-5.

b. Flexible Plastic Joint Material - materials must meet the requirements of AASHTO M 198 for Type B flexible plastic gaskets, except as follows:

1. The flash point, C.O.C.*, must be a minimum of 325° F (163° C).
2. The fire point, C.O.C.*, must be a minimum of 350° F (177° C).

* Cleveland Open Cup method, ASTM D 92

## C. HIGH-DENSITY POLYETHYLENE (HDPE) PIPE CULVERTS

### 1. Basic Materials Properties

Corrugated HDPE pipe is designated in one of two ways: Single-wall or Double-wall, and is to be manufactured in accordance with AASHTO M 252 or M 294 standards. Single-wall (Type C) has one single corrugated wall and comes in diameters of 3" thru 24". Type C HDPE pipe is used for temporary slope drain and subsurface drains. Double-wall (Types S & D) has two walls, a corrugated outer wall and a smooth inner liner, and comes in diameters of 4" thru 48". Only Type S or Type D HDPE pipe is allowed for locations under traffic.

## 2. Specific Acceptance Requirements

Corrugated HDPE pipe material must come from an approved producer who is on the NCDOT Brand Registration Program for Plastic Pipe. The current listing of approved plastic pipe producers can be found on the Department's Vendor System and web page at: http://apps02.dot.state.nc.us/MTtracking/IntroPage.asp.

Each shipment of pipe must be accompanied by a matching Bill of Lading (BOL) listing all of the pipe contained within that shipment.

NCDOT personnel must determine if Quality Control (QC) stickers are on each length of pipe in the shipment.

An example of the QC sticker:

The sticker should indicate the Facility ID No. (PP #) where the pipe was actually produced, the Producer's name, the QC Lot No., and the date the pipe was manufactured.

NCDOT QC
FACILITY ID NO.
PRODUCER NAME
QC LOT NO.
MANUFACTURED DATE

NCDOT personnel can reject any shipments that do not have QC stickers on 100% of the pipe. Please alert your local Section Materials Specialist if shipments show up at the job without the required QC stickers.

When corrugated HDPE pipe arrives on a job site, it must be visually inspected by NCDOT personnel. The NCDOT personnel will insure that the pipe has not been damaged during shipment. NCDOT personnel can reject any material damaged in shipment.

If questions do arise concerning the acceptability of materials, please notify your local Section Materials Specialist for assistance.

## 3. Coupling

The coupling system shall provide a soil-tight joint meeting the requirements of AASHTO M 294, Section 7.8. When bell and spigot couplers are utilized, gaskets meeting the requirements of ASTM F 477 shall be used. Care should be taken to limit the amount of movement after the pieces are coupled together. Excessive

movement of the coupled joint may cause slippage of the coupling system or the pipe itself. Furthermore, excessive bending of the joined pipe can cause the system to bend or deform permanently thereby resulting in exfiltration or infiltration.

## D. CORRUGATED POLYVINYL CHLORIDE (PVC) PIPE CULVERTS

### 1. Basic Materials Properties

Corrugated PVC pipe material shall meet the product specifications of ASTM F 949 and shall have a smooth interior. Corrugated PVC pipe ranges in size from 4" - 36".

### 2. Specific Acceptance Requirements

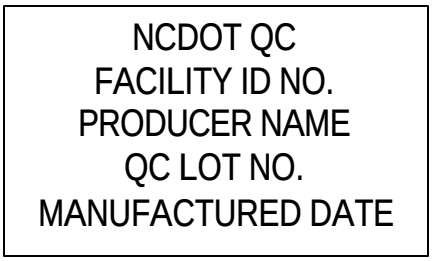
Corrugated PVC pipe material must come from an approved producer who is on the NCDOT Brand Registration Program for Plastic Pipe. The current listing of approved plastic pipe producers can be found on the Department's Vendor System and web page at: http://apps02.dot.state.nc.us/MTtracking/IntroPage.asp.

Each shipment of pipe must be accompanied by a matching Bill of Lading (BOL) listing all of the pipe contained within that shipment.

NCDOT personnel must determine if Quality Control (QC) stickers are on each length of pipe in the shipment.

An example of the QC sticker:

The sticker should indicate the Facility ID No. (PP #) where the pipe was actually produced, the Producer's name, the QC Lot No., and the date the pipe was manufactured.




NCDOT personnel can reject any shipments that do not have QC stickers on 100% of the pipe. Please alert your local Section Materials Specialist if shipments show up at the job without the required QC stickers.

When corrugated PVC pipe arrives on a job site, it must be visually inspected by NCDOT personnel. The NCDOT personnel will insure that the pipe has not been damaged during shipment. NCDOT personnel can reject any material damaged in shipment.

If questions do arise concerning the acceptability of materials, please notify your local Section Materials Specialist for assistance.

### 3. Coupling

The coupling system shall provide a soil-tight joint meeting the requirements of ASTM F 949, Section 7.8. Care should be taken to limit the amount of movement after the pieces are coupled together. Excessive movement of the coupled joint may cause slippage of the coupling system or the pipe itself. Furthermore, excessive bending of the joined pipe can cause the system to bend or deform permanently thereby resulting in exfiltration or infiltration.

## E. CORRUGATED STEEL PIPE CULVERTS AND PIPE ARCH

### 1. Basic Materials Properties

Corrugated steel pipe is fabricated from coils of flat steel that have been coated with either zinc or aluminum to prevent corrosion. Corrugated steel pipe should conform to the requirements of AASHTO M 36. Corrugated steel pipe is specified based on its inside diameter, corrugation pattern, and the thickness of the steel sheet used. Also, the term gage may be used to describe the thickness of the steel. With gage, the larger the number, the thinner the metal.

Elongated Pipe: Some installations call for pipe that has been elongated in the vertical direction by 5%. This is done to take into account the deflection that will occur in the pipe once backfilling is complete and thus retaining a circular cross section for the culvert.

Pipe Arch: This is a specific type of corrugated steel pipe used when fill heights are restricted.

Spiral Rib Pipe: This type of metal pipe has a full circular cross-section with a single thickness of smooth sheet, fabricated with helical ribs formed by a continuous lock seam. Spiral rib pipe must meet the requirements of the Type IR classification of AASHTO M 36.

## 2. Specific Acceptance Requirements

Corrugated steel pipe material must come from an approved producer who is on the NCDOT Brand Registration Program for Metal Pipe. The current listing of approved metal pipe producers can be found on the Department's Vendor System and web page at: http://apps02.dot.state.nc.us/MTtracking/IntroPage.asp.

Each shipment of pipe must be accompanied by a matching Bill of Lading (BOL) listing all of the pipe contained within that shipment.

NCDOT personnel must determine if Quality Control (QC) stickers are on at least 25% of the pipe per shipment.

An example of the QC sticker:

The sticker should indicate the Producer's name and the actual plant where the pipe was produced.

QUALITY CONTROL / QC
PRODUCER NAME
PLANT LOCATION

NCDOT personnel can reject any shipments that do not have QC stickers on at least 25% of the pipe. Please alert your local Section Materials Specialist if shipments show up at the job without the required amount of QC stickers.

When corrugated metal pipe arrives on a job site, it must be visually inspected by NCDOT personnel. The NCDOT personnel will insure that the pipe has not been damaged during shipment. NCDOT personnel can reject any material damaged in shipment. After delivery, but prior to installation, all corrugated metal pipe must be inspected by Materials and Tests technicians for coating thickness. NCDOT personnel should notify their local Materials and Tests technician for inspection when corrugated metal pipe is received on a job site or at the maintenance yard.

If questions do arise concerning the acceptability of materials, please notify your local Section Materials Specialist for assistance.

### 3. Coupling

Coupling bands for corrugated steel culvert pipe shall meet the requirements of AASHTO M 36 with the following exceptions as noted in Section 1032-3(A) of the Standard Specifications:

a. Use corrugated coupling bands except as may be otherwise provided below.
b. A hugger type corrugated band having one annular corrugation at each outside edge of the band will be acceptable.
c. Coupling bands with projections may be used where it is necessary to join new pipe to existing pipe having helical corrugations at the joint locations. Use an approved sealer with this type of coupling band.
d. Fasten coupling bands on the ends with a minimum of two 1/2" (12.7 mm) bolts.
e. Annular corrugated bands must have a minimum width of 10 1/2" (266.7 mm) where 2-2/3" (67.7 mm) by 1/2" (12.7 mm) corrugations are used.

Lifting Straps: The pipe may be furnished either with or without lifting straps for handling. Attach the lifting straps by bolting or by welding. Bolt holes for attaching the straps must be a smooth hole which is either punched or drilled. No burning of holes will be permitted. Design the lifting straps so that the holes can be plugged to prevent infiltration of backfill material.

## F. CORRUGATED ALUMINUM PIPE CULVERTS AND PIPE ARCH

### 1. Basic Materials Properties

Corrugated aluminum pipe is fabricated from coils of flat aluminum sheet. Corrugated aluminum pipe should conform to the requirements of AASHTO M 196. Corrugated aluminum pipe is specified based on its inside diameter, corrugation pattern, and the thickness of the aluminum sheet used. Also, the term gage may be used to describe the thickness of the aluminum. With gage, the larger the number, the thinner the metal.

Elongated Pipe: Some installations call for pipe that has been elongated in the vertical direction by 5%. This is done to take into account the deflection that will occur in the pipe once backfilling is complete and thus retaining a circular cross section for the culvert.

Pipe Arch: This is a specific type of corrugated aluminum pipe used when fill heights are restricted.

Spiral Rib Pipe: This type of metal pipe has a full circular cross-section with a single thickness of smooth sheet, fabricated with helical ribs formed by a continuous lock seam. Spiral rib pipe must meet the requirements of the Type IR classification of AASHTO M 196.

## 2. Specific Acceptance Requirements

Corrugated aluminum pipe material must come from an approved producer who is on the NCDOT Brand Registration Program for Metal Pipe. The current listing of approved metal pipe producers can be found on the Department's Vendor System and web page at: http://apps02.dot.state.nc.us/MTtracking/IntroPage.asp.

Each shipment of pipe must be accompanied by a matching Bill of Lading (BOL) listing all of the pipe contained within that shipment.

NCDOT personnel must determine if Quality Control (QC) stickers are on at least 25% of the pipe per shipment.

An example of the QC sticker:

The sticker should indicate the Producer's name and the actual plant where the pipe was produced.


NCDOT personnel can reject any shipments that do not have QC stickers on at least 25% of the pipe. Please alert your local Section Materials Specialist if shipments show up at the job without the required amount of QC stickers.

When corrugated metal pipe arrives on a job site, it must be visually inspected by NCDOT personnel. The NCDOT personnel will insure that the pipe has not been damaged during shipment. NCDOT personnel can reject any material damaged in shipment. After delivery, but prior to installation, all corrugated metal pipe must be inspected by Materials and Tests technicians for coating thickness. NCDOT personnel should notify their local Materials and Tests

technician for inspection when corrugated metal pipe is received on a job site or at the maintenance yard.

If questions do arise concerning the acceptability of materials, please notify your local Section Materials Specialist for assistance.

### 3. Coupling

Coupling Bands with projections may be used for circumferential pipe, helical pipe, or a combination of both. Use an approved sealer with this type of coupling band.

## G. CORRUGATED STEEL STRUCTURAL PLATE PIPE AND PIPE ARCH

### 1. Basic Materials Properties

This type of metal pipe consists of sections of plates that are bolted together in the field. These zinc-coated plates are corrugated, punched, shop curved, and hot-dip galvanized during fabrication at the producer's facility. Structural plate pipe comes in a variety of shapes and is specified based on the inside dimensions of the culvert. Also, the term gage may be used to describe the thickness of the steel. With gage, the larger the number, the thinner the metal.

Elongated Pipe: Some installations call for pipe that has been elongated in the vertical direction by 5%. This is done to take into account the deflection that will occur in the pipe once backfilling is complete and thus retaining a circular cross section for the culvert.

Pipe Arch: This is a specific type of corrugated steel pipe used when fill heights are restricted.

### 2. Specific Acceptance Requirements

Corrugated steel structural plate pipe material must come from an approved producer who is on the NCDOT Brand Registration Program for Metal Pipe. The current listing of approved metal pipe producers can be found on the Department’s Vendor System and web page at: http://apps02.dot.state.nc.us/MTtracking/IntroPage.asp.

Each shipment of pipe must be accompanied by a matching Bill of Lading (BOL) listing all of the pipe contained within that shipment.

NCDOT personnel must determine if Quality Control (QC) stickers are on at least 25% of the pipe sections per shipment.

An example of the QC sticker:

The sticker should indicate the Producer's name and the actual plant where the pipe was produced.

QUALITY CONTROL / QC
PRODUCER NAME
PLANT LOCATION

NCDOT personnel can reject any shipments that do not have QC stickers on at least 25% of the pipe sections. Please alert your local Section Materials Specialist if shipments show up at the job without the required amount of QC stickers.

When structural plate pipe arrives on a job site, it must be visually inspected by NCDOT personnel. The NCDOT personnel will insure that the pipe has not been damaged during shipment. NCDOT personnel can reject any material damaged in shipment. After delivery, but prior to installation, all structural plate pipe must be inspected by Materials and Tests technicians for coating thickness. NCDOT personnel should notify their local Materials and Tests technician for inspection when corrugated metal pipe is received on a job site or at the maintenance yard.

If questions do arise concerning the acceptability of materials, please notify your local Section Materials Specialist for assistance.

### 3. Assembly

The plate and fasteners for corrugated steel structural plate pipe and pipe arch must meet the requirements of AASHTO M 167.

Unless otherwise required by the plans or special provisions, place bolt holes along those edges of the plates that form longitudinal seams in the finished structure in 2 rows spaced 2" (51 mm) apart. Space the bolt holes a maximum of 6" (152 mm) apart.

Space bolt holes along those edges of the plates that form circumferential seams in the finished structure a maximum of 12" (305 mm) apart.

The minimum distance from the center of any bolt hole to the edge of the plate must not be less than 1 3/4 times the diameter of the bolt. The diameter of bolt holes in longitudinal seams, excepting those at plate corners, must not exceed the bolt diameter by more than 1/8" (3.1 mm). The diameter of holes in circumferential seams, including those at plate corners, must not exceed the bolt diameter by more than 1/2" (12.7 mm) and the average of the diameter on the major and minor axes must not exceed the bolt diameter by more than 1/4" (6.4 mm).

Cut plates for forming skewed or sloped ends so as to give the required angle of skew or slope. Burned edges must be free from oxide and burrs and present a workmanlike finish. Repair damaged spelter coating around cut or burned edges as required by AASHTO M 36. Furnish an erection drawing for each installation. Mark each plate as necessary to insure proper placement in the structure.

Install all bolts in accordance with the procedures specified by the manufacturer before backfill is placed. Tighten all nuts to a minimum of 100 ft•lb (135 N•m) and a maximum of 200 ft•lb (270 N•m) of torque. Check nut tightness with a properly calibrated torque wrench before, during, and after placing backfill.

## H. CORRUGATED ALUMINUM ALLOY STRUCTURAL PLATE PIPE AND PIPE ARCH

### 1. Basic Materials Properties

This type of metal pipe consists of sections of plates that are bolted together in the field. These aluminum plates are corrugated and shop curved during fabrication at the producer's facility. Structural plate pipe comes in a variety of shapes and is specified based on the inside dimensions of the culvert. Also, the term gage may be used to describe the thickness of the aluminum. With gage, the larger the number, the thinner the metal.

Elongated Pipe: Some installations call for pipe that has been elongated in the vertical direction by 5%. This is done to take into account the deflection that will occur in the pipe once backfilling is complete and thus retaining a circular cross section for the culvert.

Pipe Arch: This is a specific type of corrugated aluminum pipe used when fill heights are restricted.

## 2. Specific Acceptance Requirements

Corrugated aluminum alloy structural plate pipe material must come from an approved producer who is on the NCDOT Brand Registration Program for Metal Pipe. The current listing of approved metal pipe producers can be found on the Department's Vendor System and web page at: http://apps02.dot.state.nc.us/MTtracking/IntroPage.asp.

Each shipment of pipe must be accompanied by a matching Bill of Lading (BOL) listing all of the pipe contained within that shipment.

NCDOT personnel must determine if Quality Control (QC) stickers are on at least 25% of the pipe sections per shipment.

An example of the QC sticker:

The sticker should indicate the Producer's name and the actual plant where the pipe was produced.

QUALITY CONTROL / QC
PRODUCER NAME
PLANT LOCATION

NCDOT personnel can reject any shipments that do not have QC stickers on at least 25% of the pipe sections. Please alert your local Section Materials Specialist if shipments show up at the job without the required amount of QC stickers.

When structural plate pipe arrives on a job site, it must be visually inspected by NCDOT personnel. The NCDOT personnel will insure that the pipe has not been damaged during shipment. NCDOT personnel can reject any material damaged in shipment. After delivery, but prior to installation, all structural plate pipe must be inspected by Materials and Tests technicians for coating thickness. NCDOT personnel should notify their local Materials and Tests technician for inspection when corrugated metal pipe is received on a job site or at the maintenance yard.

If questions do arise concerning the acceptability of materials, please notify your local Section Materials Specialist for assistance.

### 3. Assembly

The plate and fasteners for corrugated aluminum alloy structural plate pipe and pipe arch must meet the requirements of AASHTO M 219.

Unless otherwise required by the plans or special provisions, bolt holes along the plate edges that will form longitudinal seams in the finished structure must be in 2 rows 1 3/4" (44.4 mm) apart and located in the valley and in the crest of each corrugation.

The minimum distance from the center of bolt holes to edge of plates must not be less than 1 3/4 times the bolt diameter. Space bolt holes along those edges of the plates that form circumferential seams in the finished structure a maximum of 10" (254 mm) apart.

The diameter of bolt holes in longitudinal seams, excepting those at plate corners, must not exceed the bolt diameter by more than 1/8" (3.1 mm). The diameter of holes in circumferential seams, including those at plate corners, must not exceed the bolt diameter by more than 1/2" (12.7 mm) and the average of the diameters on the major and minor axes must not exceed the bolt diameter by more than 1/4" (6.4 mm).

Accurately cut plates for forming skewed or beveled ends of structures to form the required final shape. Plates must be saw cut, not burned, to present a workmanlike finish free from notches or gouges.

Furnish an erection drawing for each installation. Mark each plate as necessary to insure proper placement in the structure.

Install all bolts in accordance with the procedures specified by the manufacturer before backfill is placed. Tighten all nuts to a minimum of 100 ft•lb (135 N•m) and a maximum of 200 ft•lb (270 N•m) of torque. Check nut tightness with a properly calibrated torque wrench before, during, and after placing backfill.

# I. VITRIFIED CLAY CULVERT PIPE

## 1. Basic Materials Properties

Vitrified clay pipe is formed from different clay blends in the process of vitrification. Vitrification occurs when the pipe is fired in a kiln at temperatures that reach approximately 2000° F. This process forms a chemically inert and stable compound which is resistant to abrasion and corrosion.

## 2. Specific Acceptance Requirements

Materials for vitrified clay pipe must meet the requirements of ASTM C 700.

All acceptable vitrified clay pipe is stamped approved by Materials and Tests technicians prior to shipment from the producer's facility.

When vitrified clay pipe arrives on a job site, it must be visually inspected by NCDOT personnel. The NCDOT personnel will insure that the pipe has not been damaged during shipment. NCDOT personnel can reject any material damaged in shipment.

If questions do arise concerning the acceptability of materials, please notify your local Section Materials Specialist for assistance.

## 3. Joint Materials

There are two main types of materials used for joining of vitrified clay pipe:

a. Mortar - mortar mix used for joining pipe must use materials meeting the requirements of Section 1032-9(G).

b. Flexible Plastic Joint Material - materials must meet the requirements of Section 1032-9(G).

## J. WELDED STEEL PIPE

### 1. Basic Materials Properties

Welded steel pipe is produced by the forming and welding of steel plates into the size and shape of culvert specified. Welded steel pipe is mainly used by NCDOT for jacking and boring applications.

### 2. Specific Acceptance Requirements

Materials for welded steel pipe must meet the requirements of ASTM A 139.

Welded steel pipe material must come from an approved producer who is on the NCDOT Brand Registration Program for Metal Pipe.

When welded steel pipe arrives on a job site, it must be visually inspected by NCDOT personnel. The NCDOT personnel will insure that the pipe has not been damaged during shipment. NCDOT personnel can reject any material damaged in shipment.

If questions do arise concerning the acceptability of materials, please notify your local Section Materials Specialist for assistance.

### 3. Assembly

Couplings used for welded steel pipe must meet the requirements of ASTM A 139 or as indicated in the plans and Special Provisions.

# Coatings for Pipe Culverts

Different coatings are used to protect pipe materials from both corrosion and abrasion. The actual coating used depends on the type of pipe material being used and the type of distresses the pipe is being protected against, including:

- The salinity and pH of the surrounding soil
- The salinity and pH of the water in the culvert
- The velocity and size of particles passing through the culvert
- Freezing and thawing cycles within the surrounding soil

## A. GALVANIZED COATINGS

Galvanizing is the process by which steel is coated with a thin layer of zinc. Zinc is widely used to protect corrugated steel pipe from corrosion. Zinc metal has excellent corrosion resistance in most all North Carolina environments. Zinc acts sacrificially to protect the base steel from the elements -- in other words, zinc gives itself up to corrosion, thus preventing corrosion from occurring to the base metal.

Corrugated steel pipe shall be fabricated from galvanized steel sheet meeting the requirements of AASHTO M 218. Materials and Tests technicians shall check for minimum coating thickness prior to installation of the pipe. Whether the pipe is used on contract construction projects, division design-construct projects, or on maintenance work (driveways, subdivision roads for future acceptance onto the state system, encroachment work within the right of way, etc.), please contact your local Section Materials Specialist for inspection.

## B. ALUMINIZED COATINGS (TYPE 2)

Steel pipe can also be coated for corrosion resistance using aluminum. Aluminum acts as a barrier to corrosion and protects the base metal from the elements. The Type 2 designation for this coating requires that the aluminum be commercially pure.

Corrugated steel pipe shall be fabricated from aluminized steel sheet meeting the requirements of AASHTO M 274. Materials and Tests technicians shall check for minimum coating thickness prior to installation of the pipe.

**NOTE:** Do not use plain galvanized or aluminized corrugated steel pipe in the following counties:

Beaufort, Bertie, Bladen, Brunswick, Camden, Carteret, Chowan, Columbus, Craven, Currituck, Dare, Gates, Hertford, Hyde, Jones, Martin, New Hanover, Onslow, Pamlico, Pasquotank, Pender, Perquimans, Tyrrell, and Washington.

## C. BITUMINOUS COATINGS

Bituminous coatings are a widely used method of giving corrugated steel pipe corrosion resistance. Another benefit of bituminous coatings is abrasion resistance to stormwater and particles (sand, silt, debris, etc.) within the stormwater. Applications will vary based on the stormwater velocity due to pipeline slopes and the amount and size of particles expected within the pipeline. Bituminous coatings are applied after the pipe is fabricated and must meet the minimum thickness requirements set forth in AASHTO M 190. Materials and Tests technicians sample and test the coating materials before application. They also must check for minimum coating thickness prior to installation of the pipe.

Bituminous coating of pipe may cover only half of the circumference both inside and out or may cover the entire cross section of pipe both inside and out. Another type of bituminous coating involves paving a percentage of the invert of the pipe and filling in the corrugations. Paving helps to extend the life of the pipe by further protecting the invert from corrosion and abrasion. Bituminous coatings for corrugated steel shall be one of the types below [from Standard Specifications, Section 1032-4(A)]:

### 1. Type A -- Fully Bituminous Coated:

The pipe and pipe arch must meet the requirements of Subarticle 1032-3(A) and be bituminous coated in accordance with the requirements of AASHTO M 190 for Type A pipe. Do not coat coupling bands.

### 2. Type B -- Half Bituminous Coated and Partially Paved:

The pipe and pipe arch must meet the requirements of Subarticle 1032-3(A) and be half bituminous coated and partially paved in accordance with the requirements of AASHTO M 190 for Type B pipe. Do not coat coupling bands.

### 3. Type C -- Fully Bituminous Coated and Partially Paved:

The pipe and pipe arch must meet the requirements of Subarticle 1032-3(A) and be fully bituminous coated and partially paved in accordance with the requirements of AASHTO M 190 for Type C pipe. Do not coat coupling bands.

### 4. Type D -- Fully Bituminous Coated and Fully Paved:

The pipe and pipe arch must be fully bituminous coated and fully paved as provided for Type C except that the pavement must extend for the full circumference of the inside of the pipe. The inside diameter after paving must not be less than 98 percent of the nominal diameter of the pipe. Do not coat coupling bands.

Pipe meeting the applicable requirements of Subarticle 1032-3(A) for aluminized pipe may be substituted for bituminous coated galvanized steel culvert pipe as provided in paragraphs 1 through 5 below, except that paragraphs 1, 2, and 3 will not apply in the counties of Beaufort, Bertie, Bladen, Brunswick, Camden, Carteret, Chowan, Columbus, Craven, Currituck, Dare, Gates, Hertford, Hyde, Jones, Martin, New Hanover, Onslow, Pamlico, Pasquotank, Pender, Perquimans, Tyrrell, and Washington.

1) In lieu of Type A, Fully Bituminous Coated galvanized pipe, aluminized pipe without a bituminous coating, may be used.

2) In lieu of Type B, Half Bituminous Coated and Partially Paved galvanized pipe, Type B aluminized pipe may be used. Type B aluminized pipe is aluminized pipe which has been half bituminous coated and partially paved as required by Subarticle 1032-4(A)(2).

3) In lieu of Type C, Fully Bituminous Coated and Partially Paved galvanized pipe, Type B aluminized pipe may be used.

4) In lieu of Type D, Fully Bituminous Coated and Fully Paved galvanized pipe, Type D aluminized pipe may be used. Type D aluminized pipe is aluminized pipe which has been fully bituminous coated and fully paved as required by Subarticle 1032-4(A)(4).

5) The above provisions pertaining to the substitution of aluminized pipe for galvanized pipe will also apply to the substitution of aluminized pipe arch, end sections, tees,

elbows, and eccentric reducers for galvanized pipe arch, end sections, tees, elbows, and eccentric reducers.

## D. POLYMERIC COATINGS

Polymeric coatings provide both corrosion and abrasion resistance much like bituminous coatings. The application process used for polymers allows the metal sheet to be precoated prior to fabrication of the pipe. Polymeric coatings must meet the minimum thickness requirements set forth in AASHTO M 246. Materials and Tests technicians will check polymeric coating thickness at the producer's facility.

As provided in Section 1032-4(E) of the Standard Specifications:

> A polymeric coating meeting the requirements of AASHTO M 246 for Type B coating will be acceptable in lieu of bituminous coating wherever Type A fully bituminous coated corrugated steel culvert pipe or pipe arch is called for by the contract.

## E. CONCRETE LINING

Concrete is another material used to provide additional protection for corrosion and abrasion resistance. Fully lined corrugated steel pipe can be used as provided in Section 1032-4(E) of the Standard Specifications: Concrete lined corrugated steel culvert pipe, tees, and elbows must be fully concrete lined for the full circumference of the inside of the pipe and meet the requirements of ASTM A 849 for Type C-3 pipe. The inside diameter after lining must not be less than 98% of the nominal diameter of the pipe. The corrugated metal pipe, tees, and elbows must meet the requirements of Article 1032-3 before the pipe is lined.

# Fill Height Requirements

Minimum fill height for ALL types of pipe is 12 inches as measured from the top of the pipe to the top of soil backfill, excluding any prepared stone base or pavement, unless otherwise shown on the plans, drawings, or fill height tables as referenced below.

During construction of pipe culverts, there are also requirements to be met for fill heights in respect to the construction equipment being operated over the culverts prior to completion of the finished grade.

Maximum fill height requirements for pipe culverts are dependent on both pipe material type and type of installation.

## A. DRIVEWAY TYPE DEFINITIONS FOR MAINTENANCE

Due to the site specific aspects of driveway installation for NCDOT Maintenance forces, definitions must be made of what types of driveways may be encountered. The following classifications are as set forth by the "NCDOT Policy on Street and Driveway Access to North Carolina Highways". These definitions also apply to subdivision roads that may receive future acceptance onto the North Carolina Highway System.

Facilities meeting the following definitions fall under the approval control of the Department's local District Engineer.

### 1. Private Residential

A driveway connecting to a State-maintained street or highway to provide entrance to and/or exit from a private residential dwelling for exclusive use and benefit of those residing within. This type of driveway is normally installed by NCDOT maintenance forces when pipe is furnished by others.

### 2. Residential Subdivision

A driveway connecting to a State-maintained street or highway to provide entrance to and/or exit from residential subdivisions, apartment complexes, mobile home parks, and condominiums.

### 3. Commercial

A driveway serving a commercial establishment, industry, governmental or educational institution, business, public

establishment, or other comparable traffic generator. (This classification includes single family residential streets, where required by the District Engineer).

## B. MINIMUM COVER REQUIREMENTS FOR DRIVEWAYS

Minimum cover requirements for driveways are the same for all pipe material types, unless used for Commercial Driveways. The following minimum cover requirements should be applied by the District Engineer for driveways as defined in Section A above:

| Driveway Type | Minimum Cover Required |
|---|---|
| Private Residential | 12 inches (excluding any pavement used) |
| Residential Subdivision | 12 inches (excluding any pavement used) |
| Commercial | See NCDOT Roadway Design Manual |

NOTE: Due to site-specific conditions, some driveways may not be able to get minimum cover. In these situations, every effort should be made to achieve minimum cover and any deviations from the minimum requirements will require prior approval from the responsible NCDOT Engineer.

## C. MINIMUM COVER FOR CONSTRUCTION EQUIPMENT LOADINGS

The Specifications require that no heavy equipment shall be allowed to operate over any pipe culvert until the backfill is completed to at least three (3) feet above the top of the pipe. This depth may be increased if, in the opinion of the Engineer, the Contractor's equipment would cause damage to the completed pipe culvert. In any event, however, it is the Contractor's responsibility to conduct his operations in such a manner as not to cause damage to any completed structure. Where possible, NCDOT personnel shall periodically inspect completed pipe culverts for possible damage caused by live loads developed from the construction operations. This minimum cover must be maintained until heavy equipment usage is discontinued and the Contractor is prepared to set the final grade.

## D. MAXIMUM COVER FOR FINISHED GRADE

Appendix B of this Manual shows the maximum cover allowed above the pipe culvert once the proposed finished grade has been completed. These tables should be adhered to in order to decrease the effects of the dead loads imposed on the pipe by the soil envelope above. This data is dependent on pipe material used, class of pipe used, wall thickness, area of reinforcing steel, concrete strength, corrugation pattern, and thickness of material used.

# Installation Practices

The installation of a pipe culvert is a systematic process. Following the process will help to reduce oversight and mistakes. The proper installation of a culvert is absolutely essential for its performance. If damage occurs due to improper handling or storage, pipe sections may not properly fit up in the field. If trenches are not properly excavated, bedding and backfill placement cannot be completed adequately. If bedding or backfill materials are not compacted properly, settlement will occur which could lead to failures in the roadway. If pipe joints are not correctly sealed, exfiltration or infiltration may occur.

Safety should be first and foremost during any installation. Many construction projects occur in and around existing highways that are open to traffic. If pipe installation is to occur within the roadway where traffic is to be maintained, the installation of pipe shall be done in sections so that half of the width of the roadway will be available to traffic. Because of this requirement, the contractor or NCDOT must establish traffic control. Refer to the Traffic Control Plans and Standard Drawings to make sure the traffic control is established correctly before proceeding with the pipe installation. Note that Traffic Control Plans cannot be altered without the approval of the NCDOT Traffic Control Section.

Prior to any excavation, it is the contractor's or NCDOT's responsibility to call a utility locator service, utility company, municipality, telephone company, and/or cable company to mark lines that need to be relocated. Inspectors are responsible for knowing that utility relocation is required prior to excavation and must be aware of all utilities located on this project.

When trenches are excavated, the inspector should be sure that they are safe. Excavated material should be stockpiled at a safe distance away from the trench edges. The pipe inspector may need to enter the trench to inspect the pipe and foundation during pipe installation. At these times, inform the foreman and the equipment operator to cease work. Establish eye contact with the equipment operator and stay in the operator's line of sight while in the trench. Read Chapter 5, "Excavations" in the NCDOT Safety Policy and Procedure Manual for information on excavations, trenching, and shoring.

## A. SITE PREPARATION

### 1. Material Unloading and Storage

All pipe shall be unloaded and handled with reasonable care. Metal pipe or plates shall not be rolled or dragged over gravel or rock

during handling. As required in Section 300-3 of the Standard Specifications, the Contractor shall take all necessary precautions to ensure the method used in lifting or placing the pipe does not induce stress fatigue in the pipe and the lifting device used uniformly distributes the weight of the pipe along its axis or circumference. When any section of pipe is damaged during unloading or handling, the undamaged portions may be used where partial lengths are needed. If the Engineer rejects the section as being unfit for installation, the Contractor shall remove such rejected pipe from the job site.

Non-structural damage to pipe may be repaired by the Contractor when permitted by the Engineer.

The use of any method which induces point loading on the section of pipe shall not be allowed. Figure 5-1 below shows an unacceptable method of lifting pipe during installations. This method induces major point loads at the lifting hole location.

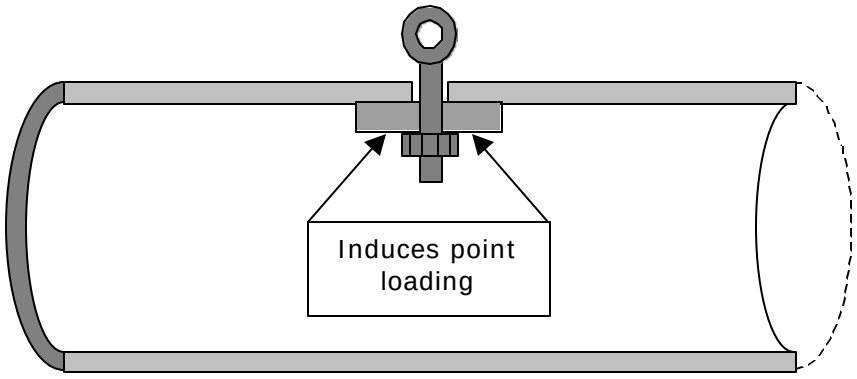



Figure 5-1

Figure 5-2 illustrates a method of handling pipe when a lifting hole is used that will uniformly distribute the weight of the pipe along its axis, as required in Section 300-3 of the Standard Specifications.

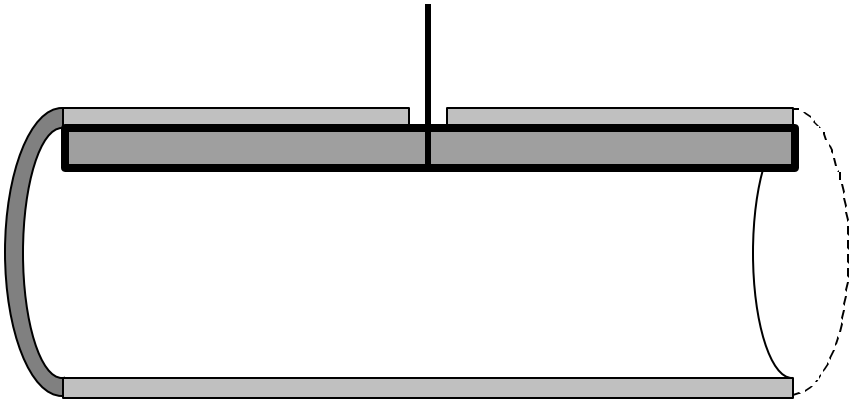


Figure 5-2

For pipe without a lifting hole, one acceptable method of lifting involves the use of a nylon strap or sling wrapped around the pipe. Figure 5-3 shows how, for shorter pipe lengths, one strap or sling can be used around the middle of the section when lifting or placing the pipe into the trench. For longer lengths, two nylon straps should be placed at the 1/3 and 2/3 points on the pipe, as shown in Figure 5-4.

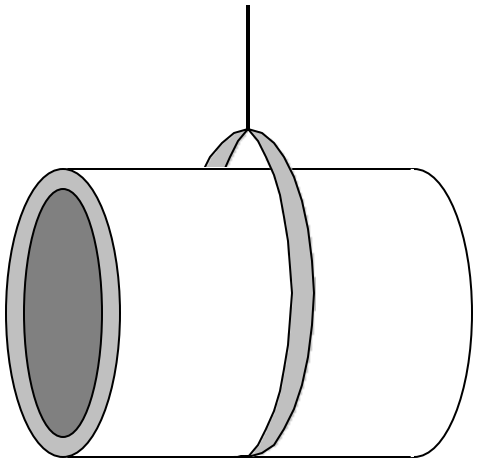


Figure 5-3

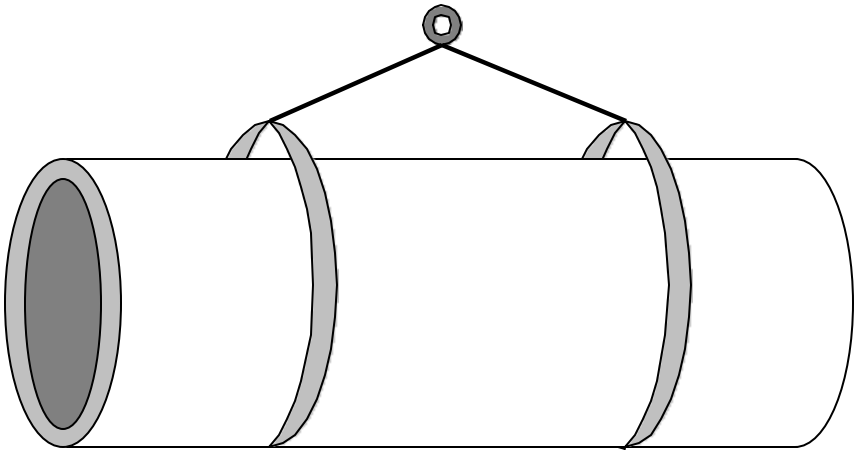


Figure 5-4

Care should always be taken in handling and storing all types of pipe. Pipe should not be dropped during loading, unloading or installation, as this can cause cracking and deformation. For safety reasons all pipe which is greater than eighteen (18) inches in diameter should be handled by mechanical equipment such as backhoes or front end loaders. Do not use forklifts or loader booms inside pipe greater than 24 inches and longer than 4 feet. The pipe should always be lifted in a horizontal position. At all times, OSHA regulations, both federal and local, should be followed when lifting and handling of pipe is performed.

Care must also be taken when storing pipe at the job site or project. Bituminous coated corrugated metal pipe, which is paved, shall be stored with the paved portion of the pipe nearest the ground. Pipe shall not be stacked higher than 6 feet for safety reasons. Coated pipe should be covered with tarps to prevent the bituminous coating from drying out and cracking due to environmental conditions and exposure to the sun.

## 2. Installation Types

There are two main types of pipe installations: Trenched installations are those where pipe is placed in natural ground or a constructed fill section with a specified trench width. Embankment installations are those where pipe is placed on natural ground and then covered by a constructed embankment.

For both types of installations, correct placement and compaction of the material surrounding the pipe are crucial. This makes the need for following the specified methods of foundation conditioning, laying pipe, and backfilling of the pipe essential. In addition, for trenched installations, the load transmitted to the pipe is directly related to the trench width. Therefore, if the actual trench width is not within the specified limits, the load transmitted to the pipe will be greater than designed and distress in the pipe may occur. Details on methods of installation can be found in the NCDOT Roadway Standard Drawings 300.01, 300.02, 300.03, and 300.04 -- see Appendix A of this Manual.

Other types of pipe installations include Jacking and Boring and Tunneling. These two types are used whenever conventional open excavation is not practical or deep installations are needed. The advantages of these installations include: no interruption in traffic on the overlying roadway, cutting and patching of existing pavement is not necessary, and depth of installation is of no concern.

## 3. Preparation of Pipe Foundation

Prepare the pipe foundation in accordance with the applicable method shown on the plans, true to line and grade, and uniformly firm. A firm, uniform foundation is a necessity because a pipe culvert performs both a hydraulic and a structural function. Distortion of the foundation under load may result in pipe failure and ultimately embankment failure.

### a. Undercut Excavation

During the preparation of the pipe foundation, unsuitable material or rock may be encountered. One must use sound judgment in determining whether a foundation contains suitable or unsuitable material. A probe rod can be used to confirm suspicions of unsuitable material. If the rod indents under firm pressure, the foundation is probably satisfactory. If the rod easily penetrates under a firm push, the foundation needs adjustment.

No pipe culvert shall rest on rock foundations or foundations that cannot be reasonably expected to support the anticipated dead and live loads. Where material is found to be of rock or of poor supporting value and when the Engineer cannot make adjustment in the location of the pipe, undercut existing

foundation material within the limits established on the plans or as shown in NCDOT Roadway Standard Drawings 300.01, 300.02, 300.03, or 300.04, as applicable.

In areas of unsuitable material, undercut to depth as directed by the Engineer. Ideally, this depth would be to some lower strata of material capable of supporting the load. In this case, the foundation conditioning could consist of any earth material considered acceptable for embankment. Many times, however, it is not practical to undercut to a depth that a suitable strata of foundation material can be obtained. In this case, the Engineer should direct the depth to be that as considered sufficient to "bridge over" the unsuitable material.

During the undercutting of the material, the pipe inspector will need to do a visual check for water (seepage and standing) in the trench foundation, especially in the mornings. A small trickle can be handled with foundation conditioning material (crushed stone or gravel) or underdrains. Read Section 300-8 and 300-9 in the Standard Specifications and the Construction Manual for the method of measuring and basis of payment for foundation conditioning material.

If more than a trickle is observed, other methods should be employed to remove standing water. Sump pumps and well-points are used frequently to keep trenches dry while excavation or work activities are ongoing.

### b. Foundation Conditioning Material

Once the sufficient undercut depth is reached, it may be possible to bridge with local material meeting the requirements of embankment material. However, if a wet condition is encountered, it will normally require a more granular type of backfill. When other than local material is used, the material must meet the requirements of Section 1016-3 for Class II or III.

Regardless of the foundation conditioning material used, it shall be compacted to a degree that will afford a firm, uniform foundation.

### c. Camber

Where pipe culverts are placed on compressible material, camber should be placed in the grade of the pipeline to compensate for settlement. The amount of camber used depends on the load imposed on the foundation materials and the compressibility of the material. Since these factors vary, judgement is required in selecting the amount of camber to be used. In an effort to provide some guidance in the selection of values for camber, a chart of these values is included in Appendix D of this Manual. Unless more precise information is available, the values taken from the chart should be used.

### d. Preparation of Bedding

Once the foundation for the pipe is completed the actual surface on which the pipe is laid must be prepared. This bedding surface distributes the resistive load of the foundation around the bottom circumference of the pipe and reduces the resulting point loading. See the Standard Drawings for more details on proper bedding requirements. The shape of the bedding should be carefully checked by template to insure the formation of a proper cradle for the pipe. The pipe should fit snugly in the cradle. Any gaps between the pipe and the cradle which are large enough to poke fingers into are too large and should be fixed. When a bell and spigot type of pipe is used, the foundation must be excavated to a sufficient depth and width to accommodate the bell such that the entire length of joint is resting snugly in the foundation. If the excavation is too large, the joint will not have the necessary foundation support. The cradle must also be straight. The line and grade of the bedding should be checked using either an offset string line, batter boards, or laser. When a string line is used, it should be supported at intervals not to exceed 50 feet so as to prevent sag. A good "visual examination" down the string line will assist in removing sags and/or errors made in establishing the string line. When the Contractor elects to utilize laser methods to establish line and grade, NCDOT personnel should insure that the instrument is properly set up and functioning correctly. The bedding should be smooth and free of large rocks or other protrusions which may also cause point loading. No material larger than 2" in size should come into direct contact with the pipe.

### 4. Invert Elevations

Invert elevations for cross pipe drainage must be set so that aquatic life movement is not substantially disrupted. To this end, inverts of cross pipe with diameters from 18" through 48" shall be buried below the streambed a minimum of 20% of the diameter of round pipe or the rise of arch pipe. Pipe diameters of 54" and larger shall be buried a minimum of 1.0 foot. Maximum burial depth will be as indicated on the plans.

Invert elevations of storm drainage systems shall be in accordance with the NCDOT Roadway Design Manual - Part I, Section 5-3, and must meet minimum cover requirements as noted above in Chapter 4.

Invert elevations for TIP projects let under the 1995 Standard Specifications shall be as directed by the Engineer. TIP projects let under the 2002 NCDOT Standard Specifications shall be as specified in Section 300-5 of the Specifications.

## B. LAYING PIPE

Problems can develop for pipe if the joints are not connected properly. The problems can range from minor to serious in nature. Typical joint defects include leakage (exfiltration and infiltration), cracks, and joint separation.

Exfiltration occurs when leaking joints allow water flowing through the pipe to leak into the supporting material. Minor leakage may not always be a significant problem unless soils are quite erosive. Leaking joints may be detected during low flows by visual observation of the joints and by checking around the ends of the culvert.

Infiltration is the opposite of exfiltration. Many culverts are essentially empty except during peak flows. When the water table is higher than the culvert invert, water may seep into the culvert between storms. This infiltration can cause settlement and misalignment problems if it carries fine grained soil particles from the surrounding backfill. Infiltration may be difficult to detect visually in its early stages, although it may be indicated by open joints, staining at the joints on the sides and top of the culvert, deposits of soil in the invert, or by depressions over the culvert.

Cracks in the joint area may be caused by improper handling during installation, improper joint material/gasket placement, and movement or settlement of the pipe sections.

Joint separations may be caused by settlement, undermining, or improper installation. Joint separations are significant because they accelerate damage caused by exfiltration and infiltration resulting in the erosion of the backfill material.

During installation, care should be taken when joining the pipes to prevent damage by mechanical equipment. Blunt forces will not be allowed, such as hitting the end of the pipe with a backhoe bucket, to push the joints of pipe together. Batter boards or other sufficient material should be used to cushion the blow, when this type of equipment is used. Damage to the pipe ends will be cause for rejection.

Ensure the first section of pipe is not disturbed as the next section is being joined to it. A major disturbance of the pipe will result in the pipe being out of line and/or grade, and it will need to be reset. Lay the pipe on the prepared foundation, bell or groove end upgrade with the spigot or tongue fully inserted to make a soil-tight joint. Make sure that the sections are compressed together properly. Any sections that are dropped or dragged should be inspected immediately for damage. Check each joint for alignment and grade as the work proceeds.

When installing multiple lines of pipe, leave a clearance equal to one-half the diameter of the pipe between each line to provide adequate space for proper compaction of the backfill material.

## C. BACKFILLING PIPE

As stated before, correct placement and compaction of the material envelope surrounding pipe is crucial to the performance of the culvert. Well-compacted material surrounding the pipe serves three main purposes:

1) Provides the lateral pressures needed to support the pipe structurally,
2) Prevents settlement that can induce unwanted stresses on the pipe, which can ultimately cause pipe failure or failure of the overlying roadway.
3) Reduces the movement of groundwater around the outside of the pipe, which can undermine the pipe and possibly lead to failure.

The type of material used for backfill is dependent on the fill height requirements specified:

- **Fill Height is 30 feet or less:**

  An "approved backfill material" is required and may be any material which is considered acceptable for embankment. The backfill material should be suitable local material if available. Backfill material must be kept free of rocks greater than 2", frozen lumps, chunks of highly plastic clay, organic materials like tree stumps, and other objectionable material.

- **Fill Height is over 30 feet through 40 feet:**

  Select backfill material is to be used meeting the requirements of Class II select material as shown in Section 1016-3.

- **Fill Height is over 40 feet through 50 feet:**

  Select backfill material is to be used meeting the requirements of Class III select material as shown in Section 1016-3.

- **Fill Height is over 50 feet:**

  Select backfill material is to be used meeting the requirements of Class IV select material as shown in Section 1016-3.

Backfill should be placed around the pipe in accordance with the applicable method shown on the plans or the Standard Drawings, in layers not to exceed six (6) inches loose, unless otherwise permitted. Approval for increasing layer depths above six (6) inches should be granted only when the backfill meets the criteria for Class I or Class II select material as shown in Section 1016-3.

No subsequent layers shall be placed until the preceding layer has been satisfactorily compacted. The lifts of backfill shall be kept approximately equal in height on each side of the pipe to prevent distortion of alignment and pipe cross section by the compactive effort. Care also should be taken during backfill and compaction operations to prevent damage to the joints.

Periodic density tests shall be made on pipe backfill to verify the fact that the method of compaction is giving satisfactory results. This is especially important at the start of backfilling operations to allow the Engineer to get the "feel" of satisfactory compaction. This "feel", whether found by using one's thumb, heel , or a probing rod, may be used as a guide when density tests are not being made. Density testing is also very important whenever the type of compactor being used changes. Wherever possible, density

tests should be made on pipe backfill placed in a trench section where the top of the trench represents the subgrade line. It is in this area of pipe backfill that most pavement irregularities and failures occur due to a lack of proper backfill compaction.

# Pipe End Treatment Guidelines

Endwalls or other end treatments give culverts positive foundation support at the entrance and exit, control of water flow, and help prevent the erosion of surrounding embankments. All endwalls, except the straight endwall, decrease water flow.

The most common types of end treatment in North Carolina are the straight endwall, U-endwall, flared end section, mitered end section, and wing endwall.

The plans indicate the type of end treatment to be installed. Standard numbers 310, 320, and 838 in the Roadway Standard Drawings give details of end treatments and endwalls.

On the plans, rip rap is shown at the ends of the pipe. Standard Drawing 868.02 gives a guide for rip rap at pipe outlets. Read Section 868 in the Standard Specifications for requirements on the placement of rip rap.

End treatments should be installed soon after pipe installation. Before end treatment construction begins, the pipe should be checked for scour and erosion. If endwalls are to be constructed, they should be constructed after the pipe is laid, but before fill is placed, since the fill will back up to it.

## PIPE END TREATMENT GUIDELINES
## (from NCDOT Roadway Design Manual, Chapter 5)

The following guidelines apply to TIP projects on the primary system. The guidelines do not apply to the secondary road system. The criteria provided within this section is intended as a guide only. Engineering judgment should be used to determine if a different, but more appropriate, treatment is necessary.

The following guidelines for Pipe End Treatment shall be used in conjunction with the guidelines on clear zone distances. (See Appendix C of this Manual to determine clear zone distances.)

Recommended Pipe End Treatments are listed below in preferential order. Use the first recommendation listed under each heading if practical.

### A. PIPE END TREATMENT FOR CROSS PIPES ON ALL ROADWAYS

(For further information, See “Roadway Standard Drawings”, Std. No’s. 310.03 and 310.05 -- Appendix A of this Manual)

### 1. Pipes Outside Clear Zone

Use endwall on inlet end for 36 inches or over, unless specified otherwise by Hydraulics Unit.

### 2. Pipes Inside Clear Zone

a. Extend all pipe beyond clear zone and use endwall on inlet end for 36 inches or over, unless specified otherwise by Hydraulics Unit.

b. Use a Cross Pipe end section (4:1 slope) for 30 inches or under. Use guardrail for 36 inches or over with endwall on inlet end, unless specified otherwise by Hydraulics Unit. On the outlet end, use a Cross Pipe end section (4:1 slope) with safety bars, or protect with guardrail.

## B. PIPE END TREATMENT FOR PARALLEL PIPES

(For further information, See “Roadway Standard Drawings”, Std. No’s. 310.02 and 310.04 -- See Appendix A of this Manual)

### 1. At Median Crossover Locations

a. Use a median drop inlet with 10:1 or flatter slopes.

b. At existing locations without sufficient depth for drainage structures, use Parallel Pipe end sections and 6:1 slope.

### 2. At Grade Intersections and Driveways

a. * Multilane Highways with Design Speed greater than 50 mph.

1. Place all pipe beyond Clear Zone (NCDOT Roadway Design Manual, Part I, 5-20, F-2 -- See Appendix C of this Manual) and use an endwall on inlet end of 36 inches or over, unless specified otherwise by Hydraulics Unit.
2. On approach ends, use a median drop inlet with 6:1 or flatter slopes where practicable and where existing or proposed drainage systems are available.

3. On approach ends, use parallel pipe end section (6:1 slope) for 24 inches or under and use guardrail for 30 inches or over. Trailing ends require no special treatment other than endwalls on the inlet end for 36 inches or over, unless specified otherwise by Hydraulics Unit.

b. *Multilane Highways with Design Speeds = 50 mph and All Two Lane Highways.

No special end treatment is required on two lane highways and multilane highways with design speeds = 50 mph. However, endwall placement is required on inlet end for 36 inches or over, unless otherwise specified by Hydraulics Unit.

* Note: This treatment for multilane highways applies to new construction and major reconstruction projects. It does not apply to resurfacing, bridge replacement, or spot safety projects. Pipe end treatment on these type of projects (including private installations) will be the same as existing pipes unless accident history warrants special consideration.

Endwalls shall be constructed perpendicular to the centerline of pipe unless specific site conditions warrant construction of an endwall parallel to the roadway (See Hydraulics Unit for approval). It will be necessary to extend the pipe to allow the end of the endwall to tie into the toe of the fill. See NCDOT Roadway Design Manual, Part I, 5-20, F-1 -- See Appendix C of this Manual, for an example. Any additional backfill material necessary to extend this pipe shall be covered under Section 300 of the NCDOT Standard Specifications for Roads and Structures. The quantities for the endwalls constructed perpendicular to the centerline of pipe will be based on a 90° skew rather than the skew of the pipe.

On multiple pipe installations, additional pipe length shall be provided such that a line projected along the face of the endwall is perpendicular to the centerline of pipes. On minimum type driveways, the total graded width should not be less than 16 feet. Sound engineering judgment should be used in determining the proper driveway width and length of pipe based upon factors such as skew of drive, height of cover, type of drive and unusual traffic patterns. When sufficient right of way is available, driveway pipe should be located outside the clear roadside recovery area and the roadway ditch should be transitioned accordingly. See NCDOT Roadway Design Manual, Part I, 5-20, F-2 -- See Appendix C of this Manual for an example.

Providing a clear roadside recovery area is desirable in all locations, but the design will be more compatible on projects with minimum access points. (For example, partial control of access projects or projects on new locations.)

# Repair Methods For Pipe

Damage can happen to pipe during transport and handling. When damage done to pipe may decrease its expected life or may prevent it from serving its use as intended, repairs must be made or the pipe must be rejected. In all cases, the Engineer shall have final acceptance approval of the pipe and any repairs made.

## A. CONCRETE

Repairs done to all types of concrete pipe must be done so with an approved concrete repair material. These repair materials shall be used in accordance with the manufacturer's directions. A listing of Approved Concrete Repair materials is available on the Department's Vendor system and web page at: http://apps02.dot.state.nc.us/MTtracking/IntroPage.asp.

## B. GALVANIZED COATINGS

Repair of galvanized coatings shall be in accordance with Section 1076-6 of the Standard Specifications:

> Repair galvanized surfaces that are abraded or damaged at any time after the application of zinc coating by thoroughly wire brushing the damaged areas and removing all loose and cracked coating, after which paint the cleaned areas with 2 coats of organic zinc repair paint meeting the requirements of Article 1080-9. Ensure that the total thickness of the 2 coats is not less than 3 dry mils (0.075 mm). In lieu of repairing by painting with organic zinc repair paint, other methods of repairing galvanized surfaces that are abraded or damaged are allowed provided the proposed method is acceptable to the Engineer.

## C. BITUMINOUS COATINGS

Repair of bituminous coatings damaged during transport, unloading, or installation shall be repaired as directed by the Engineer using available hot bituminous repair or cold tar patching materials. Care should be taken to ensure no damage to the surrounding bituminous material occurs during repair.