MEMORANDUM: RECOMMENDATIONS FOR PIPE MATERIAL SELECTION

Moser and Associates Engineering for CDOT Region 6

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Memorandum to File: Recommendations for Pipe Material Selection for Construction Project 17536, I-76 Bridge Replacement over the South Platte River, Unincorporated Adams County, Colorado, C 0761-204.

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Moser and Associates Engineering

cc: Justin Werdel
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Subject: Recommendations for Pipe Material Selection

The following memorandum consists of recommendations for Pipe Materials Selection for the I-76 Bridge Replacement over the South Platte River project.

Memorandum: Recommendations for Pipe Material Selection for Construction Project 17536, I-76 Bridge Replacement over the South Platte River, Unincorporated Adams County, Colorado, NH C 0761-204.

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REFERENCE DOCUMENTS

CDOT M Standards 2006
CDOT Pipe Material Selection Policy
Standard Special Provisions SSP 603 and 712

1. RECOMMENDATION

In accordance with the Colorado Department of Transportation Standard Specifications for Road and Bridge Construction, the following justification supports the decision to recommend Class 7 exposure severity reinforced concrete pipe as specified in 601.04 for use on project 17536, also known as the I-76 Bridge Replacement over the South Platte River, Unincorporated Adams County, Colorado, C 0761-204.

2. PROCESS TO DETERMINE PIPE MATERIAL SELECTION RECOMMENDATION

The following steps are in compliance with the CDOT Pipe Material Selection Policy and are listed in chronological order. A response demonstrating compliance with each step follows.

3. STEP I:DETERMINE APPLICATION

> **Step I: Determine Application** – In all cases, the Project Manager will use the latest version of CDOT's *Drainage Design Manual*. The pipe selection process begins when the Project Manager determines the location of the new pipe. The Project Manager will then determine and document the specific use of the pipe:
>
> - Cross Drain
> - Side Drain
> - Storm Sewer

Compliance:
The specific use for the pipes associated with this project is for storm sewer.

4. STEP II: DETERMINE ABRASION LEVEL

Step II: Determine Abrasion Level – An estimate of the potential for abrasion is required to determine acceptable pipe types and whether there is a need for invert protection. Four levels of abrasion are referred to in this guidance, and the following guidelines are established for each level:

- Abrasion Level 1 – This level applies where the conditions are nonabrasive. Nonabrasive conditions exist in areas of no bed load and very low velocities. This is the level assumed for the soil side of drainage pipes. This is also the level assumed for the inverts of cross drains and side drains installed in typically dry drainages.
- Abrasion Level 2 – This level applies where low abrasive conditions exist. Low abrasive conditions exist in areas of minor bed loads of sand and velocities of 5 fps or less.
- Abrasion Level 3 – This level applies where moderately abrasive conditions exist. Moderately abrasive conditions exist in areas of moderate bed loads of sand and gravel and velocities between 5 fps and 15 fps.
- Abrasion Level 4 – This level applies where severely abrasive conditions exist. Severely abrasive conditions exist in areas of heavy bed loads of sand, gravel, and rock and velocities exceeding 15 fps.

Compliance:
The project conditions were evaluated, and it was determined that Abrasion Level

- Per hydrologic calculations, the maximum 5-year peak flow in the storm sewers = 11 cfs, and the maximum 100-year peak flow in the storm sewer = 22 cfs. The maximum slope = 5%.
- The South Platte River has a minor bed load consisting of silt and sand.
- The engineer determines the abrasion level of the system to be ABRASION LEVEL 1.

5. STEP III: DETERMINE CORROSION LEVEL

Step III: Determine Corrosion Level – The station of each proposed pipe must be supplied to the appropriate Region Staff (Region). The Region will determine a sampling schedule to ensure that corrosive forces are adequately addressed. The Region will sample soil and water at these locations. The resulting sample testing information will be used in flow charts (Figures 1 and 2) to select appropriate material.

The Project Manager will document the following properties of the soil and water:

- Sulfate Levels
- Chloride Levels
- Resistivity
- pH
- Moisture Levels

This information will be obtained at all pipe locations supplied by the Project Manager and documented in the project records by the Project Manager. If the project is small enough, or the alluvium of the area is sufficiently homogeneous, a reduced sampling schedule will be acceptable as determined by the Region.

Compliance:
The table below lists the properties of the on site soil samples taken for the project by summarizing the Soil Chemistry testing results for the project by sample ID:

Table III-a
Summary of Laboratory Test Results by Boring

SAMPLE DATA			CORROSION					
Boring/ Sample	Depth (feet)		pH	CR Level	Sulfates	CR Level	Chlorides	CR Level
	Top	Bottom			%		%	
B-1/ S-12	60.0	61.5	7.7	0	0.009	0	10	0
B-3/ S-2	9.5	11.0	6.9	0	0.007	0	45	0
B-4/ S-2	7.5	9.0	7.0	0	0.005	0	200	0
B-4/ S-9	42.5	44.0	7.2	0	0.013	0	15	0

A table listing the full results can be found at the end of this document.

Utilize Table 1 of the CDOT Pipe material Selection Policy with the sulfate percentage of 0.013, the worst case corrosive value.

Table 1
Guidelines for selection of corrosion resistance levels

	SOIL			WATER		
CR Level	Sulfate (SO_4) % max	Chloride (Cl) % max	pH	Sulfate (SO_4) ppm (max)	Chloride (Cl) ppm (max)	pH
*CR 0	0.05	0.05	6.0-8.5	50	50	6.0-8.5
CR 1	0.10	0.10	6.0-8.5	150	150	6.0-8.5
CR 2	0.20	0.20	6.0-8.5	1,500	1,500	6.0-8.5
CR 3	0.50	0.50	6.0-8.5	5,000	5,000	6.0-8.5
CR 4	1.00	1.00	5.0-9.0	7,500	7,500	5.0-9.0
CR 5	2.00	2.00	5.0-9.0	10,000	10,000	5.0-9.0
CR 6	>2.00	>2.00	<5 or >9	>10,000	>10,000	<5 or >9

*No special corrosion protection recommended when values are within these limits.
Concrete pipe used when the pH of either the soil or water is less than 5 shall be coated in accordance with subsection 706.07. When needed, specify the coating in a special provision or plan note.

Table 1, above, and observations of field conditions of existing pipes are to be used as aids in the determination of a CR level.

Region 2 of the Colorado Department of Transportation considers the project to meet Corrosion Resistance Number 0 (CR0) due to the percent of Sulfate in the soil samples.

6. STEP IV: SELECTION OF PIPE MATERIAL TYPE

Step IV: Selection of Pipe Material Type – Use the flowcharts in this document to identify acceptable pipe material types. If metal pipe is determined to be an allowable material type as determined in Figure 1 of this document, use Table 2 to determine whether there are additional requirements for metal pipes.

Compliance:

The current project uses pipes in Storm Sewers, therefore Figure 2 of the CDOT Pope Material Selection Policy will be used, as stated above.

Figure 2

STORM-SEWERS

Storm-sewers are often inundated with water for a period of time. CDOT has observed that dissimilar materials (i.e. concrete to metal or plastics) when joined will often not form a water tight seal. Therefore, it is recommended that only reinforced concrete pipe (RCP) be used in storm sewers.

Determine Corrosion Resistance #
(Table 1)

↓

CR 0 – Reinforced Concrete Pipe allowed for Class 7 by Table 624-1[1]
CR 1 – Reinforced Concrete Pipe allowed for Class 7 by Table 624-1[1]
CR 2 – Reinforced Concrete Pipe allowed for Class 8 by Table 624-1
CR 3 – Reinforced Concrete Pipe allowed for Class 9 by Table 624-1[1]
CR 4 – Reinforced Concrete Pipe allowed for Class 9 by Table 624-1[1]
CR 5 – Reinforced Concrete Pipe allowed for Class 10 by Table 624-1[1]
CR 6 – Reinforced Concrete Pipe allowed for Class 10 by Table 624-1[1]

[1] – If abrasion level is 3 or 4, concrete shall have a minimum compressive strength of 4,500 psi. Cementitious requirements for Sulfate Protection Classes are listed in 601.04. A higher level of protection may be used. Concrete may be used when the pH and chlorides exceed the levels listed in Table 1

When extending an existing pipe, the same size and type of material must be specified. If conditions are Abrasive level 1 or 2 **and** CR 0, specify material type from Section 603 pay items.

Figure 2 yields a Class 7 Pipe to enter into Table 624-1.

TABLE 624-1

Materials Allowed for Class of Pipe

Material Allowed **	**Class of Pipe***										
	0	**1**	**2**	**3**	**4**	**5**	**64**	**7**	**8**	**9**	**104**
CSP	Y	N	N	N	N	N	N	N	N	N	N
Bit. Co. CSP	Y	Y[1]	N	N	N	N	N	N	N	N	N
A.F. Bo. CSP	Y	Y	Y	Y	Y	Y	Y	N	N	N	N
CAP	Y	Y[2]	Y[2]	Y[2]	Y[2]	Y	N	N	N	N	N
PCSP - both sides	Y	Y	Y	Y	N	N	N	N	N	N	N
PVC	Y	Y	Y	Y	Y	Y	Y	N	N	N	N
PE	Y	Y	Y	Y	Y	Y	Y	N	N	N	N
RCP (SP0)[3,5]	Y	Y	N	N	N	N	N	Y	N	N	N
RCP (SP1)[3,5]	Y	Y	Y	N	N	N	N	Y	Y	N	N
RCP (SP2)[3,5]	Y	Y	Y	Y	Y	N	N	Y	Y	Y	N
RCP (SP3)[3,5]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

* As determined by the Department in accordance with the CDOT *Pipe Selection Guide* . Determination is based on abrasion and corrosion resistance.

** Y=Yes; N=No.

[1] Coated Steel Structural Plate Pipe of equal or greater diameter, conforming to Section 510, may be substituted for Bit. Co. CSP at no additional cost to the project.

[2] Aluminum Alloy Structural Plate Pipe of equal or greater diameter, conforming to Section 510, may be substituted for CAP at no additional cost to the project.

[3] SP= Class of Sulfate Protection required in accordance with subsection 601.04 as revised for this project. RCP shall be manufactured using the cementitious material required to meet

[4] For pipe classes 6 and 10, the RCP shall be coated in accordance with subsection 706.07 when the pH of either the soil or water is less than 5. The Contract will specify when RCP is

[5] Concrete shall have a compressive strength of 4500 psi or greater.

Where class of pipe specified allows the use of metal pipe, its use will be limited in accordance with the resistivity requirements in Table 624-2. The Contract will state whether the resistivity requirements apply.

iv. The Table 624-1 allows for Reinforced Concrete Pipe, SP2 and SP3.

v. Use a value of SP2 (SO4 = 0.38) to enter into table 601.04 resulting in a Class 2 severity exposure.

Table 601.04

REQUIREMENTS TO PROTECT AGAINST DAMAGE TO CONCRETE BY SULFATE ATTACK FROM EXTERNAL SOURCES OF SULFATE

Severity of sulfate exposure	Water-soluble sulfate (SO_4) in dry soil, percent,	Sulfate (SO_4) in water, ppm	Water cementitious ratio, maximum	Cementitious material requirements
Class 0	0.00 to 0.10	0 to 150	0.45	Class 0
Class 1	0.11 to 0.20	151 to 1500	0.45	Class 1
Class 2	0.21 to 2.00	1501 to 10,000	0.45	Class 2
Class 3	2.01 or greater	10,001 or greater	0.4	Class 3

For this project, the RCP will have to meet the requirements of section 601.04, with a Class 2 sulfate exposure resistance concrete.

Class 2 requirements for sulfate resistance shall be one of the following:

(1) ASTM C 150 Type V with a minimum of a 20 percent substitution of Class F fly ash by weight

(2) ASTM C 150 Type II or III with a minimum of a 20 percent substitution of Class F fly ash by weight. The Type II or III cement shall have no more than 0.040 percent expansion at 14 days when tested according ASTM C 452

(3) ASTM C 1157 Type HS; Class C fly ash shall not be substituted for cement.

(4) ASTM C 1157 Type MS plus Class F fly ash where the blend has less than 0.05 percent expansion at 6 months or 0.10 percent expansion at 12 months when tested according to ASTM C 1012

(5) A blend of portland cement meeting ASTM C 150 Type II or III with a minimum of 20 percent Class F fly ash by weight, where the blend has less than 0.05 percent expansion at 6 months or 0.10 percent expansion at 12 months when tested according to ASTM C 1012.

(6) ASTM C 595 Type IP(HS); Class C fly ash shall not be substituted for cement.

7. STEP V: VERIFY FILL HEIGHT

Step V: Verify Fill Height – Check Fill Height tables in the Standard Plans. Determine if Project Special Provisions are required and/or if any other Standard Special Provisions are applicable.

TYPE OF PIPE	HEIGHT OF FILL OVER TOP OF PIPE, H (FEET) CLASS OF PIPE (0.01 IN. CRACK D-LOAD)				
	CLASS CIR II CLASS VE II CLASS HE II 1000 D	CLASS CIR III CLASS VE III CLASS HE III 1350 D	CLASS CIR IV CLASS VE IV CLASS HE IV 2000 D	CLASS CIR V CLASS VE V 3000 D	CLASS VE VI 4000 D
CIRCULAR (CIR)	MIN. TO 18	MIN. TO 25	± 25 TO 37	± 37 TO 45	
VERTICAL ELLIPTICAL (VE)	MIN. TO 18	MIN. TO 25	± 25 TO 37	± 37 TO 45	± 45 TO 62
HORIZONTAL ELLIPTICAL (HE)	MIN. TO 18	MIN. TO 25	± 25 TO 37		

ALLOWABLE RANGE OF HEIGHTS FOR FILL
OVER REINFORCED CONCRETE PIPE
(ALL SIZES)

M 603-2 Standard Plans fill height Table.

Compliance:
Fill heights are not expected to exceed 6 feet. The project requirements for pipe material that are justified in Step IV of the CDOT Pipe Material Selection Policy are not changed due to fill height requirements.

8. STEP VI: ADDRESS EXCEPTIONS TO THIS POLICY

> **Step VI: Address Exceptions to This Policy** – All exceptions to this policy require a Justification letter and must be approved by the Chief Engineer and the FHWA.

Compliance:
There are no anticipated exceptions in this project that will require approval of a justification letter from the Chief Engineer and the Federal Highway Administration.

9. STEP VII: DOCUMENTATION

> **Step VII: Documentation** – All design decisions regarding pipe material type selection must be documented and a letter placed in the project file. A copy of all selection letters are to be sent the Area Engineer prior to final design decisions being made, for guidance and to verify consistency.

Compliance:
This 'Memorandum: Recommendation for Pipe Material Selection' is addressed to the Project File and is sent as a copy to the Project Manager and the Area Engineer for Region 6 for their verification of consistency with the CDOT Pipe Material Selection Policy.

10. ENGINEERING PRACTICES AND JUDGMENT

Selection Process – All decisions regarding pipe material type will be based on engineering practices and judgments. The Project Manager (PM) will consider such factors as durability, environmental considerations, soil conditions, fill heights, need for water tight joints, slopes of inverts, and hydraulic characteristics of pipe material inside surfaces.

Compliance:

- Hydraulic Capacity – The project is located in an urban setting, and the storm sewer pipes will have a low depth of cover. The relatively small pipe diameters are hydraulically efficient and allow a shallow depth of installation. The pipes will have smooth interior walls with Manning's N values in the range of 0.013 which is consistent with the Manning's N value for RCP.
- Roadway Compaction Requirements – The shallow depth of the pipes will allow a very low depth of cover given the site constraints. This requires that during construction, the pipe wall strength will be able to withstand the construction activity with a depth of cover less than the final road surface. Compaction around the pipe is important for a strong final road section.
- Water-tight Seal at Inlet and Manhole Interface – The storm sewer will need to be water-tight and make good connection to manholes and inlets. REC will allow such connections.
- Matrix of Selection – For each category, the pipe was considered to meet (yes) or not to meet (no) the engineering judgment criteria.

11. SOIL TESTING RESULTS

SHANNON WILSON, INC.

TABLE B-1
SUMMARY OF LABORATORY TEST RESULTS BY BORING

SAMPLE DATA				CORROSION			
Boring	Sample	Depth (feet) Top	Depth (feet) Bottom	pH	Resistivity (ohm-cm)	Sulfates (ppm)	Chlorides (ppm)
B-1	S-1	5.0	6.5				
	S-2	10.0	11.5				
	S-3	15.0	16.5				
	S-4	20.0	21.5				
	S-5	25.0	26.5				
	S-6	30.0	31.5				
	S-7	35.0	36.5				
	S-8	40.0	41.0				
	S-9	45.0	45.2				
	S-10	50.0	51.3				
	S-11	55.0	55.9				
	S-12	60.0	61.5	7.7	2700	90	10
	R-4	67.0	67.3				
		67.3	68.6				
B-2	S-1	5.0	6.5				
	S-4	20.0	20.2				
	S-5	25.0	25.7				
	S-6	30.0	30.3				
	S-7	35.0	35.8				
	S-8	40.0	40.8				
	S-9	45.0	45.6				
	S-10	50.0	50.8				
	S-11	55.0	55.4				
	S-12	60.0	60.7				
B-3	S-1	4.5	6.0				
	S-2	9.5	11.0	6.9	2400	65	45
	S-3	14.5	16.0				
	S-6	39.0	39.5				
	S-8	50.0	50.3				
B-4	S-1	2.5	4.0				
	S-2	7.5	9.0	7.0	1400	54	200
	S-3	12.5	14.0				
	S-4	17.5	19.0				
	S-5	22.5	24.0				
	S-6	27.5	29.0				
	S-7	32.5	33.4				
	S-8	37.5	39.0				
	S-9	42.5	44.0	7.2	2500	125	15
	S-10	47.5	48.2				
	R-2	53.9	54.6				
	R-4	64.2	65.1				
	R-5	68.3	69.0				
	R-7	74.4	74.5				

NOTES: 1) Refer to Appendix A, Figure A-1 for definitions.
2) Gravel defined as particles larger than the No. 4 sieve size, Sar

TABLE B-1
SUMMARY OF LABORATORY TEST RESULTS BY BORING

SAMPLE DATA				CORROSION			
Boring	Sample	Depth (feet)		pH	Resistivity	Sulfates	Chlorides
		Top	Bottom		(ohm-cm)	(ppm)	(ppm)
P-1	S-1	1.0	2.5				
	S-2	3.0	4.5				
	S-3	7.5	9.0				
	Bulk	2.0	4.0				
P-2	S-1	1.0	2.5				
	S-2	3.0	4.5				
	S-3	8.0	9.0				
P-3	S-1	1.5	3.0				
	S-2	3.5	5.0				
	S-3	8.0	9.0				

NOTES: 1) Refer to Appendix A, Figure A-1 for definitions.
2) Gravel defined as particles larger than the No. 4 sieve size, Sar