WEST VIRGINIA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
DESIGN DIRECTIVE

DD-503
DESIGN OF ALTERNATE PIPE MATERIALS
March 10, 2003

Attached is the West Virginia Department of Transportation, Division of Highways, guidelines for the "Design of Alternate Pipe Materials" to be used on all projects.

Attachment

DESIGN OF ALTERNATE PIPE MATERIALS

The goal of this design directive is to provide guidance on the selection of appropriate pipe materials in terms of service life, hydraulic efficiency and structural capacity. The design process includes consideration of the factors shown in Section 1 through Section 5 below. The most cost efficient designs will be selected and specified per Section 6 of this directive, unless other criteria needs to be considered.

SECTION 1: ROADWAY CLASSIFICATION

The following table summarizes allowable conduit materials based on the design classification and service life requirement of the roadway that the pipe is to be placed under. Design classification is site specific rather than project specific and refers to the roadway that is directly over the culvert. Plastic pipe (PVC & HDPE) is allowed for use in median and slope drains when the pipe is not located under the roadway pavement and under the pavement when the ADT is less than 3000 and the fill height is less than 15 feet as described in the table below. Materials listed below should provide satisfactory service life provided they are used within the environmental ranges listed in Section 4 entitled Corrosion. Some culverts may require additional invert protection when placed in conditions where the potential for damage due to abrasion exists. Guidelines for additional invert protection are listed in Section 5, Abrasion. Refer to DD-502 for allowable fill heights for each pipe material.

Table 503-1
Allowable Alternate Pipe Materials

DESIGN CRITERIA	ALLOWABLE CONDUIT MATERIALS
Under roadway pavement with an ADT ≥ 3000 or Height of cover ≥ 15 ft.	Cast in Place or Precast Reinforced Concrete Box Cast in Place or Precast Reinforced Concrete Arch Reinforced Concrete Pipe and Elliptical Reinforced Concrete Pipe Aluminized Steel, Type 2 Corrugated Metal Pipe and Pipe-Arch (16-10 gage only) Aluminized Steel, Type 2 Spiral Rib Pipe and Pipe-Arch (16-10 gage only) Galvanized Steel, Pipe and Pipe-Arch Galvanized Steel Corrugated Metal Plate Pipe and Pipe-Arch (12 gage Minimum) Galvanized Steel, Plate Arch Galvanized Steel, Plate Box Culvert Aluminum Alloy Corrugated Metal Pipe and Pipe-Arch Aluminum Alloy Spiral Rib Pipe and Pipe-Arch Aluminum Structural Plate Pipe and Pipe-Arch Aluminum Structural Plate Arch Aluminum Structural Plate Box Culvert Pre-coated Galvanized Corrugated Metal Pipe and Pipe-Arch (16-10 gage only) Bituminous Coated Galvanized and Aluminized Steel Type 2 Bituminous Coated and Paved Galvanized and Aluminized Steel Type 2
Under roadway pavement with an ADT < 3000 and Height of Cover < 15 ft.	All of the above HDPEPP - High Density Polyethylene Plastic Pipe (smooth interior), installed in type F trench, as shown in WVDOH Typical Sections & Related Details, Repaving Pipe Trenches PVCPP - Polyvinyl Chloride Plastic Pipe (smooth interior), installed in type F trench
Under roadway pavement with an ADT < 400 and Height of Cover < 15 ft. Any pipes not directly under the roadway pavement	All of the above HDPEPP - High Density Polyethylene Plastic Pipe (smooth interior) installed in accordance with Standard Specification 604. PVCPP - Polyvinyl Chloride Plastic Pipe (smooth interior) installed in accordance with Standard Specification 604.

SECTION 2: HYDRAULICS

The designer should use the following table when assigning a Manning's "n" value for the various pipe options allowed in Section 1, Roadway Classification. Recommended Design Values should be used unless the designer has a justifiable reason for selecting a different value from the Range of Acceptable Values.

Table 503-2
Manning's "n" Value for Alternative Pipe Materials[1]

TYPE OF CONDUIT	DESCRIPTION/ CORRUGATION	"n" VALUE	
		RECOMMENDED DESIGN VALUE	RANGE OF ACCEPTABLE VALUES
Corrugated Metal Pipe			
24" dia.or less, Helical	2 2/3" x ½"	0.015	0.012 - 0.015
> 24" dia., Helical	2 2/3" x ½"	0.023	0.015 - 0.023
Helical	3" x 1"	0.028	0.027 - 0.028
Helical	5" x 1"	0.025	0.024 - 0.026
Annular	6" x 2"	0.033	0.028 - 0.033
Annular	9" x 2 ½"	0.035	0.033 - 0.037
(Spiral Rib Metal Pipe)	¾" x ¾' x 7½"	0.012	0.011 - 0.012
Concrete Pipe			
Round & Elliptical	Smooth	0.012	0.011 - 0.012
Cast-in-Place Box	Smooth	0.013	0.012 - 0.015
Pre-cast Box	Smooth	0.013	0.012 - 0.015
Plastic Pipe			
HDPEPP	Corrugated	0.023	0.018 - 0.025
PVCPP	Cor. w/ Smooth Liner	0.009	0.007 - 0.011
HDPEPP	Cor. w/ Smooth Liner (In type F trench)	0.013	0.010 - 0.017
HDPEPP	Cor. w/ Smooth Liner	0.015	0.013 - 0.022
Steel Pipe, non-galvanized	Smooth	0.015	-
Cast Iron Pipe	Smooth	0.015	-
Clay Sewer Pipe	Smooth	0.013	-

Tabulated "n"-values apply to circular pipes flowing full. For noncircular or partially full conduits the tabulated values may be modified as shown in Appendix B of HDS No.5, Hydraulic Design of Highway Culverts.

SECTION 3: STRUCTURE

Refer to DD-502 for maximum cover and minimum cover for all pipes. The maximum values in DD-502 are conservative. The designer may exceed the limits set in DD-502 if the pipe is designed in accordance with AASHTO LRFD Section 12, *BURIED STRUCTURES AND TUNNEL LINERS*.

SECTION 4: CORROSION

Corrosion resistant material should be used in areas where there is a past history of corrosive water and soil.

Depending on the scope of the project, the project manager will determine whether to obtain pH, resistivity and sulfate content data of the soil and water for pipe locations. Consider the size and quantity of pipe, class of road the pipe is under, the cost and disruption to traffic for future replacement and the availability of soil and water for testing.

When chemical data are not obtained or available, the designer shall take a conservative approach in the specifying pipe materials. *If corrugated metal pipe is to be considered as an option, it shall be Aluminized Type 2, or Pre-coated Galvanized Steel.* If structural steel plate is to be used, then it will be galvanized with a field-paved invert. Plastic and concrete pipe materials are acceptable in most environmental conditions without soil and water testing.

CORROSION (Continued)

Environmental Ranges

The type of conduit material specified should only be used within the following limits.

TABLE 503-4
ALLOWABLE ENVIRONMENTAL RANGES
FOR ALTERNATE PIPE MATERIAL

MATERIAL	pH RANGE	MINIMUM SOIL OR WATER RESISTIVITY (ohm*cm)
Aluminized Type 2 steel pipe	5- 9	1500
Bituminous coated steel pipe with or without a paved invert	4 - 10	1500
Aluminum alloy pipe, box culvert and structural plate	4 - 9	500
Galvanized steel pipe	5.8 - 8	2000 (<8000)[1]
Galvanized steel structural plate pipe, pipe arches, arches, and long spans (3 oz. coating)	5 - 10	2000 (<8000)[1]
Plastic pipe (PVCPP or HDPEPP)	3 - 12	-
Pre-coated steel pipe (Polymer coated)	3 - 12	100
Reinforced concrete pipe and structures	5 - 9	1000 [2]

(1) If the water resistivity is greater than 8,000 ohm-cm, it could be an indication of soft water. Soft water lacks the minerals that allow the galvanized steel to form its protective scale. The invert of the pipe should be paved to provide adequate corrosion protection (see section 5 for paving options).

(2) A resistivity of less than 1,000 ohm-cm is an indication of the presence of chlorides. As chlorides can attack the reinforcing steel, the reinforcing cage should be epoxy coated.

(3) Steel structural plate is galvanized and is not available with aluminized coating. Galvanized structural plate culverts shall have a paved invert.

(4) Galvanized pipes that are placed in corrosive soils shall be fully bituminous coated.

CORROSION (Continued)

Sulfate concentration is also a durability concern for concrete. Type II and Type V cement are designed to resist sulfate attack. However, Type V cement is not readily available. Reducing the water/cement ratio reduces permeability and is the single most important factor in increasing concrete resistance to sulfate attack. Increasing the cement content also improves sulfate resistance. Precast concrete pipe and box culvert are produced using 658 pounds of cement per cubic yard of concrete with a water cement ration of 0.44 or less. Only a minor adjustment in the water cement ration is required to meet the severe Sulfate condition. For very severe conditions, type II cement should be used and the water cement ratio should be reduced to 0.35. The following table illustrates the actions required for a given sulfate concentration. This information should be included in the plans when severe and very severe sulfate conditions are encountered.

Table 503-5
Sulfate Concentration For
Reinforced Concrete Pipe

Conditions			Requirements		
Relative Degree of Sulfate Attack	% Water-Soluble Sulfate in Soil Samples	PPM Sulfate in Water Samples	Cement Type	Cement Content (lbs/cy)	Maximum Water/ Cement Ratio
Negligible	0.00 - 0.10	0 - 150	-	-	-
Positive	0.10 - 0.20	150 - 1,500	I	470	0.45
			II	376	0.45
Severe	0.20 - 2.00	1,500 - 10,000	I	658	0.4
			II	517	0.4
Very Severe	>2.00	>10,000	II	658	0.35

SECTION 5: ABRASION

The designer should assess the abrasion potential for proposed culvert installations. Consider the slope of the stream and the size of the stream bed material. Calculate the velocity of the flow in the channel upstream of the proposed culvert and in the proposed culvert to determine if the abrasive material in the streambed could be transported at a sufficient velocity to cause damage to the invert of the conduit. A 2-year storm (Q_2) shall be used to determine the velocity for abrasion potential. The designer should consider abrasion of the culvert invert as well as flow capacity and sediment transport in establishing the slope of the culvert.

If all the water entering a conduit is runoff from a paved surface or enters through perforations in a conduit wall, it is considered a storm drain and abrasion is not a concern. Regardless of velocity, a closed system as described carries little bedload, and therefore has very little abrasion potential.

There is a potential for higher than normal abrasion during construction due to runoff from disturbed areas that have not yet been vegetated or paved. If the designer expects this situation to occur, then construction related abrasion may be addressed by either specifying pipe materials that are more durable or requiring sediment traps upstream of culverts to prevent large sediment from entering the culvert.

Three sided structures do not require invert protection; however, the potential for scour at the footings will need to be addressed. It may be less expensive to provide a concrete slab below the streambed between the footings instead of extending the footings to rock.

ABRASION (Continued)

The following chart is to be used to select the appropriate invert protection for culverts. Use the velocity of the 2-year storm flow in the pipe or in the channel upstream of the pipe, whichever is greater. As previously stated, abrasion is not a concern for storm drains.

Table 503-6
Invert Protection Chart
For Abrasive Flows

CULVERT MATERIAL	2-Year (Q_2) Storm Design Velocity			
	0 to 5 ft/sec	5 to 10 ft/sec	10 to 15 ft/sec	Greater than 15 ft/sec
Aluminized Steel Type 2	None	None	Paved invert	Paved Invert
Aluminum Alloy	None	None	Add one gage	Add two gages
Galvanized Steel Pipe	None	Paved invert	Paved invert	Paved invert
Bituminous Coated CSP	None	Paved invert	Paved invert	Paved invert
Galvanized Steel Plate	None	Paved invert	Paved invert	Paved invert
Pre-Coated	None	None	None	Paved invert
Plastic (PVC or HDPE)	None	None	None	None
Reinforced Concrete Pipe	None	None	None	At least 2" concrete cover over reinforcing steel

NOTES:

1. Paved inverts may be bituminous or concrete.
2. A 100 percent factory-applied 5000-psi concrete lining may be substituted for concrete paving when invert protection is required in small diameter pipes.
3. Steps must be taken to prevent chemical interaction with the aluminum during the concrete curing process when concrete is used to line or pave Aluminized or Aluminum pipes. Two options are: A) coat the pipe with polymer or bituminous material, B) add a corrosion inhibitor to the concrete.
4. When soil and water chemical tests shows that corrosion is not a problem, then the gage thickness of steel may be increased instead of paving the invert.

SECTION 6: ALTERNATE MATERIALS

When using this directive, many products may be found to satisfy the project requirements. The designer should include economical designs that meet the requirements stated above. A table similar to the examples below should be included in the plans adjacent to the drainage table when alternate materials are used. Because of the difference in roughness coefficients between various options, it may be necessary to specify different size options for each run of pipe. In this event, the smallest diameter pipe or structure should be listed first in the table.

Table 503-7
Example Listing of Alternate
Pipe Materials

		Reinforced Concrete Pipe, II (604037)				**Bituminous Coated & Paved Galvanized Steel Pipe, A2 (604004)**	**Aluminum Coated Corr. Steel Pipe, A2 (604076)**	**Plastic**	
								PVC (604052)	**HDPE (604050)**
Location	Length (ft)	Size (in)	Cement type	Min. Cement Content (lb/cy)	Max.W/C Ratio	Size (in)	Size (in)	Size (in)	Size (in)
Sta. to Sta.	50	18	I	470	0.45	18	18	18	18
Sta. to Sta.	75	18	I	658	0.40	24	24	18	24
Sta. to Sta.	60	24	II	658	0.35	30	30	24	30

(1) Thickness (mil) - (pay item " Y " letter, see Section 604 for details)
Corrugation Size (in) – (pay item " Z " number, see Section 604 for details)

" Y " Letter	Thickness	" Z " Number	Corrugation .
A	64	2	2 2/3" x ½"
B	79	3	3" x 1"
C	109	5	5" x 1"
K	100	7	¾" x ¾" x 7 ½"
L	125	6	6" x 2"
M	150	9	9" x 2 ½"

(1) For product availability reasons, corrugated metal pipe should be specified with a 5"x1" corrugation instead of a 3"x1" corrugation whenever possible.