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SECTION 701
HYDRAULIC CEMENT

701.01 Portland Cement. Portland cement shall conform to the requirements of the following cited specifications for the type specified or permitted:

Type	Specification
Portland Cement	ASTM C 150
Masonry Cement	ASTM C 91
Blended Hydraulic Cement	ASTM C 595

In addition to the standard chemical requirements for portland cement in ASTM C 150, the maximum percent of alkalies shall be as specified in Table 2 of ASTM C 150 for low-alkali cement.

Where blended hydraulic cement is used the substitution of fly ash for the blended hydraulic cement is not allowed.

Where either Type I or Type II cement is allowed, blended hydraulic cement which conforms to one of the following may be substituted:

(1) ASTM C 595 Type IP or Type IP(MS).
(2) ASTM C 1157 Type GU or Type MS

Where Type II cement is required, blended hydraulic cement which conforms to one of the following may be substituted:

(1) ASTM C 595 Type IP(MS)
(2) ASTM C 1157 Type MS

Where Type V cement is required, blended hydraulic cement which conforms to ASTM C 1157 Type HS may be substituted.

For paving concrete where Class F fly ash is required, blended hydraulic cement may be substituted for the cement plus fly ash. The weight of blended cement must equal the weight of cement plus fly ash. The blended cement must conform to one of the following:

(1) ASTM C 595 Type IP or Type IP(MS) where 15 to 25% Class F fly ash has been blended with Type I or Type II cement (ASTM C 150). The Type I or Type II cement shall be low-alkali cement conforming to the requirements of ASTM C150, Table 2. The Class F fly ash shall conform to ASTM C 618 including all chemical requirements of Table 1-A except for footnote A.
(2) ASTM C 1157 Type GU or Type MS which conform to Option R (Low Reactivity with Alkali-Reactive Aggregates).

Blended cements containing fly ash shall not be used in bridge decks.

Unless otherwise permitted by the Engineer, the product of only one mill of any one brand and type of portland cement shall be used on the project.

The Contractor shall provide suitable means for storing and protecting the cement against dampness. Cement which, for any reason, has become partially set or which contains lumps of caked cement will be rejected. Cement salvaged from discarded or used bags shall not be used.

701.02 Fly Ash. Fly ash for concrete shall conform to the requirements of ASTM C 618, Class C or Class F. All chemical requirements of ASTM C 618 Table 1-A shall apply, with the exception of footnote A.

Class C fly ash will not be permitted where sulfate resistant cement is required.

Fly ash shall be from a preapproved source. Preapproval shall include submission of a report from the supplier documenting the results of testing the fly ash from that source in accordance with the Toxicity Characteristic Leaching Procedure (TCLP) described in 40 CFR 261, Appendix II. The report shall include the results of TCLP testing for heavy metals and other contaminants found in the fly ash. The report shall list the contaminants tested, the results for each contaminant tested, and the allowable levels for each contaminant tested. A new report shall be submitted for each preapproved source annually. Additional TCLP testing may be required when the Department suspects that the fly ash source may have become contaminated.

For any source of fly ash that has not been preapproved, the Contractor shall notify the Engineer of the source 45 days prior to use in the project.

The fly ash shall be subject to sampling and testing by the Department. Test results that do not meet the physical and chemical requirements may result in the suspension of the use of fly ash until the corrections necessary have been taken to insure that the material meets the specifications.

The fly ash intended for use on the project shall have been tested and accepted prior to its use.

SECTION 702
BITUMINOUS MATERIALS

702.01 Asphalt Cements.

(a) *Viscosity Graded Asphalt Cements.* Viscosity graded asphalt cements shall conform to the requirements of AASHTO M226, Table 2.

AC-20 (Rubberized) shall be asphalt cement thoroughly blended with a minimum of two percent by mass of rubber and shall conform to the requirements of Table 702-1.

TABLE 702-1
AC-20 (Rubberized)

Property	Requirement		AASHTO
	Min.	Max.	Test No.
Viscosity, 60 °C, Pa·s (140 °F, poises)	160 (1600)		T 202
Viscosity, 135 °C, mm^2/s (275 °F, centistokes)	210 (210)		T 201
Penetration, 25 °C (77 °F), 100g, 5 sec	40		T 49
Ductility, 4 °C (39.2 °F), 5 cm/min, cm	50		T 51
Toughness, joules (inch-pounds)	12.4 *(110)*		*CP L-2210
Tenacity, joules (inch-pounds)	8.5 (75)		*CP L-2210
Tests on residue from thin film oven test:			
Viscosity, 60 °C, Pa·s (140 °F, poises)		800 (8000)	T 202
Ductility, 4 °C (39.2 °F), 5 cm/min, cm	25		T 51

*Colorado Procedure.

(b) *Superpave Performance Graded Binders.* Superpave Performance Graded Binders shall conform to the requirements listed in Table 702-2. (Taken from AASHTO Provisional Standard MP1)

TABLE 702-2
following page

TABLE 702-2
Superpave Performance Graded Binders

PROPERTY	REQUIREMENT FOR PG BINDER							AASHTO Test No.
	58-22	58-28	58-34	64-22	64-28	70-28	76-28	
Original Binder Properties								
Flash Point Temp., °C, minimum	230	230	230	230	230	230	230	T48
Viscosity at 135 °C, Pa•s, maximum	3	3	3	3	3	3	3	TP 48
Dynamic Shear, Temperature °C, where G*/Sin @ 10 rad/s ≥ 1.00 kPa	58	58	58	64	64	70	76	TP 5
Ductility, 4 °C (5 cm/min) cm, minimum					50			T 51
Toughness, joules, minimum					12.4			*CP L-2210
Tenacity, joules, minimum					8.5			*CP L-2210
RTFO Residue Properties								T 240
Mass Loss, percent maximum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	T 240
Dynamic Shear, Temp., °C, where G*/Sin @ 10 rad/s ≥ 2.20 kPa	58	58	58	64	64	70	76	TP 5
Elastic Revovery, 25 °C, percent minimum						50	50	*CP L-2211 Method A
Ductility, 4 °C (5 cm/min) cm, minimum					25			T 51
PAV Residue Properties, Aging Temperature 100 °C								PP 1
Dynamic Shear, Temp.,°C, where G*/Sin @ 10 rad/s ≤ 5000 kPa	22	19	16	25	22	25	28	TP 5
Creep Stiffness, @ 60 s, Test Temp. in °C,	-12	-18	-24	-12	-18	-18	-18	
S, maximum, MPa	300	300	300	300	300	300	300	TP 1
m-value, minimum	0.300	0.300	0.300	0.300	0.300	3.00	0.300	TP 1
**Direct Tension, Temp. in °C, @ 1 mm/min., where Failure Strain ≥1.0%	-12	-18	-24	-12	-18	-18	-18	TP 3

* Colorado Procedure.

**If the creep stiffness (S) is below 300 MPa, the direct tension test is not required. If S is between 300 and 600 MPa the direct tension failure strain requirement can be used in lieu of the creep stiffness requirement. The m-value requirement must be satisfied in both cases.

The Contractor shall furnish certified test results from an independent laboratory for the required Superpave PG asphalt binder to the Engineer with a copy to the Bituminous Engineer of CDOT Staff Materials, prior to the approval of the mix design (Form 43). The independent laboratory shall not be owned, in part or whole, by a supplier of the binder, the Contractor, or affiliates of either.

A complete quality control test report showing compliance with the requirements listed in Table 702-2 shall be submitted for every 500 tons of binder manufactured for each construction project. A copy shall be furnished to the Engineer and the Bituminous Engineer of CDOT Staff Materials at the time of delivery.

Blending of Superpave PG asphalt binders at the project site will not be allowed. The binder must be manufactured to the specification requirements prior to delivery to the project.

Superpave PG asphalt binders shall be sampled at the same location as listed in the Field Materials Manual for Asphalt Cement and the sample rate shall be one PG binder sample per 1000 metric tons (1000 tons) of mix or fraction thereof or as specified in the project plans.

(c) *Dampproofing.* Asphalt for dampproofing shall conform to the requirements of ASTM D 449, and the asphaltic primer shall conform to the requirements of ASTM D 41.

702.02 Liquid Asphaltic Materials. Liquid asphaltic materials shall conform to the requirements of AASHTO M 81, M 82, and ASTM D 2026 for the designated types and grades.

Primer for dampproofing shall meet the requirements of ASTM D 41.

RC-800 (Rubberized) shall be a blend of asphalt cement, rubber, and cutter stock. The asphalt cement shall be blended with a minimum of 1½ percent by mass of rubber prior to adding cutter stock. The final product shall meet the requirements of Table 702-3.

TABLE 702-3

Property	Requirement		AASHTO
	Max.	Min.	Test No.
Flash point °C (°F)	27 (80)		T 79
Kinematic viscosity, 60 °C, mm^2/s (140 °F, centistokes)	800 (800)	1600 (1600)	T 201
Distillation test:			
Distillate, percent by volume of total distillate to 360 °C (680 °F)			
To 225 °C (°F)	15		
To 260 °C (°F)	45		
To 316 °C (°F)	75		
Residue from distillation to 360 °C (680 °F): Volume percent of sample by difference	75		T 78

702.03 Emulsified Asphalts. Emulsified asphalts shall conform to AASHTO M 140 or M 208 for the designated types and grades. When grade CSS-lh or SS-lh emulsified asphalt is used for tack coat, residue penetration test values shall be between 40 and 120.

(a) Polymerized rapid set emulsified asphalt for seal coat shall conform to the following requirements for either CRS-2P or HFRS-2P.

1. CRS-2P (Cationic, Polymerized) shall be an emulsified blend of polymerized asphalt, water, and emulsifiers. The asphalt cement shall be polymerized prior to emulsification and shall contain a minimum of three percent polymer by mass of asphalt cement. The emulsion standing undisturbed for a minimum of 24 hours shall show no white, milky separation and shall be smooth and homogenous throughout. The emulsion shall be pumpable and suitable for application through a distributor. The emulsified blend shall conform to the requirements of Table 702-4.

TABLE 702-4

Property	Requirement		AASHTO
	Max.	Min.	Test No.
Viscosity, Saybolt Furol at 50 °C (122 °F), s	50	450	T 59
Storage Stability Test, 24 hrs., %		1.0	T 59
Demulsibility, %	40		T 59
Particle Charge Test	Positive		T 59
Sieve Test, %		0.1	T 59
Oil Distillate by volume, %		3.0	T 59
Residue by distillation, %	65		T 59
Tests on residue: Penetration, 25 °C (77 °F), 100g, 5 s	70	150	T 49
Solubility in trichloroethylene, %	97.5		T 44
Toughness, 25 °C, joules (77 °F, inch-pounds)	7.9 (70)		*CP L-2210
Tenacity, 25 °C, joules (77 °F, inch-pounds)	5.1 (45)		*CP L-2210

*Colorado Procedure.

2. HFRS-2P (Anionic, Polymerized, High Float) shall be an emulsified blend of polymerized asphalt, water, and emulsifiers. The asphalt cement shall be polymerized prior to emulsification and shall contain a minimum of three percent polymer by mass of asphalt cement. The emulsion, standing undisturbed for a minimum of 24 hours shall show no white, milky separation, and shall be smooth and homogenous throughout. The emulsion shall be pumpable and suitable for application through a distributor. The emulsified blend shall conform to the requirements of Table 702-5.

TABLE 702-5

Property	Requirement		AASHTO
	Min.	Max.	Test No.
Viscosity,Saybolt Furol at 50 °C (122 °F), s	50	450	T 59
Storage Stability Test, 24 hrs., %		1.0	T 59
Sieve Test, %		0.1	T 59
Demulsibility, 0.02 N, $CaCl_2$,%	40		T 59
Oil Distillate by volume, %		3.0	T 59
Residue by distillation, %	65		T 59[1]
Tests on residue:			
Penetration, 25 °C (77 °F), 100g, 5 s	70	150	T 49
Float Test, 60 °C (140 °F), s	1200		T 50
Ductility, 25 °C (77 °F), 5 cm/min., cm	75		T 51
Solubility in Trichloroethylene, %	97.5		T 44
Elastic Recovery, 25 °C (77 °F), %	58		*CP L-2211

[1] AASHTO T 59 with modifications to include a 205 ± 5 °C (400 °F ± 10 °F) maximum temperature to be held for 15 minutes.
* Colorado Procedure.

(b) *Emulsion for prime coat.* Emulsion for prime coat shall conform to the following requirements for either Asphalt Emulsion Prime in Table 702-6, or Penetrating Priming Stabilizer in Table 702-7.

TABLE 702-6
For Asphalt Emulsion Prime

Property	Requirement	AASHTO Test No.
Viscosity,Saybolt Furol, at 50 °C (122 °F), s	15-150	T 59
Settlement	1% max.	T 59
% Residue	65% min.	T 59 to 260 °C (500 °F)
Oil Distillate by Volume, %	7% max.	T 78
Tests on Residue from Distillation:		
Solubility in Trichloro-ethylene, %	97.5 min.	T 44
Tests on Residue from Cutback Distillation to 360 °C (680 °F):		
Viscosity, 60 °C, mm/s (140 °F, centistokes)	3,000 (3000) min.	T 202

TABLE 702-7
For Penetrating Priming Stabilizer

Property	Requirement		AASHTO Test No.
	Max.	Min.	
Flash (T.O.C.), °C (°F)	38 (100)		T 79
Saybolt Furol Viscosity at 50 °C (122 °F), s	30	100	T 72
Kinematic Viscosity at 60 °C, mm^2/s (140 °F, centistokes)	60	212	T 201
Residue by evaporation, %	55		T 59
Tests on residue:			
Penetration, 25 °C (77 °F), 5 sec, mm	25		T 49
Softening Point Ring & Ball, °C (°F)		71 (160)	T 53

(c) *Recycling Agent.* Recycling Agent for Item 406, Cold Bituminous Pavement (Recycle) shall be either a high float emulsified asphalt (polymerized) or an emulsified recycling agent as follows:

1. High Float Emulsified Asphalt (Polymerized). High Float Emulsified Asphalt (Polymerized) for Cold Bituminous Pavement (Recycle) shall be an emulsified blend of polymer modified asphalt, water, and emulsifiers conforming to Table 702-8 for HFMS-2sP. The asphalt cement shall be polymerized prior to emulsification, and shall contain a minimum of three percent polymer.

   The emulsion standing undisturbed for a minimum of twenty-four hours shall show no white, milky separation, and shall be smooth and homogeneous throughout.

The emulsion shall be pumpable and suitable for application through a pressure distributor.

2. Emulsified Recycling Agent. Emulsified Recycling Agent for use in Cold Bituminous Pavement (Recycle) shall conform to the requirements in Table 702-9.

TABLE 702-8
HIGH FLOAT EMULSIFIED ASPHALT (POLYMERIZED) (HFMS-2sP)

Property	Requirement		AASHTO
	Min.	Max.	Test No.
Tests on Emulsion:			
Viscosity, Saybolt Furol at 50 °C (122 °F), sec	50	450	T 59
Storage Stability test, 24 hours, %		1	T 59
Sieve test, %		0.10	T 59
Asphalt Content, % Residue	65		T 59
Oil distillate by volume, %	1	7	T 59
Tests on Residue:			
Penetration, 25 °C (77 °F), 100g, 5 sec	150	300*	T 49
Float Test, 60 °C (140 °F), sec	1200		T 150
Solubility in TCE, %	97.5		T 44
Elastic Recovery, 4 °C (39.2 °F), %	50		CPL 2211**

*When approved by the Engineer, Emulsified Asphalt (HFMS-2sP) with a residual penetration greater than 300 mm may be used with Cold Bituminous Pavement (Recycle) to address problems with cool weather or extremely aged existing pavement. Emulsified Asphalt (HFMS-2sP) with a residual penetration greater than 300 mm shall meet all other properties listed in Table 702-9.
** Colorado Procedure

TABLE 702-9
EMULSIFIED RECYCLING AGENT

Property	Requirement		
	Min.	Max.	Test
Tests on Emulsion:			
Viscosity @ 25 °C, SFS	15	85	ASTM D 244
Pumping Stability	Pass		GB Method[1]
Sieve Test, %w		0.1	ASTM D 244[2]
Cement Mixing, %w		2.0	ASTM D 244
Particle Charge	Positive		ASTM D 244
Conc. of Oil Phase	60		ASTM D 244[3]
Tests on Residue:			
Viscosity @ 60 °C , CST	1000	4000	ASTM D 2170
Flash Point, COC, °C (° F)	232		ASTM D 92
Volatility:			
IBP, °C	163		ASTM D1160, 10mm
2%V, °C	204		"
5%V, °C	221		"
RTF-C Weight Change, %W		2	ASTM D 2872
Compatibility. PC/S	0.5		ASTM D 2006 -70
Saturates, %w		28	ASTM D 2007
Asphaltenes, %w		7.0	ASTM D 2006 -70
Chemical Composition:			
(PC+A1)/(S+A2)	0.6	1.0	ASTM D 2006 -70
RTF-C Ratio		2.5	ASTM D 2872
Specific Gravity	0.98	1.02	ASTM D 70

[1]Pumping stability is determined by charging 450 ml of emulsion into a one liter beaker and circulating the emulsion through a gear pump (Roper 29.B22621) having a 1/4" (6.3 mm) inlet and outlet. The emulsion passes if there is no significant separation after circulating ten minutes.
[2]Test procedure identical with ASTM D 244 except that distilled water shall be used in place of two percent sodium

oleate solution.
[3]ASTM D 244 Evaporation Test for percent of residue is modified by heating 50 gram sample to 149 °C (300 °F) until foaming ceases, then cooling immediately and calculating results.

702.04 Rejuvenating Agents. Asphalt rejuvenating agents shall be composed of a petroleum resin-oil base uniformly emulsified with water and shall conform to the physical and chemical requirements of Table 702-10.

TABLE 702-10

Property	Test Method	Requirement
Viscosity, S.F., @ 25 °C (77 °F), s	ASTM D244	15-40
[1]Residue, % min.	ASTM D244	60-65
[2]Miscibility Test	ASTM D244	No coagulation
[3]Sieve Test, % max.	ASTM D244	0.10
Particle Charge Test	ASTM D244	Positive
Tests on residue from ASTM D244 (Mod):		
Viscosity, 60 °C (140 °F), mm^2/s	ASTM D445	100-200
Asphaltenes, % max.	ASTM D4124	0.75
[4]Maltenes Dist. Ratio $\frac{PC+A_1}{S+A_2}$	ASTM D4124	0.3-0.5

[1] ASTM D244 Modified Evaporation Test for percent of residue is made by heating 50-gram sample to 149 °C until foaming ceases, then cool immediately and calculate results.
[2] Test procedure identical with ASTM D244 except that .02 Normal Calcium Chloride solution shall be used in place of distilled water.

[3] Test procedure identical with ASTM D244 except that distilled water shall be used in place of 2% sodium oleate solution.
[4] In the Maltenes Distribution Ratio Test by ASTM Method D4124.

PC = Polar Compounds A_2 = Second Acidaffins
A_1 = First Acidaffin
S = Saturates

702.05 Recycling Agents. Asphalt recycling agents shall conform to the following physical and chemical requirements:

TABLE 702-11

Property	Test Method	Requirement
Viscosity @ 60 °C (77 °F), mm^2/s (cSt)	ASTM D2170	200-800 (200-800)
Specific Gravity	ASTM D 70	Report
Flash Point C.O.C., °C (°F) min.	ASTM D 92	204 (400)
Oven Weight Change, 5 hrs. @ 163 °C (325 °F), % max.	ASTM D1754	4
*Viscosity Ratio, % max.	ASTM D2170	3
Saturates, % max.	ASTM D4124	30

$$\text{* Viscosity Ratio} = \frac{\text{Viscosity after oven wt. change test, measured @ 60 °C (77 °F)}}{\text{Original Viscosity @ 60 °C (77 °F)}}$$

702.06 Hot Poured Joint and Crack Sealant. Hot poured material for filling joints and cracks shall conform to the requirements of ASTM D 3405 or D 1190. ASTM D 1191 mortar blocks shall be used for concrete bond test. ASTM D 1190 material must pass asphalt compatibility test, Section 9, ASTM D 3407.

Sealant material shall be supplied preblended, prereacted, and prepackaged. If supplied in solid form the sealant material shall be cast in a plastic or other dissolvable liner having the capability of becoming part of the crack sealing liquid. The sealant shall be delivered in the manufacturer's original sealed container. Each container shall be legibly marked with the manufacturer's name, the trade name of the sealer, the manufacturer's batch or lot number, the application temperature range, the recommended application temperature, and the safe heating temperature.

The sealant shall be pretested by the Department prior to use.

SECTION 703
AGGREGATES

The grading and composition requirements for coarse and fine aggregates for concrete are set forth in Table 703-1.

All sieve sizes and designations described in this section refer to laboratory sieves having square openings and conforming to ASTM E 11.

TABLE 703-1
following page

TABLE 703-1
Concrete Aggregate Gradation Table, Percentages Passing Designated Sieves and Nominal Size Designation

Sieve Size	Coarse Aggregates (From AASHTO M 43)								Fine Aggregate
	No. 3	No. 4	No. 6	No. 7	No. 8	No. 57	No. 67	No. 357	No. 467	AASHTO M6
	50 mm to 25.0 mm (2" to1")	37.5 mm to 19.0 mm (1½" to ¾")	19.0 mm to 9.5 mm (¾" to3/8")	12.5 mm to 4.75 mm (½" to #4)	9.5 mm to 2.36 mm (3/8" to #8)	25.0 mm to 4.75 mm (1" to #4)	19.0 mm to 4.75 mm (¾" to #4)	50 mm to 4.75 mm (2" to #4)	37.5 mm to 4.75 mm (1½" to #4)	4.75 mm to 150 µm (#4 to #100)
63 mm(2½")	100							100		
50 mm (2")	90-100	100						95-100	100	
37.5 mm (1½")	35-70	90-100				100			95-100	
25.0 mm (1")	0-15	20-55	100			95-100	100	35-70		
19.0 mm (¾")		0-15	90-100	100			90-100		35-70	
12.5 mm (½")	0-5		20-55	90-100	100	25-60		10-30		
9.5 mm (3/8")		0-5	0-15	40-70	85-100		20-55		10-30	100
4.75 mm (#4)			0-5	0-15	10-30	0-10	0-10	0-5		95-100
2.36 mm (#8)				0-5	0-10	0-5	0-5		0-5	
1.18 mm (#16)					0-5					45-80
300 µm (#50)										10-30
150 µm (#100)										2-10

703.01 Fine Aggregate for Concrete. Fine aggregate for concrete shall conform to the requirements of AASHTO M 6. The amount of material finer than 75 µm (No. 200) sieve shall not exceed three percent by dry weight of fine aggregate, when tested in accordance with AASHTO T 11 or Colorado Procedure 31, Method D, unless otherwise specified. The minimum sand equivalent, as tested in accordance with AASHTO T 176 shall be 80 unless otherwise specified. The fineness modulus, as determined on CDOT Form No. 619, shall not be less than 2.50 nor greater than 3.50 unless otherwise approved.

703.02 Coarse Aggregate for Concrete. Coarse aggregate for concrete shall conform to the requirements of AASHTO M 80, except that the percentage of wear shall not exceed 45 when tested in accordance with AASHTO T 96. Coarse aggregate shall conform to the grading in Table 703-1. Sizes 357 and 467 shall each be furnished in two separate sizes and combined in the plant in the proportions necessary to conform to the grading requirements. Compliance with grading requirements will be based on the combination and not on each individual stockpile.

703.03 Aggregate for Bases. Aggregates for bases shall be crushed stone, crushed slag, crushed gravel, natural gravel, or crushed reclaimed concrete or asphalt material which conforms to the quality requirements of AASHTO M 147 except that the requirements for the ratio of minus 75 µm (No. 200) sieve fraction to the minus No. 40 sieve fraction, stated in 2.2.2 of AASHTO M 147, shall not apply. The requirements for the Los Angeles wear test (AASHTO T 96) shall not apply to Class 1, 2, and 3. Aggregate for bases shall meet the grading requirements of Table 703-2 for the class specified for the project, unless otherwise specified.

The liquid limit shall be as shown in Table 703-2 and the plasticity index shall not exceed six when the aggregate is tested in accordance with AASHTO T89 and T 90 respectively.

TABLE 703-2
Classification for Aggregate Base Course

Sieve Size	Mass Percent Passing Square Mesh Sieves						
	LL not greater than 35			LL not greater than 30			
	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7
100 mm (4")		100					
75 mm (3")		95-100					
63 mm (2½")	100						
50 mm (2")	95-100			100			
37.5 mm (1½")				90-100	100		
25.0 mm (1")					95-100		100
19.0 mm (¾")				50-90		100	
4.75 mm (# 4)	30-65			30-50	30-70	30-65	
4.75 mm (# 8)						25-55	20-85
4.75 µm (#200)	3-15	3-15	20 max.	3-12	3-15	3-12	5-15

NOTE: Class 3 material shall consist of bank or pit run material.

703.04 Aggregate for Hot Plant Mix Bituminous Pavement. Aggregates for hot plant mix bituminous pavement shall be of uniform quality, composed of clean, hard, durable particles of crushed stone, crushed gravel, natural gravel, or crushed slag. Excess of fine material shall be wasted before crushing. For Gradings S, SX, and SG, a percentage of the aggregate retained on the 4.75 mm (No. 4) sieve shall have at least two mechanically induced fractured faces when tested in accordance with Colorado Procedure 45. This percentage will be specified in Table 403-1, as revised for the project in Section 403. The angularity of the fine aggregate shall be a minimum of 45.0% when determined according to CP L-5113, Method A. Aggregate samples representing each aggregate stockpile shall be non-plastic if the percent of aggregate passing the Number 4 sieve is greater than or equal to 10 percent by weight of the individual aggregate sample. Plasticity will be determined in accordance with AASHTO T 90.

Reclaimed material shall be of uniform quality. The maximum size of the reclaimed asphalt pavement shall be 38 mm (1½ inches) prior to introduction into the mixer. The maximum aggregate size contained in the combination of reclaimed asphalt pavement and new aggregate shall not exceed the maximum specified in Table 703-3. The hot bituminous pavement shall not contain more than 15 percent reclaimed asphalt pavement.

The material shall not contain clay balls, vegetable matter, or other deleterious substances. The aggregate for Gradings S, SX, and SG shall have a percentage of wear of 45 or less when tested in accordance with AASHTO T 96.

TABLE 703-3
Master Range Table for Hot Bituminous Pavement

Sieve Size	Percent by Weight Passing Square Mesh Sieves		
	Grading S	Grading SG	Grading SX
37.5 mm (1½")		100	
25.0 mm (1")	100	90 - 100	
19.0 mm (¾")	90 - 100		100
12.5 mm (½")	*	*	90 - 100
9.5 mm (3/8")	*	*	*
4.75 mm (#4)	*	*	*
2.36 mm (#8)	23 - 49	19 - 45	28 - 58
1.18 mm (#16)			
600 µm (#30)	*	*	*
300 µm (#50)			
150 µm (#100)			
75 µm (#200)	2 - 8	1 - 7	2 - 10

* These additional Form 43 Screens will initially be established for the Contractor's Quality Control Testing using values from the As Used Gradation shown on the Design Mix.

703.05 Aggregate for Cover Coat Material. Aggregates for cover coat material shall be crushed stone, crushed slag, crushed gravel, or natural gravel. Aggregates shall be composed of clean, tough, durable fragments free from an excess of flat, elongated, soft, or disintegrated pieces and free from fragments coated with dirt or other objectionable matter. Slag shall be air-cooled blast-furnace slag reasonably uniform in density.

The aggregate shall conform to the following requirements:

(1) Percentage of wear, Los Angeles Test (AASHTO T 96), not more than 35.

(2) When blast-furnace slag is used, mass per cubic meter shall be at least 1120 kilograms (weight per cubic foot shall be at least 70 pounds).

(3) For Type I, II, or IV cover coat material, 90 percent by weight of the particles retained on the 4.75 mm (No. 4) sieve shall have at least two fractured faces when tested in accordance with Colorado Procedure 45.

(4) Lightweight aggregate used for cover coat material shall be an aggregate prepared by expanding shale, clay, or slate in a rotary fired kiln. Lightweight aggregate shall have a dry loose unit weight of 560 to 880 kg/m^3 (35 to 55 pounds/cubic foot) determined in accordance with AASHTO T 19, Shoveling Procedure. The total mass of the test sample of lightweight aggregate used in AASHTO T 96 (Los Angles Abrasion) shall be 2000 g.

TABLE 703-4
Gradation Specifications for Cover Coat Aggregate

Sieve Size	Percent by Weight Passing Square Mesh Sieves		
	9.5 mm (3/8") Type 1	12.5 mm (1/2") Type II	19.0 mm (3/4")* Type IV
19.0 mm (3/4")			100
12.5 mm (1/2")		100	95-100
9.5 mm (3/8")	100	70-100	60-80
4.75 mm (No. 4)	0-15	0-4	0-10
75 µm (# 200)	0-1.0	0-1.0	0-1.0

*Type IV shall be used only with lightweight aggregates.

703.06 Mineral Filler. Mineral filler shall conform to the requirements of AASHTO M 17 and shall consist of rock dust, slag dust, hydrated lime, hydraulic cement, fly ash, or other suitable mineral matter. It shall be free of organic impurities and agglomerations. When used, it shall be dry enough to flow freely.

Mineral filler shall be graded within the following limits:

Sieve Size	Mass percent passing
600 µm (No. 30)	100
300 µm (No. 50)	95-100
75 µm (No. 200)	70-100

Mineral filler shall have a plasticity index not greater than four excluding hydrated lime and hydraulic cement.

703.07 Bed Course Material.

(a) Bed course material for sidewalks, curbing, and bikeways shall consist of cinders, sand, slag, gravel, crushed stone, or other approved material of such gradation that all particles shall pass through a sieve having 19.0 mm (¾") square openings.

(b) Bed course material for slope protection, or riprap filter blanket shall be a porous, free draining material consisting of sand, gravel, cinders, slag, crushed stone, or other approved free draining material. This material shall meet the following gradation requirements:

Sieve Size	Mass Percent Passing Square Mesh Sieves
75 mm (3")	100
4.75 mm (No. 4)	20-65
75 µm (No. 200)	0-10

703.08 Structure Backfill Material.

(a) Class 1 structure backfill shall meet the following gradation requirements:

Sieve Size	Mass Percent Passing Square Mesh Sieves
50 mm (2")	100
4.75 mm (No. 4)	30-100
300 µm (No. 50)	10-60
75 µm (No. 200)	5-20

In addition this material shall have a liquid limit not exceeding 35 and a plasticity index of not over six when determined in conformity with AASHTO T 89 and T 90 respectively.

(b) Class 2 structure backfill shall be composed of suitable materials developed on the project. To be suitable for use under this classification, backfill shall be free of frozen lumps, wood, or other organic material. If the material contains rock fragments that, in the opinion of the Engineer, will be injurious to the structure, the native material shall not be used for backfilling and the Contractor shall furnish Class 1 structure backfill material at the contract unit price. If contract unit price does not exist for Class I structure backfill, it will be paid for in accordance with subsection 104.03.

703.09 Filter Material. Filter material shall consist of free draining sand, gravel, slag, or crushed stone. The grading requirements are set forth in Table 703-5.

TABLE 703-5
Gradation Specifications for Filter Material

Sieve Size	MassPercent Passing Square Mesh Sieves		
	Class A	Class B	Class C
75 mm (3")	100		
37.5 mm (1½")		100	
19.0 mm (¾")	20-90		100
4.75 mm (No. 4)	0-20	20-60	60-100
1.18 µm (No. 16)		10-30	
300 µm (No. 50)		0-10	10-30
150 µm (No. 100)			0-10
75 µm (No. 200)	0-3	0-3	0-3

703.10 Aggregate for Median Cover. Aggregate for median cover shall consist of clean crushed stone, crushed gravel, or natural gravel. The percentage of wear, when tested in accordance with AASHTO T 96, shall not be more than 70. The grading requirements shall be as follows:

Sieve Size	Mass Percent Passing Square Mesh Sieves
63 mm (2½")	100
50 mm (2")	95-100
19.0 mm (¾")	0-15

SECTION 704
MASONRY UNITS

704.01 Clay or Shale Brick. Brick shall conform to the requirements of one of the following specifications:

Sewer and Manhole Brick-AASHTO M 91.
Building Brick-AASHTO M 114.

704.02 Concrete Brick. Concrete brick shall conform to the requirements of ASTM C 55.

704.03 Concrete Masonry Blocks. Concrete masonry blocks may be rectangular or segmented and, when specified, shall have ends shaped to provide interlock at vertical joints. The blocks shall conform to the requirements of ASTM C 139, or, for hollow blocks, to ASTM C 90. Dimensions and tolerances shall conform to the above applicable requirements or those specified on the plans.

704.04 Masonry Mortar. Masonry mortor shall be Type S conforming to ASTM C 270.

SECTION 705
JOINT, WATERPROOFING, AND BEARING MATERIALS

705.01 Joint Fillers.

(a) *Joint Sealant with Backer Rod.* The joint sealant material shall be a silicone that is on the Department's approved silicone sealant list. The silicone materials shall be stored and applied in accordance with manufacturer's recommendations, but they shall not be exposed to ambient temperatures in excess of 52 °C degrees Celsius (125 °F) or stored in direct sunlight. The backer rod placed prior to joint sealant shall be constructed of closed cell polyethylene strand as approved.

(b) *Preformed Joint Fillers.* Preformed fillers for joints shall conform to the requirements of AASHTO M 213 and shall be punched to admit the dowels where called for on the plans. The filler for each joint shall be furnished in a single piece for the full depth and thickness required for the joint unless otherwise authorized by the Engineer. When the use of more than one piece is authorized for a joint, the abutting ends shall be fastened securely, and held accurately to shape, by stapling or other positive fastening satisfactory to the Engineer.

705.02 (unused)

705.03 Gaskets. Rubber gasketed joints shall conform to the requirements of ASTM C 443M (ASTM C 443) and shall be flexible and able to withstand expansion, contraction, and settlement.

All rubber gaskets shall be stored in as cool a place as practicable, preferably at 21 °C (70 °F) or less. Rubber gaskets shall not be exposed to the direct rays of the sun for more than 72 hours.

Rubber gaskets, of the type requiring lubrication, shall be lubricated with the lubricant recommended and supplied by the manufacturer of the pipe.

705.04 Pipe Joint Sealing Compounds. Joint sealing compounds for concrete pipe shall conform to the requirements of AASHTO M 198.

Joint sealants for metal pipe shall conform to the pipe manufacturer's recommendations.

705.05 Compression Ring. Compression ring jointing connections for clay pipe, made of resilient material, shall conform to the requirements of ASTM C 425.

705.06 Bearing Materials

TABLE 705-1
following page

TABLE 705-1
Polyisoprene (Natural Rubber) Elastomer

Specimen Properties	ASTM Test Procedure	Requirements		
		50 Duro	60 Duro	70 Duro
Physical Properties				
Hardness	D 2240	50 ± 5	60 ± 5	70 ± 5
Tensile Strength, MPa (psi) min.	D 412	15.5 (2250)	15.5 (2250)	15.5 (2250)
Ultimate Elongation, % min.	D 412	450	400	300
Heat Resistance, 70 Hr/70 °C (158 °F)				
Change in Durometer Hardness, Max. Points		+10	+10	+10
Change in Tensile strength, % max.	D 573	-25	-25	-25
Change in Ultimate Elongation,% max.	D 573	-25	-25	-25
Compression Set, % max. 22 Hr./70 °C (158 °F)	D 395 Method B	25	25	25
Ozone Resistance, 20% strain 25 pphm Ozone in Air by Vol. 38° ± 1 °C (100 °F ±2°) /48 Hr. Mounting Procedure ASTM D 518, Procedure A	D 1149	No Cracks	No Cracks	No Cracks
Adhesion Bond Made During Vulcanization, N/mm (Lb. Per Inch)	D 429, B	7 (40)	7 (40)	7 (40)
Low Temperature Brittleness: Grade 3 at -40 °C (-40 °F) Grade 4 at -48 °C (-55 °F) Grade 5 at -57 °C (-70 °F)	D 746 Procedure B	No Failure	No Failure	No Failure
Instantaneous Thermal Stiffening: Grade 3 at -40 °C (-40 °F) Grade 4 at -46 °C (-50 °F) Grade 5 at -54 °C (-65 °F)	D 1043	1/3	1/3	1/3

TABLE 705-1
Polyisoprene (Natural Rubber) Elastomer, continued

Low Temperature Crystallization: Grade 3, 14 Days at -26 °C (-15 °F) Grade 4, 21 Days at -37 °C (-35 °F) Grade 5, 28 Days at -37 °C (-35 °F)	Quad Shear Test as described in Annex A of ASTM D 4014	[2] [3]	[2] [3]	[2] [3]

[1] Stiffness at test temperature shall not exceed 4 times the stiffness measured at 23 ºC (73 ºF).

[2] Stiffness at test time and temperature shall not exceed 4 times the stiffness measured at 23 ºC (73 ºF) with no time delay. The stiffness shall be measured with a quad shear test rig in an enclosed freezer unit. The test specimines shall be taken from a ramdomly selected bearing. A ± 25º strain cycle shall be used and a complete cycle of strain shall be applied with a period of 100 seconds. The first 3/4 cycle of strain shall be discarded and the stiffness shall be determined by the slope of the force deflection curve for the next ½ cycle of loading.

[3] ASTM D 1043 refers to the “Modulus of Rigidity” while ASTM D 4014 refers to the “Shear Modulus Stiffness”. The word “stiffness” is used to describe both terms.

TABLE 705-2
Chloroprene (Neoprene) Elastomer

Specimen Properties	ASTM Test Procedure	Requirements		
		50 Duro	60 Duro	70 Duro
Physical Properties				
Hardness	D 2240	50 ± 5	60 ± 5	70 ± 5
Tensile Strength, MPa min. (psi)	D 412	17.2 (2500)	17.2 (2500)	17.2 (2500)
Ultimate Elongation, % min.	D 412	400	350	300
Heat Resistance, 70 Hr/100 °C (212 °F)				
Change in Durometer Hardness, Max. Points		+15	+15	+15
Change in Tensile strength, % max.	D 573	-15	-15	-15
Change in Ultimate Elongation,% max.	D 573	-40	-40	-40
Compression Set, % max. 22 Hr./100 °C (212 °F)	D 395 Method B	35	35	35

TABLE 705-2 Chloroprene (Neoprene) Elastomer, continued

Ozone Resistance, 20% strain 100 pphm Ozone in Air by Vol. 38° ± 1 °C (100 °F ±2°) /100 Hr. Mounting Procedure ASTM D 518, Procedure A	D 1149	No Cracks	No Cracks	No Cracks
Adhesion Bond Made During Vulcanization, N/mm (Lb. Per Inch)	D 429, B	7 (40)	7 (40)	7 (40)
Low Temperature Brittleness: Grade 3 at -40 °C (-40 °F) Grade 4 at -48 °C (-55 °F) Grade 5 at -57 °C (-70 °F)	D 746 Procedure B	No Failure	No Failure	No Failure
Instantaneous Thermal Stiffening: Grade 3 at -40 °C (-40 °F) Grade 4 at -46 °C (-50 °F) Grade 5 at -54 °C (-65 °F)	D 1043	[1] [3]	[1] [3]	[1] [3]
Low Temperature Crystallization: Grade 3, 14 Days at -26 °C (-15 °F) Grade 4, 21 Days at -37 °C (-35 °F) Grade 5, 28 Days at -37 °C (-35 °F)	Quad Shear Test as described in Annex A of ASTM D 4014	[2] [3]	[2] [3]	[2] [3]

[1] Stiffness at test temperature shall not exceed 4 times the stiffness measured at 23 ºC (73 ºF).

[2] Stiffness at test time and temperature shall not exceed 4 times the stiffness measured at 23 ºC (73 ºF) with no time delay. The stiffness shall be measured with a quad shear test rig in an enclosed freezer unit. The test specimines shall be taken from a ramdomly selected bearing. A ± 25º strain cycle shall be used and a complete cycle of strain shall be applied with a period of 100 seconds. The first 3/4 cycle of strain shall be discarded and the stiffness shall be determined by the slope of the force deflection curve for the next ½ cycle of loading.

[3] ASTM D 1043 refers to the “Modulus of Rigidity” while ASTM D 4014 refers to the “Shear Modulus Stiffness”. The word “stiffness” is used to describe both terms.

Elastomeric Bearing Pads - Laminates shall be rolled mild steel sheets conforming to either AASHTO M 183M/ M 183 or Grade C or D of ASTM A 570/ A 570M or ASTM A 611 unless otherwise specified.

A Durometer hardness of 60 shall be used unless otherwise shown on the plans.

The elastomer portion of the elastomeric compound shall be 100 percent virgin natural polyisoprene (natural rubber) or 100 percent virgin chloroprene (neoprene), and shall be not less than 60 percent by volume of the total compound.

Sheet Lead - Sheet lead shall conform to the requirements of ASTM B 29 for common desilverized lead.

Polytetrafluoroethylene (PTFE) Sheets - PTFE resin shall be virgin material conforming to the requirements of ASTM D 1457. The specific gravity shall be 2.13 to 2.19 and the melting point shall be 328 ± 1 °C (623 °F ± 2°F).

Filler material shall be milled glass fibers, carbon, or other approved inert filler materials.

Finished unfilled PTFE sheet shall be made from PTFE resin and shall conform to the following requirements:

Tensile strength (min.)	ASTM D 1457	19.3 MPa (2800 psi)
Elongation (min.)	ASTM D 1457	200%

Filled PTFE sheet shall be made from PTFE resin uniformly blended with inert filler material. Finished filled PTFE sheet containing glass fiber or carbon shall conform to the following requirements:

Mechanical	**ASTM Method**	**15% Glass Fiber**	**25% Carbon**
Tensile Strength (min.)	D 1457	14 MPa (2000 psi)	9 MPa (1300 psi)
Elongation (min.)	D 1457	150%	75%
Physical	**ASTM Method**	**15% Glass Fiber**	**25% Carbon**
Specific Gravity (min.)	D 792	2.20	2.10
Melting Point	D 1457	327 °C ± 10 °C (621 °F ± 18 °F)	327 °C ± 10 °C (621 °F ± 18 °F)

The maximum coefficient of friction for the PTFE shall be as follows:

Bearing Pressure	3.4 MPa (500 psi)	13.8 MPa (2000 psi)	20.7 MPa (3000 psi)
Unfilled PTFE	0.08	0.06	0.04
Filled PTFE	0.12	0.10	0.08

The average bearing pressure on the PTFE sliding surface due to all loads shall not exceed:

Type II Bearing Device Unfilled and Filled PTFE	13.8 MPa (2000 psi)
Type III Bearing Device Filled PTFE	24 MPa (3500 psi)
Unfilled PTFE (Recessed)	24 MPa (3500 psi)
Unfilled PTFE (Not Recessed)	14 MPa (2000 psi)

The edge load pressure due to all loads and rotations shall not exceed:

Unfilled and filled PTFE (Type II and III Bearing Device)	35 MPa (5000 psi)

Stainless Steel Sheets - The stainless steel sheet shall be 1.52 mm (16 gage) minimum thickness and shall conform to ASTM A 240/ A240M, Type 304.

Adhesive Material - Adhesive material shall be an epoxy resin meeting the requirements of Federal Specification MMM-A-134, FEP film or approved equal.

Certification and Testing - The Contractor shall furnish a manufacturer's certification that the material proposed for use on the project meets the requirements set forth in the tables above. The Department also reserves the right to test random samples of full size bearings proposed for use on the project. The following values shall be met under laboratory testing of full size bearings.

(a) Compressive strain of any layer of an elastomeric bearing shall not exceed seven percent at 5.5 MPa (800 psi) average unit pressure, or at the design dead load plus live load pressure when so shown on the plans.

(b) The shear resistance of the bearing shall not exceed 205 kPa (30 psi) for 50 durometer, 275 kPa (40 psi) for 60 durometer, or 340 kPa (50 psi) for 70 durometer, polyisoprene compounds, nor 340 kPa (50 psi) for 50 durometer, 515 kPa (75 psi) for 60 durometer, or 755 kPa (110 psi) for 70 durometer, chloroprene compounds. Shear resistance shall be measured at 25 percent strain of the total effective rubber thickness after an extended four-day ambient temperature of minus -29 ºC (-20 °F).

Components of nominal hardness between values shown may be used and test requirements interpolated. When test specimens are cut from the finished product a 10 percent variation in "physical properties" will be permitted.

Tolerances - Flash tolerance, finish and appearance shall meet the requirements of the latest edition of the Rubber Handbook as published by the Rubber Manufacturers Association, Inc., RMA F3 and T.063 for molded bearings and RMA F2 for extruded bearings.

For both plain and laminated bearings, the permissible variation from the dimensions and configuration required by the plans and these specifications shall be as follows:

1.	Overall Vertical Dimensions	
	Average Total Thickness	
	32 mm (1¼") or less	-0, + 3 mm (+1/8")
	Average Total Thickness over	
	32 mm (1¼")	-0, + 6 mm (+¼")
2.	Overall Horizontal Dimension	
	900 mm (36") and less	-0, + 6 mm (+¼")
	Over 900 mm (36")	-0, + 13 mm (+½")
3.	Thickness of Individual Layers of Elastomer (Laminated Bearings Only)	± 3 mm (± 1/8")
4.	Variation from a Plane parallel to the Theoretical Surface (as determined by measurements at the edges of the bearings)	
	Top	3 mm (1/8")
	Sides	6 mm (¼")
	Individual Non-Elastic Laminates	3 mm (1/8")
5.	Position of Exposed Connection Members	3 mm (1/8")
6.	Edge Cover of Embedded Laminates or Connection Members	-0, +3 mm (+ 1/8")
7.	Size of Holes, Slots or Inserts	± 3 mm (±1/8")
8.	Position of Holes, Slots or Inserts	± 3 mm (±1/8 ")

For Type V bearings, the average bearing pressure on the PTFE sliding surface due to all loads shall not exceed 13.8 MPa (2000 psi) for unfilled and filled PTFE.

For Type V bearings, the edge load pressure due to all loads and rotations shall not exceed 34.5 MPa (5000 psi) for unfilled and filled PTFE.

705.07 Protective Covering for Bridge Deck Waterproofing Membrane. The protective covering shall be composed of one or more layers of felt thoroughly bonded together and saturated with asphalt. Both exposed sides shall be asphalt-coated. The nominal mass per one hundred constructed square meters shall be 270 kilograms (55 pounds per 100 square feet). The surfaces shall be coated with suitable mineral matter to prevent the material from sticking to itself.

The covering may be furnished either in rolls or sheets.

The covering shall be free of visible external defects, such as holes, ragged or untrue edges, breaks, cracks, tears, protuberances, and indentations.

The covering furnished in rolls shall not crack nor be so sticky as to cause material damage upon being unrolled at atmospheric temperatures as low as 10 °C (50 °F).

The covering shall conform to the following requirements when tested in accordance with Colorado Procedure L-2202:

Property Determined	Specification
Width	Min. 900 mm (35½"), Max. 1540 mm (60½")
Pliability at 25 °C (77 °F)	At least 4 of 5 strips shall not crack when bent 90° over a rounded corner of 13 mm (½") radius.
Behavior on heating to 80 °C (176 °F)	Max. 1.5 percent volatile loss. No flowing, sagging or blistering.
Mass per square meter (weight per square foot)	Minimum 2.4 kg (0.5 lbs)

Protective covering may be conditionally accepted in the field based on visual inspection for appearance, workmanship, and mass per square meter (weight per square foot) of a representative specimen.

705.08 Prefabricated, Reinforced Membrane and Primer. The membrane shall be a factory laminated sheet composed of either rubberized asphalt, bituminous mastic, or similar compounds reinforced with synthetic or fiberglass fabric. It shall be uniformly manufactured free from blemishes, discontinuities, and other defects. The membrane shall be supplied in rolls, having a minimum width of 750 mm (30") and shall conform to the following requirements:

Property Determined	Test Procedure	Specification
Thickness	-----	1.8 mm (70 mils) minimum
Pliability	CP L-2203	No cracks

The primer used to bond membrane to the deck and to seal seams and patches shall be a water resistant adhesive compatible with the membrane. The primer shall be of suitable consistency for application by brush, roller, or spray without further dilution.

705.09 Single Component, Hot Applied, Elastomeric Membrane. The membrane shall be capable of being sprayed or spread to a uniform thickness at the application temperature recommended by the manufacturer. After cooling it shall form a tough resilient membrane, well bonded to the concrete surface and shall conform to the requirements of ASTM D 3405, except that blocks for the bond test shall be as described in ASTM D 1191.

The membrane material shall be pretested by the Department prior to use.

705.10 Waterstop. Neoprene waterstop shall be made of suitable synthetic rubber. Neoprene waterstop shall conform to the applicable requirements designated in the latest edition of the Corp of Engineers Specifications for Rubber Waterstops CRD-C513.

Plastic waterstop shall be made of polyvinyl chloride (PVC) plastic. Plastic waterstop shall conform to the requirements designated in the latest edition of the Corp of Engineers Specifications for Polyvinyl chloride Waterstops CRD-C572.

SECTION 706
CONCRETE AND CLAY PIPE

706.01 Nonreinforced Concrete Pipe. This pipe shall conform to the requirements of AASHTO M 86M (M 86) for the specified diameters and strength classes.

706.02 Reinforced Concrete Pipe. This pipe shall conform to the requirements of AASHTO M 170M (M 170) for the specified diameters and strength classes. Unless otherwise specified, pipe wall design and use of elliptical reinforcement in circular pipe are optional. Reinforced concrete pipe being jacked shall be Class V and shall be furnished with grouting nipples spaced not more than 2.4 m (8 feet) apart. Joints for this pipe shall come equipped with steel rings and rubber gaskets conforming to ASTM C 361M (C 361) and as described in Bureau of Reclamation Specifications for Type R-2 joints.

Elliptical pipe conforming to AASHTO M 207M (M 207) shall be furnished when required on the plans. Arch pipe conforming to AASHTO M 206M (M 206) shall be furnished when required on the plans.

Precast reinforced concrete end sections shall have at least one line of reinforcement conforming to the requirements of AASHTO M 170M (M 170) equivalent to the square millimeters per meter (square inches per linear foot) for elliptical reinforcement in circular pipe, Class II, Wall B.

706.03 Perforated Concrete Pipe. This pipe shall conform to the requirements of AASHTO M 175M (M 175) for the specified diameters and strength classes. Unless otherwise specified, perforations shall be Type 1.

706.04 Drain Tile. This pipe shall conform to the requirements of AASHTO M 178M (M 178) or M 179 for the specified material, diameters and quality classes.

706.05 Porous Concrete Pipe. This pipe shall conform to the requirements of AASHTO M 176M (M 176) for the specified diameters.

706.06 Vitrified Clay Pipe. This pipe shall conform to the requirements of AASHTO M 65 for the specified diameter and strength class.

706.07 Coated Concrete Pipe. This pipe may be reinforced or nonreinforced in accordance with the requirements shown on the plans for the designated diameters and strength classes, and in addition, shall be coated with asphalt mastic conforming to the requirements of AASHTO M 243.

Asphalt mastic shall be uniformly applied in two coats by spray or brush to the entire designated surface to be coated, to a total thickness of 1.3 mm (50 mils). Asphalt mastic may also be applied by trowel in one coat provided the required thickness is obtained. The first coat shall be dry to touch before the second coat is applied. The second coat shall be dry to touch before any handling or backfilling operations.

The finished coat shall cover the surface to be protected evenly, without running, and without any visible holidays, bubbles, or bare spots.

SECTION 707
METAL PIPE

707.01 Ductile Iron Pipe. This pipe shall conform to the requirements of ASTM A 716 for the specified diameters and strength classes. Unless otherwise specified either smooth, corrugated or ribbed pipe may be furnished.

707.02 Corrugated Steel Pipe and Pipe Arches. These conduits and coupling bands shall conform to the requirements of AASHTO M 36M (M 36), except for the following:

Sawed ends and butt welded joints will be permitted for pipe with helical corrugations formed with continuous lock or welded seams provided all burrs are removed from sawed ends and provided the welds are acceptable.

Pipe fabricated with resistance spot welds shall also conform with the following additional requirement: Where double welding is necessary, adjacent welds shall not be closer than two spot weld nugget diameters from center to center.

Shop formed elliptical pipe shall be furnished where specified. Field elongation will be accepted as an alternate to shop elongation when done in a neat workmanlike manner.

Special fittings and elbows for these conduits shall be the same metal thickness as the conduit to which they are joined, and shall conform to the applicable requirements of AASHTO M 36M (M 36).

Semicircular corrugated steel pipe for encasement, along with required fastening devices, shall conform to the requirements of this subsection and the requirements of Military Specification MIL-P-236, Type I or II, Class 1.

Coupling Bands. Coupling bands shall conform to the requirements of AASHTO M 36M (M 36) with the following exceptions:

(1) The use of channel bands as described in 9.1 of AASHTO M 36M (M 36) will not be allowed.
(2) Connecting bands shall be at least 265 mm (10½") wide.

707.03 Bituminous Coated Corrugated Steel Pipe and Pipe Arches. Conduit, fittings, elbows, end sections and coupling bands shall be fully coated with bituminous material conforming to the requirements of AASHTO M 190, Type A coating or materials conforming to the requirements of AASHTO M 243, except that the use of tar base material will not be permitted. Coatings shall be shop applied. The finished coat shall uniformly cover the surface to be protected. The coating shall not contain any visible holidays, bubbles or bare spots. Minimum thickness shall be 1.3 mm (50 mils) measured on the crest of the corrugations.

In complying with AASHTO M 190, each section shall be given a double dip application. In the first immersion, the section shall remain submerged until the metal has reached a temperature that will allow the hot bituminous material to penetrate and seal each joint.

Other coatings meeting the requirements of AASHTO M 190 or M 243 will be acceptable upon written approval by the Engineer.

Materials meeting the requirements of AASHTO M 243 shall be uniformly applied by spray, trowel, or brush to the entire designated surface to be coated, to a minimum thickness of 1.3 mm (50 mils). The coating shall be dry to the touch prior to any handling or backfilling operations.

Special fittings and elbows for conduits shall be of the same gage as the conduit to which they are joined.

When aramid fiber bonded corrugated steel pipe is specified the pipe shall conform to ASTM A 885 and the bituminous coating shall conform to the requirements of AASHTO M 190, Type A.

707.04 Corrugated Steel Pipe for Underdrains. This pipe shall conform to the requirements of AASHTO M 36M (M 36), Type I, except that all reference to "sleeve type coupler" or "coupling" as described in 9.1 and 9.2 therein shall be disregarded. Sleeve type couplers or couplings will not be permitted.

Perforated pipe shall have Class 1 perforations.

707.05 Bituminous Coated Corrugated Steel Pipe for Underdrains. This pipe shall conform to the requirements of AASHTO M 36M (M 36), Type I.

Perforated pipe shall have Class 1 perforations.

Underdrain, fittings, elbows, end sections, and coupling bands shall be fully coated with bituminous material conforming to the requirements of AASHTO M 190, Type A coating or materials conforming to the requirements of AASHTO M 243, except that the use of tar base material will not be permitted. Coatings shall be shop applied. The finished coat shall uniformly cover the surface to be protected. The coating shall not contain any visible holidays, bubbles or bare spots. Minimum thickness shall be 1.3 mm (50 mils) measured on the crest of the corrugations.

In complying with AASHTO M 190, each section shall be given a double dip application. In the first immersion, the section shall remain submerged until the metal has reached a temperature that will allow the hot bituminous material to penetrate and seal each joint.

Other coatings meeting the requirements of AASHTO M 190 or M 243 will be acceptable upon written approval by the Engineer.

Materials meeting the requirements of AASHTO M 243 shall be uniformly applied by spray, trowel, or brush to the entire designated surface to be coated, to a minimum thickness of 1.3 mm (50 mils). The coating shall be dry to the touch prior to any handling or backfilling operations.

Special fittings and elbows for underdrains shall be of the same gage as the conduit to which they are joined.

The specified minimum size of perforations shall apply after coating.

707.06 Corrugated Aluminum Pipe. This pipe and coupling bands shall conform to the requirements of AASHTO M 196M/ M196, Type 1 pipe.

707.07 Corrugated Aluminum Pipe for Underdrains. This pipe shall conform to the requirements of AASHTO M 196M/ M196. Non-perforated pipe shall be Type 1. Perforated pipe shall be Type III, with Class I perforations.

707.08 Extensions. Connecting bands and extensions to existing culverts shall be of the same type metal or alloy, unless otherwise shown on the plans.

707.09 Repair of Damaged Coating. Units on which the spelter coating has been damaged shall be either regalvanized as provided under AASHTO M 36M (M 36) or painted with one full brush coat of a zinc rich paint meeting Military Specification DOD-P-21035A, or by other approved process on properly cleaned surface, as determined by the Engineer.

Bituminous coated material which has been damaged shall be repaired with field-applied asphalt mastic conforming to

AASHTO M 243. Other coating material may be used when approved by the Engineer.

707.10 Polymer Precoated Corrugated Steel Pipe. Polymer precoated corrugated steel pipe shall conform to the requirements of AASHTO M 245M/ M 245.

SECTION 708
PAINTS

708.01 General. This specification covers ready-mixed paint. Paint shall be easily mixed. The mixed paint shall be free from agglomerates, skins and foreign matter and shall be of suitable consistency for the method of application. Paint shall have satisfactory spreading qualities and give a smooth, continuous coating free from breaks or sags. Paint shall be able to withstand one year of storage without detrimental deterioration. In a 3/4 full, tightly closed container, paint shall show no skinning after 48 hours.

Color where designated by number refers to Federal Standard 595B. All proportions specified herein shall be by weight.

708.02 List of Paints.

PAINTS	SPECIFICATION
Structural Steel Bridge Paint	Subsection 708.03
White Wood Primer	TT-P-25
Outside White Paint	TT-P-102, Class A
Exterior Black Paint	TT-P-61
Black or White Baking Enamel	TT-E-489, Class B
Federal Yellow Enamel	TT-E-489, Class A
Aluminum Paint	Subsection 708.04
Pavement Marking Paint	Subsection 708.05

708.03 Structural Steel Bridge Paint. All structural steel shall be painted as follows:

Inorganic Zinc-Rich Polyurethane System. The primer shall be an approved inorganic zinc-rich primer conforming to the requirements of Table 1 of the STEEL STRUCTURES PAINTING COUNCIL SPECIFICATION NO. 20 (SSPC-PAINT 20) (Nov. 1, 1982). The vehicle of this primer shall be SSPC-Paint 20, Type 1-C.

The primer shall be applied according to the manufacturer's recommendations with a minimum dry film thickness of 80 micrometers (3 mils).

The manufacturer shall certify in writing to the Engineer that the SSPC-SP 6 steel cleaning is compatible with the primer used.

The top coat shall be an approved high-build polyurethane enamel with a minimum dry film thickness of 80 micrometers (3 mils). To prevent bubbling, a mist coat shall be applied prior to application of the top coat.

708.04 Aluminum Paint. The paint shall be supplied ready-mixed in the proportion of 240 grams of aluminum paste (ASTM D 962, Type II, Class B) to one liter of mixing varnish (2 pounds of aluminum paste per 1 gallon of mixing varnish) (see subsection 708.06 (c)). Aluminum paint shall dry to touch in 1/2 to 4 hours and dry hard in 18 hours maximum. Material will be inspected for leafing on a vertical primed steel surface at a spreading rate of 10 m^2/L (400 square feet per gallon).

708.05 Pavement Marking Paint. Pavement marking paint shall conform to the requirements listed in the table below. All proportions are by weight. Pigment composition and vehicle composition shall not vary by more than 1.0 percent of each amount specified.

Finished Paint Pigment (White and Yellow) 49.0% to 52.0%

Pigment Composition	White	Yellow
Titanium Dioxide, ASTM D 476, Type III	27.0%	
Yellow Pigment		35.0%*
Calcium Carbonate, ASTM D 1199, Type GC-II	18.0%	53.3%
Magnesium Silicate ASTM D 605	54.3%	11.0%
Pigment Suspending Agents (see below)	0.7%	0.7%

*The pigment for yellow paint shall consist of a blend of organic yellow pigment and other pigments and fillers as are necessary to result in a colorfast paint complying with all provisions of this specification. The paint shall contain no lead or other material such that the dry film could be considered a hazardous waste under EPA or Colorado Department of Health Regulations.

Vehicle Composition	White & Yellow
Alkyd Resin Solution, AASHTO M 248, Type F	70.0%
VM&P Naphtha, Fed. Spec. TT-N-95, Type I	30.0%
Driers, ASTM D 600 cl. B, and Anti-Skinning Agent, Methanol	

Pigment Suspending Agent

Organo-montmorillonite conforming to subsection 708.06(b) shall be added to achieve the desired storage and stability requirements.

Properties of Finished Paint

The paint at the time of container filling shall be free of skins, pigment agglomerates and foreign matter and shall meet the following requirements:

Fineness of grind, Hegman, minimum	2
Consistency, Krebs-Stormer, K.U. @ 25 °C (77 °F)	70-80
Drying time, a wet film of paint 380 micrometers thick tested according to ASTM Method D 711, minutes maximum	30

Reflectance. The white paint shall have a daylight 45°, 0° luminous directional reflectance of not less than 80% when compared to magnesium oxide (ASTM E 1347)

Color. The color of the yellow paint shall visually match color chip No. 33538 of Federal Standard 595B. In case of dispute, the color shall be within the green and red tolerance limits when compared with the standard color chips of the Standard Yellow for Highway Signs and Markings - U.S. Department of Transportation, Washington, D.C. The manufacturer shall supply test data showing that the yellow pavement marking

paint will retain the yellow color within these limits for a period of one year under outdoor sunlight exposure.

708.06 Materials - Specifications

(a) *Paint Pigments:*

Chrominum Oxide, (Green)	ASTM D 263
Magnesium Silicate	ASTM D 605
Phthalocyanine Blue	ASTM D 963 [D 963 Discontinued]
Titanium Dioxide	ASTM D 476, Class IV
Red Iron Oxide	ASTM D 84, Class 1
Black Iron Oxide	ASTM D 769
Yellow Iron Oxide	ASTM D 768

(b) Organo-montmorillonite shall be an organic ammonium compound of montmorillonite with a high gelling efficiency in a wide range of organic liquids. It shall be a fine, creamy, white powder with maximum water content of 3.0% and a maximum of 5.0% retained on the 75 µm (No. 200) sieve. Organo-montmorillonite shall be prewetted with methanol or ethanol as recommended by the manufacturer.

(c) *Varnish for Aluminum Paint.*

MATERIAL	SPECIFICATION
Resin- 100% Phenol Formaldehyde	MIL-R-15189A
Oil-Tung	ASTM D 12
Mineral Spirits	ASTM D 235
Xylene	ASTM D 364 [D 364 Discontinued]
Driers - Cobalt and/or manganese	ASTM D 600
PROPERTIES OF VARNISH	
Viscosity (G-H)	A-C
Oil Length	275 liters per 100 kilograms of resin (33 gal.)
Nonvolatile	55% min.
Proportion of Thinners	90% Mineral Spirits, 10% Xylene

Color (Hellige)	12 max.
Zinc Reactivity	None
Kauri Reduction	140% min.
Rosin and Rosin Derivatives	None
Appearance	Clear and Transparent
Drying Time: Set to Touch	1 to 3 hrs.
Dry Hard	18 hrs. max.

Alkali Resistance. No visible attack to film dried 72 hours after 8 hours in 5% sodium hydroxide solution at 21 °C (70 °F).

708.07 Pavement Primers. The type and application rate of epoxy resin primer shall be as recommended by the thermoplastic or preformed plastic pavement marking manufacturer.

A primer application rate of zero will not be accepted, except for thermoplastic marking and inlaid preformed plastic pavement marking placed on new asphalt surfaces as recommended by the manufacturer and approved in writing by the Engineer. However, if the Engineer determines that a new asphalt surface has become soiled, prior to placement of the pavement markings, pavement primer will be required and shall be applied as approved.

The epoxy resin primer material may be accepted at the job site on the basis of a manufacturer's certification, or a sample may be sent to the Laboratory for testing, in which case three weeks shall be allowed between sampling and intended use.

708.08 Masonry Coating Class 5 Finish. Masonry coating shall be a hydraulic cement base coating designed for use on porous surfaces of concrete as a decorative, protective, and water repellant coating. The powder shall consist of a heavy cement base coating packaged in a dry form and shall conform to Federal Specification TT-P-35, Type I, Class B. The liquid acrylic shall be an approved combination of polymers and modifiers designed for use with portland cement, shall be fully

compatible with water, and shall be a product of the manufacturer of the cement base powder. All materials shall be delivered to the project site in sealed containers bearing manufacturer's original labels.

708.09 Inspection and Testing. The manufacturer shall notify the Engineer well in advance of actual paint manufacture in order to arrange for sampling and testing of raw materials and inspection of paint production.

Test methods shall be according to ASTM or, if not covered therein, Federal Test Method Standard No. 141.

All paint shall have been approved before delivery.

SECTION 709
REINFORCING STEEL AND WIRE ROPE

709.01 Reinforcing Steel. Reinforcing steel shall conform to the requirements of the following specifications:

Deformed and Plain Billet-Steel Bars for Concrete Reinforcement	ASTM A 615/A 615M
Axle-steel Deformed and Plain Bars for Concrete Reinforcement	ASTM A 617/A 617M
Low-Alloy Steel Deformed Bars for Concrete Reinforcement [to be Welded]	ASTM A 706/A 706M
Fabricated Deformed Steel Bar Mats for Concrete Reinforcement	ASTM A 184/A 184M
Steel Welded Wire Fabric, Plain, for Concrete Reinforcement	AASHTO M 55M/M 55
Steel Welded Wire Fabric, Deformed for Concrete Reinforcement	AASHTO M 221M/ M 221
Epoxy Coated Reinforcing Bars	AASHTO M 284/ M 284M

Unless otherwise designated, bars conforming to ASTM A 615/A 615M & ASTM A 617/A 617M shall be furnished in Grade 420 (60) for #16 (# 5) bars and larger and Grade 300 (40) or 420 (60) for bars smaller than #16 (# 5).

In ASTM A 184/A 184M, bar material conforming to ASTM A 616/A 616M will not be permitted.

709.02 Wire Rope. The wire rope shall conform to the requirements of AASHTO M 30 for the specified diameter and strength class.

709.03 Dowel Bars and Tie Bars. Tie bars for longitudinal and transverse joints shall conform to AASHTO M 284M (AASHTO M 284) and shall be grade 300 (40), epoxy-coated, and deformed. Bar size shall be as designated on the Standard Plan M-412-1.

Dowel bars for transverse joints shall conform to AASHTO M 254 for the coating and to ASTM A 615M, grade 420 (ASTM A 615, grade 60) for the core material and shall be epoxy-coated, smooth, and lightly greased, precoated with wax or asphalt emulsion, or sprayed with an approved material for their full length. Bar size shall be as designated on the Standard Plan M-412-1.

SECTION 710
FENCE AND GUARDRAIL

710.01 Barbed Wire. Steel barbed wire shall conform to the requirements of ASTM A 121, Class I. Aluminum barbed wire shall be manufactured in accordance with ASTM B 211M (B 211) with alloy 5052-O for the line wire and alloy 5052-H38 for the barbs.

710.02 Woven Wire. Woven wire shall conform to the details and requirements shown on the plans and to the following:

Zinc coated steel woven wire shall conform to the requirements of ASTM A 116, coating Class I.

Aluminum coated steel woven wire shall conform to the requirements of ASTM A 584, coating Class I.

Fittings and attachments shall be zinc coated to conform to the requirements of AASHTO M 232.

710.03 Chain Link Fabric. Chain link fabric and required fittings and hardware shall conform to the requirements of AASHTO M 181 for the kind of metal, sizes of wire and mesh specified.

Zinc coating for steel fabric shall conform to ASTM A 392, Class I; and aluminum coating for steel fabric to ASTM A 491, Class I.

710.04 Snow Fence. Wire-bound picket fence shall conform to the requirements of ASTM F 537. Posts shall conform to the requirements of AASHTO M 281.

710.05 "W" Beam Rail. The rail elements shall be corrugated sheet steel beams conforming to the requirements of

AASHTO M 180 of the designated class and type. The beams shall be galvanized, shop painted or corrosion resistant as may be specified. The same requirements shall apply to metal offset devices.

Corrosion resistant steel for rail elements and terminals shall not be painted or galvanized.

Corrosion resistant beam rails shall consist of corrugated sheet steel conforming to the requirements of AASHTO M 180, Type IV and shall have a corrosion resistance of at least 4 times that of carbon steel without copper (0.02 Max), or twice that of carbon steel with copper. The sheet steel may be either in coils or cut lengths when processed for corrugation.

All corrosion resistant material shall be sandblasted to provide a uniform weathered appearance.

All corrosion resistant steel parts shall be handled with care to avoid gouges, scratches, or dents. Care shall be exercised to keep foreign material such as paint, grease, oil, or crayon, from contact with the surface. Steel parts damaged either physically or by contact with foreign substances, will not be accepted.

During shipment or site storage, corrosion resistant steel parts must be positioned to allow free drainage and air circulation on the surfaces. Natural oxide formation on the steel may occur and will not be considered objectionable.

The Contractor shall furnish three copies of a certified mill test report to the Engineer. This report shall show the results of physical and chemical tests of the metal and its coating.

710.06 Timber For Wood Sound Barrier. Timber shall be any of the timber species given in subsection 508.02 including all species defined as "Native." Throughout the project, posts

shall be of one species; boards may be of another species; and rails may be a mix of any permissible species, except where single sided fence is built, the rails shall be of one species. The exposed board surfaces shall be of one finish throughout the entire fence and may be rough sawn, SIS, S1S2E, or S48; posts and rails may have any of the finishes. Species selected for posts, rails, and boards shall conform to the grading rules of the Western Wood Products Association (WWPA), the Southern Pine Inspection Bureau (SPIB), or the West Coast Lumber Inspection Bureau (WCLIB) for grading and strength.

Posts. WWPA or WCLIB posts and timbers, No. 1 or better; or SPIB timbers No. 2SR or better.

Rails. WWPA, WCLIB, or SPIB: Light framing, standard or better; or structural joists and planks, No. 2 or better.

Boards. WWPA No. 2 common or better; or SPIB No. 1 or better.

Treatment. The selected species shall be pressure treated lumber conforming in all respects to the American Wood Preserver's Association (AWPA) standards, Sections C1 and C2 (Soil contact for posts, above ground for balance of fence). A treatment report is required from the treatment plant.

Preservative. Section P5 of AWPA standards.

All lumber shall be manufactured in accordance with Product Standard 20-70 as published by the Department of Commerce, and shall be grade marked by a grading agency or have an accompanying certificate from the grading agency. The grading agency shall be certified by the Board of Review of the American Lumber Standards Committee.

All posts, rails, and fence board materials shall be dried after treatment to a maximum of 19 percent moisture content.

710.07 Fence Posts. Wood posts shall conform to the details and dimensions indicated on the plans. Wood posts shall be straight, sound, and seasoned with ends sawed off square or as indicated. All knots shall be trimmed flush with the surface. Wood posts shall be peeled and shall be treated with preservative in accordance with AASHTO M 133 and AWPA C14. When native cedar posts are called for on the plans, the requirements for peeling and for treating may be omitted.

All dimension timber and lumber required for fences or gates shall be sound, straight, and free from knots, splits, and shakes. It shall be of the species and grades indicated on the plans.

Concrete posts shall be made of concrete of the class specified, and shall contain steel reinforcement as shown on the plans.

Steel posts shall be galvanized in accordance with AASHTO M 111. Fittings, hardware and other appurtenances not specifically covered by the Contract shall be standard commercial grade, and in accord with current standard practice. Pipe material for fence posts shall conform to the requirements shown on the plans and to the requirements of Class 1 Pipe, Grade A or Grade B, of Federal Specification RR-F-191/3C.

710.08 Guardrail Posts. Posts shall be of either wood or steel. When the choice of post is at the option of the Contractor, there shall be only one kind furnished on the project unless otherwise specified in the Contract.

(a) Wood posts shall be fabricated from an approved or specified timber species and shall be of the quality, diameter or section, and length as specified or as shown in the Contract. Treated posts shall be fabricated or framed before treatment, and shall conform to the requirements of AASHTO M 133.

(b) Steel posts shall be of the section and length as specified or as shown in the Contract. Steel shall conform to the requirements of AASHTO M 183M/ M 183 for the grade specified.

The posts shall be galvanized or corrosion resistant as may be specified.

All corrosion resistant material shall conform to the requirements of AASHTO M 222M/ M 222.

(c) Concrete deadmen for end anchorages shall be as specified or as shown in the Contract.

710.09 Guardrail Hardware. Splices, end connections, end anchor rods, and accessories shall be as specified or as shown in the Contract.

Bolts, nuts, and washers shall be galvanized in accordance with AASHTO M 232, Class C, or AASHTO M 298, Class 50, Type 1. All other fittings shall be galvanized in accordance with AASHTO M 111. Bolts, nuts, and washers for corrosion resistant guard rail shall be of corrosion resistant material and conform to or exceed the requirements of ASTM A 307.

Where high strength bolts are required, they shall conform to the requirements of ASTM A 325.

SECTION 711
CONCRETE CURING MATERIALS AND ADMIXTURES

711.01 Curing Materials. Curing materials shall conform to the following requirements:

Burlap Cloth made from Jute or Kenaf	AASHTO M 182
Liquid Membrane-Forming Compounds for Curing Concrete	AASHTO M 148
Sheet Materials for Curing Concrete	AASHTO M 171

Straw used for curing shall consist of threshed straw of oats, barley, wheat, or rye. Clean field or marsh hay may be substituted for straw when approved by the Engineer. Old dry straw or hay which breaks readily in the spreading process will not be accepted.

711.02 Air-Entraining Admixtures. Air-entraining admixtures shall conform to the requirements of AASHTO M 154.

Admixtures which have been frozen will be rejected in accordance with subsections 106.05 and 106.06.

711.03 Chemical Admixtures. Chemical admixtures for concrete shall conform to the requirements of AASHTO M 194.

Admixtures which have been frozen will be rejected.

SECTION 712
MISCELLANEOUS

712.01 Water. Water used in mixing or curing shall be reasonably clean and free of oil, salt, acid, alkali, sugar, vegetable, or other substance injurious to the finished product. Water will be tested in accordance with, and shall meet the suggested requirements of AASHTO T 26. Water known to be of potable quality may be used without test. Where the source of water is relatively shallow, the intake shall be so enclosed as to exclude silt, mud, grass, or other foreign materials.

712.02 Calcium Chloride. Calcium chloride shall conform to the requirements of AASHTO M 144.

712.03 Hydrated Lime. Hydrated lime for aggregate pretreatment shall conform to the requirements of ASTM C 207, Type N. In addition, the residue retained on a 75 µm (No. 200) sieve shall not exceed 10% when determined in accordance with ASTM C 110. (Drying of the residue in an atmosphere free from carbon dioxide will not be required.)

712.04 (unused)

712.05 Precast Concrete Units. Precast concrete manhole base sections, riser sections, and grade rings shall conform to ASTM C 478M (C 478). All other precast units shall be cast in substantial forms. Structural concrete used shall attain a minimum 28-day compressive strength of 21 MPa (3000 psi) as determined in accordance with AASHTO T 22. When air-entrained concrete is specified, it shall have an air content of 5 to 8 percent by volume. The precast units shall be cured in accordance with AASHTO M 170M (M 170). Additional reinforcement shall be provided as necessary to provide for handling of the precast units.

A sufficient number of cylinders shall be cast and field cured from each batch, or truck-mixer load, of concrete to permit

compression tests at 7, 14, and 28 days, and to allow for at least two cylinders for each test. When the strength requirement is met the units will be certified for use.

Cracks in units, honeycombed or patched areas in excess of 190 cm^2 (30 square inches), excessive water absorption, or failure to meet strength requirements will be cause for rejection.

712.06 Frames, Grates, Covers, and Steps. Metal units shall conform to the plan dimensions and to the following specification requirements for the designated materials.

Gray iron castings shall conform to the requirements of AASHTO M 105, Class 30.
Carbon-steel castings shall conform to the requirements of AASHTO M 103/ M 103M, grade 415-205, Class 2.

Ductile iron castings shall conform to the requirements of ASTM A 536. Grade shall be optional unless otherwise designated. Structural steel shall conform to the requirements of AASHTO M 183M/ M 183.

Malleable iron castings shall conform to the requirements of ASTM A 47M (A 47). Grade shall be optional unless otherwise designated.

Steps shall conform to the requirements of AASHTO M 199M (M 199).

Galvanizing, where specified for these units shall conform to the requirements of AASHTO M 111.

712.07 (unused)

712.08 Geosynthetics. Geosynthetic rolls shall be furnished with suitable wrapping to protect against moisture and extended ultraviolet exposure prior to placement. Each roll

shall be labeled to provide product identification sufficient for inventory and quality control purposes. Rolls shall be stored in a manner which protects them from the elements. If stored outdoors, they shall be elevated and protected with a waterproof cover. The Contractor shall furnish to the Engineer a certified test report from the producer, containing all data required to verify compliance with the specifications listed in the appropriate table.

Securing pins shall be made from galvanized steel wire or other approved wire material, 2.3 mm (0.091 inch) or larger in diameter. They shall be U-shaped, with legs 150 mm (6 inches) long and a 25 mm (1 inch) crown.

Physical requirements of geosynthetics for various applications are given in Tables 712-1 through 712-8. Unless otherwise stated, all property values represent minimum average roll values (MARV) in the weakest principle direction (i.e., average test results from any sampled roll in a lot sampled for conformance or quality assurance testing shall meet or exceed the minimum values in the Tables). Stated values are for non-critical, non-severe conditions. Lots shall be sampled in accordance with ASTM D 4354.

(a) *Geomembrane.* Geomembrane shall be manufactured for stopping seepage loss. The lining shall consist of virgin polyvinyl chloride (PVC) resins, plasticizers, stabilizers, and such materials that, when compounded, will meet the physical requirements for the thickness specified as listed in Table 712-1.

Individual widths of PVC materials shall be fabricated into large sections by dielectric sealing into a single piece, or into a minimum number of panels, up to 30 m (100 feet) wide, as required to fit the facility. Lap joints with a minimum joint width of 13 mm (½ inch) shall be used. After fabrication, the lining shall be accordion folded in both directions and packaged for minimum

handling in the field. Shipping boxes shall be substantial enough to prevent damage to contents.

TABLE 712-1
Physical Requirements for Geomembrane

Property	Thickness 0.25 mm (10 mil)	Thickness 0.51 mm (20 mil)	Thickness 0.76 mm (30 mil)	Test Method
Thickness, % Tolerance	±7	±5	±5	ASTM D 1593
Tensile Strength, kN/m (lbs/in.) width	3.50 (20)	8.75 (50)	12.25 (70)	ASTM D 882, Method B
Modulus @ 100% Elongation, kN/m (lbs/in.)	1.58 (9)	3.50 (20)	5.25 (30)	ASTM D 882, Method B
Ultimate Elongation, %	350	350	350	ASTM D 882, Method A
Tear Resistance: N (lbs)	18 (3.2)	29 (6.5)	38 (8.5)	ASTM D 1004
Low Temperature Impact, °C (°F)	-23 (-13)	-26 (-15)	-29 (-20)	ASTM D 1790
Water Extraction, % max.	0.15	0.15	0.15	ASTM D 3083
Volatile loss, % max.	1.5	0.9	0.7	ASTM D 1203, Method A
Pinholes, No. /8 m^2 (No. Per 10 sq. Yds.) max.	1	1	1	
Bonded Seam Strength, % of tensile strength	80	80	80	
Resistance to Soil Burial				
% Change Maximum from Original Value)				ASTM D 3083
(1) Tensile Strength	±5.0	±5.0	±5.0	
(2) Elongation @ Break	±20.0	±20.0	±20.0	
(3) 100% Modulus	±20.0	±20.0	±20.0	

(b) *Geotextiles for Erosion Control, Drainage, and Silt Fence.*Fibers used in the manufacture of geotextiles, and the threads used in joining geotextiles by sewing, shall consist of long chain synthetic polymers composed of at least 95% by weight polyolefins, polyesters, or polyamides. They shall be formed into a network such that the filaments or yarns retain dimensional stability relative to each other, including selvedges.

Geotextiles for erosion control shall conform to the physical requirements of Table 712-2 for the appropriate class.

Geotextiles for drainage applications shall be nonwoven and shall conform to the physical requirements of Table 712-3.

Geotextiles for silt fence applications shall conform to the physical requirements of Table 712-4.

TABLE 712-2
Physical Requirements for Erosion Control Geotextiles

Property	Class A[1]	Class B[2]	Test Method
Grab Strength, N (lbs)	900 (200)	400 (90)	ASTM D 4632
Elongation, % min.	15	15	ASTM D 4632
Seam Strength, N (lbs)[3]	800 (180)	360 (80)	ASTM D 4632
Puncture Strength, N (lbs)	360 (80)	180 (40)	ASTM D 4833
Trapezoid Tear, N (lbs)	225 (50)	135 (30)	ASTM D 4533
Apparent Opening Size (AOS) US Std Sieve	AOS less than 0.297 mm (greater than No. 50 sieve)		CW 002215 ASTM D 4751
Permeability, cm/s[4]	k fabric >k soil for all classes		ASTM D 4491
Ultraviolet Degradation at 500 hours	50% strength retained for all classes		ASTM D 4355

[1] Class A erosion control geotextiles are used where installation stresses are more severe than for Class B applications.

[2] Class B erosion control geotextiles are used in structures or under conditions where the fabric is protected by a sand cushion or by “zero drop height” placement of stone. Stone placement depth should be less than 900 mm (3 feet) and stone weights should not exceed 115 kilograms (250 lbs).

[3] Values apply to both field and manufactured seams, if required.

[4] A nominal coefficient of permeability may be determined by multiplying permittivity value by nominal thickness. The k value of the fabric should be greater than the k value of the soil.

TABLE 712-3
Physical Requirements for Drainage Geotextiles

Property	Class A[1]	Class B[2]	Test Method
Grab Strength, N (lbs)	800(180)	360 (80)	ASTM D 4632
Seam Strength, N (lbs)[3]	710(160)	310(70)	ASTM D 4632
Puncture Strength, N (lbs)	360 (80)	110(25)	ASTM D 4833
Trapezoid Tear, N (lbs)	225 (50)	110(25)	ASTM D 4533
Apparent Opening Size (AOS) US Std Sieve	AOS less than 0.297 mm (greater than No. 50 sieve)		ASTM D 4651
Permeability, cm/s[4]	k fabric >k soil for all classes		ASTM D 4491
Ultraviolet Degradation at 500 hours	50% strength retained for all classes		ASTM D 4355

[1] Class A drainage geotextiles are used where installation stresses are more severe than for Class B applications, i.e. very coarse sharp angular aggregate is used, a heavy degree of compaction (95% AASHTO T 99) is specified or depth of trench is greater than 3 meters (10 feet).

[2] Class B drainage geotextiles are used with smooth graded surface having no sharp angular projections and sharp angular aggregate is not used; compaction requirements are light (>95% AASHTO T 99), and trenches are less than 3 meters (10 feet) in depth.

[3] Values apply to both field and manufactured seams, if required.

[4] A nominal coefficient of permeability may be determined by multiplying permittivity value by nominal thickness. The k value of the fabric should be greater than the k value of the soil.

TABLE 712-4
Physical Requirements are Temporary Silt Fence Geotextiles

Property	Wire Fence Supported Require-ments	Self Supported Require-ments	Test Method
Tensile strength, N (lbs)	400 (90) minimum	400 (90) minimum	ASTM D 4632
Elongation at 50% minimum tensile strength	N/A	50 maximum	ASTM D 4632
Permittivity[1] s-1	0.01 minimum	0.01 minimum	ASTM D 4491
Apparent Opening Size (AOS), mm[1]	0.84 maximum	0.84 maximum	ASTM D 4751
Ultraviolet Degradation at 500 hours	minimum 70% Strength Retained	minimum 70% Strength Retained	ASTM D 4355

[1] Permittivity and AOS do not relate directly to filtration performance of silt fence fabrics. Values presented reflect minimum criteria of products currently used. Performance tests such as VTM-51 (from Virginia Highway Research Council) may be used to evaluate silt fence performance if deemed necessary by the engineer.

Since the permeability coefficient of the soil will be unknown in most non-critical, non-severe applications for erosion control and drainage, the soil-permeability coefficients listed in Table 712-5 may be used as a guide for Comparing the permeability coefficient of the fabric with that of the in-place soil.

TABLE 712-5
Typical Values of Permeability Coefficients[1]

Turbulent Flow	Particle Size Range Millimeters(inches)		Effective Size	Permeability Coefficient-k cm/s
	D max	D min	D 20 mm (inches)	
Derrick STONE	3000(120)	900 (36)	1200(48)	100
One-man STONE	300 (12)	100 (4)	150 (6)	30
Clean, fine to coarse GRAVEL	80 (3)	10 (¼)	13 (½)	10
Fine, uniform GRAVEL	8 (3/8)	1.5 ($^1/_{16}$)	3 (1/8)	5
Very coarse, clean,uniform SAND	3 (1/8)	0.8 ($^1/_{32}$)	1.5 ($^1/_{16}$)	3

TABLE 712-5 (continued)
Typical Values of Permeability Coefficients[1]

Laminar Flow	Particle Size Range Millimeters(inches)		Effective Size	Permeability Coefficient-k cm/s
	D max	D min	D 10 mm	
Uniform, coarse SAND	2 (1/8)	0.5 ($^1/_{64}$)	0.6	0.4
Uniform, medium SAND	0.5	0.25	0.3	0.1
Clean, well-graded SAND & GRAVEL	10	0.05	0.1	0.01
Uniform, fine SAND	0.25	0.05	0.06	40×10^{-4}
Well-graded, silty SAND & GRAVEL	5	0.01	0.02	4×10^{-4}
Silty SAND	2	0.005	0.01	1.0×10^{-4}
Uniform SILT	0.05	0.005	0.006	0.5×10^{-4}
Sandy CLAY	1.0	0.001	0.002	0.05×10^{-4}
Silty CLAY	0.05	0.001	0.0015	0.01×10^{-4}
CLAY (30% to 50% clay sizes)	0.05	0.0005	0.0008	0.001×10^{-4}
Colloidal CLAY (-2 m 50%)	0.01	10	40	10^{-9}

[1] Basic Soils Engineering, R.K. Hough, 2nd Edition, Ronald Pess Co.; 1969, Page 76.

(c) *Paving Geotextile.* The paving geotextile shall be constructed of nonwoven synthetic fibers; resistant to chemical attack, mildew, and rot; and shall conform to the physical requirements of Table 712-6.

TABLE 712-6
Physical Requirements for Paving Geotextiles

Property	Requirements	Test Method
Tensile Strength, N (lbs)	450 (100)	ASTM D 4632
Mass per Area, g/m^2 (oz/yd^2)	140 (4)	ASTM D 3776
Elongation-at-Break, %, min.	50	ASTM D 4632
Asphalt Retention, L/m^2 (gal./sq yd.)	0.9 (0.2)	Texas DOT Item 3099
Melting Point, °C (°F)	149 (300)	ASTM D 276

(d) *Weed Barrier Geotextile.* Geotextile for weed barrier shall be a nonwoven, spunbound polypropylene polyester or polyolefin extruded in such a manner as to form a mat and shall conform to the physical requirements of Table 712-7.

TABLE 712-7
Physical Requirements for Weed Barrier

Property	Requirements	Test Method
Grab Strength, N (lbs)	310 (70)	ASTM D 4632
Puncture Strength, N (lbs)	135 (30)	ASTM D 4833
Trapezoid Tear, N (lbs)	110 (25)	ASTM D 4533
Water Flow Rate, L/s/m^2 (gal/sq yd/min)	110 (160)	ASTM D 4491
Ultraviolet Degradation at 150 hours	45% strength retained	ASTM D 4355

(e) *Separator Geotextile.* Geotextile separator material shall consist of permeable sheets of polymeric yarn or fiber oriented into a woven or non-woven stable network which retains its relative structure during handling, placement and long-term service. The geotextile shall meet or exceed the properties shown in Table 712-8.

TABLE 712-8
Physical Requirements for Separator[1]

Property	Class A		Class B		Test Method
	Elongation < 50%[2]	Elongation > 50%[2]	Elongation < 50%[2]	Elongation > 50%[2]	
Grab Strength, N (lbs)	1200 (270)	800 (180)	800 (180)	510 (115)	ASTM D 4632
Puncture Resistance,N (lbs)	445 (100)	310 (70)	310 (70)	180 (40)	ASTM D 4833
Trapezoidal Tear Strength, N (lbs)	445 (100)	335 (75)	310 (70)	180 (40)	ASTM D 4533
Apparent Opening Size, mm (US Sieve Size)	AOS < 0.3 mm (US Sieve Size No. 50)				ASTM D 4751
Permittivity, sec^{-1}	0.02 default value, must also be greater than that of soil				ASTM D 4491
Permeability, cm/sec	k fabric > k soil for all classes				ASTM D 4491
Ultraviolet Degradation at 500 hours	50% strength retained for all classes				ASTM D 4355

1 Strength values are in the weaker principle direction
2 As measured in accordance with ASTM D 4632

712.09 Gabions and Slope Mattresses. All wire used in the manufacture and assembly of the mesh shall conform to Federal Specification QQ-W-461H, finish 5, class 3.

Wire mesh for Gabions (cage thickness 300 mm [12"] and greater) shall be 11 gage (U.S.) (3.05 mm), soft temper.

Wire mesh for Slope Mattress (cage thickness up to 250 mm [10"]) shall be 14 gage (U.S.) (2.03 mm), soft temper.

Samples for testing shall include at least one sample of each component of the mesh.

Tie and connecting wire shall be supplied for securely fastening all edges of the gabions and diaphragms. Gabions shall be provided with 4 cross connecting wires in each cell ½ unit high and 8 in each cell one unit high. Gabions shall also have inner tie wires connecting the front face to the rear face at approximate spacing of 300 mm (12") in both vertical and horizontal dimensions. Tie wire shall meet the same specifications for wire used in the mesh except that tie wire for gabion cages shall not be more than 2 gages lighter.

All wire used, including tie and connecting wire, shall be certified by mill test reports showing compliance with specification requirements.

Mesh Openings - The longer dimension of the mesh openings for gabions and slope mattresses shall be as shown on the plans.

Wire Mesh - Wire mesh shall be woven in such a manner as to be non-raveling and have elasticity. Tests for compliance with these and the following properties shall be performed by the Contractor. A certified test report, showing these required results and information shall be supplied with each project. Tests are to be run on cages of the same specification, made within a year prior to the date of letting.

Non-raveling - The mesh for both gabions and slope mattresses shall show no raveling beyond the mesh opening in which the break occurred when the loading is continued after the first break in the test conducted with the pull parallel to the axis of the wire twist.

Elasticity - For gabions, when pulled parallel to the axis of the wire twist and deformation is controlled by spreader bars, no wire shall break until the mesh has been stretched ,at least 4.5%. The pull test shall be performed both parallel and perpendicular to the axis of the wire twist and in either case, the first wire break shall not occur until the loading on the table below has been reached.

Edge Wire Connection - The edge wire connection for both gabions and slope mattresses shall be strong enough so that when tested the first wire break shall occur in the wire mesh.

Selvedge - The selvedge on each sheet of mesh for both gabions and slope mattresses shall be galvanized steel wire (as described above) 2 gages heavier than that used in the body of the mesh. For gabions, it shall be attached to the wire mesh strong enough so that when tested, no wire shall break until the loading on the table below has been reached. For slope mattresses, the first wire break shall be in the wire mesh.

Field Connections - The field connections between adjacent wire baskets shall be made as recommended by the manufacturer and shall develop a connection strong enough that the failure under test shall occur in the mesh rather than in the lacing.

TABLE FOR MINIMUM STRENGTH TESTS FOR GABION BASKETS ONLY

Part	Minimum Strength kN/m (lbs/foot)
Wire Mesh	
Pulled parallel to wire twist	50 (3400)
Pulled perpendicular to wire twist	15 (1000)
Connection of Selvedge wire to mesh	32 (2200)

Dimensions - Gabions and slope mattresses shall be supplied in the various sizes shown on the plans. Cages and mattresses furnished by a manufacturer shall be of uniform size.

Tolerances - All gabion and slope mattress dimensions are subject to a tolerance limit of ± 3% of manufacturer's stated sizes.

Riprap - Riprap shall consist of hard, dense, sound, rough fractured stone or local sandstone, as nearly cubical as practicable. Thin slab type stones and flaking rock shall not be used.

Stone shall have a specific gravity of at least 2.25 and shall be resistant to the action of air and water. Flaking or fragmental rock will not be permitted.

The sizes of riprap stone for gabions and slope mattresses shall conform to the following:

	Stone Size
Gabions (cage thickness 300 mm [12"] or greater)	100 to 200 mm (4 to 8")
Slope Mattress	50 to 100 mm (2 to 4")

Soil Anchor Stakes for Wire Mesh Slope Mattresses:
Soil anchor stakes shall be steel and may be:

(1) Crane rails of a convenient size, min. 20 kg/m (40 pounds per yard).
(2) Size DN 50 (2") steel pipe conforming to ASTM A 53 either black or galvanized.
(3) Size 76 x 76 x 9.5 mm (3"x3"x 3/8") structural steel angles conforming to ASTM A 36/ A 36M or better.
(4) Used rails, pipe or angles may be used provided the material is not rusted or damaged to such an extent that the strength of the stakes is affected.

Soil anchor stakes shall be of the lengths called for on the plans.

712.10 Epoxy. Epoxy used for bonding new, or wet concrete, to old concrete shall be an approved product and shall be of the type specifically intended for bonding wet concrete to existing concrete. Each container of epoxy shall conform to ASTM C 881.

712.11 Plastic Pipe for Underdrains. Polyethylene perforated or nonperforated corrugated pipe shall conform to AASHTO M 252.

Perforated or nonperforated Polyvinyl Chloride Pipe-Smooth Interior, Smooth or Ribbed Exterior, shall conform to ASTM F 758 or ASTM F 949.

712.12 Geocomposite Drains. Geocomposite drains, underdrains, and edge drains for subsurface drainage shall be constructed of a drainage geotextile and a semi-rigid drainage core. A drainage pipe collector may also be included in the drain system.

The drainage geotextile shall conform to the physical requirements of subsection 712.08, Table 712-3, for the Geotextile (Drainage) (Class B). The drainage pipe collector, when used,

shall conform to the requirements designated in subsection 605.02 for the type of pipe used.

The semi-rigid drainage core shall be constructed of material that will not deteriorate in subsurface conditions, and shall conform to the physical requirements of Table 712-8.

TABLE 712-8
Physical Requirements for Drainage Core

Property	Value	Test Method
Compressive Strength, kPa (lbs/sq. in.)	140 (20)	ASTM D 1621
In-Plane Flow Capacity L/s/m (gal/min/ft), minimum	2.12 (10)	ASTM D 4716
Minimum Core Thickness, mm (inch)	6 (0.25)	

712.13 Plastic Pipe. Plastic pipe shall conform to the following requirements for the type of pipe used:

Ribbed Type: AASHTO Interim Specifications Bridges, Section 18, Soil Thermoplastic Pipe Interaction systems; material specifications are ASTM F 894 for polyethylene, and ASTM F 794 for poly (vinyl) chloride.

Corrugated Type: AASHTO M 294.
Smooth Type: ASTM F 679.
Couplings shall be as recommended by the pipe manufacturer.

SECTION 713
TRAFFIC CONTROL MATERIALS

713.01 Signs-General. Aluminum or steel used for traffic control shall conform to Table 713-1.

TABLE 713-1

APPLICATION	Aluminum		Steel
	ASTM designation	ALLOY No. Temper	ASTM designation
Sign panels	B 209M (B 209)	6061-T6 5052-H36 5052-H38	*A 446M Grade A
Traffic controller cabinets	B 209M (B 209)	6061-T6	A 36M (A 36)
Clip bolts	B 211M (B 211)	2024-T4	
Locknuts or steel nuts and bolts	B 211M (B 211)	2017-T4	*A 307
Clips and backing angles	B 221M (B 221)	6061-T6	

* Steel sheets shall have a Z600 zinc coating in accordance with ASTM A 653/ A 653M and a light phosphate coating. Phosphate coating of 1000 mg/m^2 (3.5 oz./sq.ft.) will be required for application with retroreflective sheeting. Nuts and bolts shall be galvanized or cadmium plated.

713.02 Aluminum Sign Panel Tolerances. Aluminum sign panel sheet dimensional tolerances shall conform to the applicable requirements of the American National Standards Institute Dimensional Tolerances for Aluminum Products,

ANSI-H35.2(M), with the following exceptions:
The flatness tolerances shall be one-half the values listed in Table 3.12, and shall apply to all aluminum alloy grades permitted for sign panels.

Sign blanks are to be tensile leveled for sheet thickness less than 2.5 mm (0.09"), and stretcher leveled for thickness equal to or greater than 2.5 mm (0.09").

The individual sign blank bow tolerance (deviation of a side edge from a straight line) shall not exceed 1 mm (1/32"), and the dimensions of the opposing sides shall be within 2 mm (1/16").

Aluminum sign panel shall be subject to the requirements of the first paragraph of subsection 713.09.

713.03 (unused)

713.04 Sign Panel Backgrounds. Retroreflective sheeting background material used shall be of the type as specified on the plans and shall conform to the requirements specified in subsection 713.10.

All retroreflective sheeting shall be sealed at the seams and edges as recommended by the manufacturer.

The aluminum sign blanks shall receive a chemical treatment conforming to ASTM B 449, Class 2 prior to placement of any retroreflective sheeting.

713.05 Hardware. All hardware shall be compatible with sign material and shall not cause any discoloration due to weather.

713.06 Messages. Letter design shall be in accordance with the following:

Letter design for commercial legend shall be Series “E” for capitals, and Series “E Modified” for upper and lower case letters and numbers. The “E Modified” legend shall have an increased stroke width of 20 percent of the required legend height. The Inter-letter spacing shall be “Colorado Improved” in accordance with the Colorado Supplement to the Standard Highway Signs.

Silk screen process figures shall be in accordance with the plans and series figures described in the current editions of “Standard Alphabets for Highway Signs” and “Standard Highway Signs”, published by the FHWA, and the “Colorado Supplement to Standard Highway Signs”.

For overhead signs, the legend and borders shall be VIP sheeting or equivalent. The background retroreflective sheeting shall be Type III.

713.07 Reflectors. Reflectors shall consist of a clear and transparent acrylic plastic prismatic reflex lens with a smooth front face, except for the legibly molded manufacturer’s trademark, and a back hermetically sealed surface with prismatic configuration effecting total internal reflection of light. Firmly fused to the back surface shall be a backing material. The backing material shall be white opaque plastic of the same type as the lens and delineator reflectors may be backed with a plastic coated metallic foil. Delineator reflectors shall be housed in embossed aluminum and provided with a single grommetted mounting hole. The delineator unit shall withstand the combined corrosion test described in ASTM B 117.

713.08 Glass Beads for Traffic Markings. Glass beads for Traffic Paint shall conform to AASHTO M 247, Type 1 or Type 2, non-flotation grade.

Glass beads for Thermoplastic Pavement Marking shall conform to AASHTO M 247, Type 1.

Glass beads for epoxy pavement marking shall conform to AASHTO M 247, Type 1. The beads shall be silicon treated to meet the requirements of section 4.4.2 of AASHTO M 247.

Glass beads shall be furnished in fully identified containers and shall be free of extraneous material or clumps.

Glass beads for methyl methacrylate pavement marking shall conform to AASHTO M 247, type 1 non-floatation and shall be applied by the first bead applicator. Glass beads applied by the second bead applicator shall be AASHTO M 247, type 1 silane coated (AC-02) flotation beads.

713.09 Sampling and Inspection. The Engineer shall be notified well in advance of beginning of shop work so that adequate arrangements may be made for sampling and inspection. Shop inspection may be waived and complete inspection made when the fabricated sign panels are delivered to the site of the work.

The following samples shall be submitted to the Engineer for approval:

(1) A 300 mm x 300 mm (12"x12") sample of finished material for figure frames.
(2) A 300 mm x 300 mm (12"x12") sample of retroreflective sheeting representing each lot used on the project.
(3) Two reflectors for each 100, or part thereof, of each size and color, with a limit of 53 samples for any one size or color. When retroreflective buttons are so affixed to the cutout frames that their removal for testing will cause breakage, it shall be the responsibility of the sign fabricator to furnish a representative sample of retroreflective buttons.
(4) 1 kg (2 pounds) of glass beads, representing each lot used on the project.
(5) 500 ml (1 pint) of paint of each color, representing each lot used on the project.

(6) 500 g (1 pound) of thermoplastic marking material and one liter of each primer component.
(7) 1 m (36" strip) of preformed plastic pavement marking.
(8) 1 m (36" strip) of pavement marking tape.
(9) 0.1 m^2 (one square foot) of preformed thermoplastic pavement marking material.

713.10 Quality Requirements of Reflective Materials. Reflective devices and retroreflective sheeting shall be materials which have been prequalified by the Department.

(a) *Reflective Devices.*

1. *Reflective Quality Requirements.*

A. *Delineator and Median Barrier Reflectors.* The specific intensity of each delineator and median barrier reflector shall be at least equal to the following minimum values when tested in accordance with AASHTO T 257, with an observation angle of 0.1 degrees.

Entrance Angle Degrees	Specific Intensity Candela per Lux (Candlepower per Foot-Candle)			
	Crystal	Yellow	Red	Green
0	10 (110)	4.6 (50)	3.1 (33)	2.0 (22)
20	5.6 (60)	2.8 (30)	1.7 (18)	1.1 (12)

B. *Cut-out Figure Reflectors.* The specific brightness of crystal reflectors used in cut-out figures shall be at least equal to the following minimum values.

Observation Angle Degrees	Entrance Angle Degrees	Specific Brightness Candela per Square Meter per Lux (Candlepower per Sq. In. per Foot-Candle)
0.1	0	2000 (14.0)
0.1	20	800 (5.6)

2. *Material and Component Requirements.* Plastic for delineator and cutout figure reflectors shall be poly methyl methacrylate conforming to requirements of ASTM D 788, Grade 8. The reflectors shall meet test requirements of Colorado Procedure L-2115, Sec. 3.2 and 3.3.

(b) *Retroreflective Sheeting.* Retroreflective sheeting for traffic control devices shall conform to the requirements of ASTM D 4956.

713.11 Traffic Signals. Electrical conduit, pull boxes and junction boxes shall conform to the requirements of Section 613 and subsection 715.06, and to the details shown on the plans.

Conductors shall be nineteen strand or seven stranded, tinned copper wire, rated at 600 volts and individually insulated with heat stabilized polyethylene. Conductors and cables shall be copper and conform to Specification 19-1 of the IMSA.

Direct-burial cable shall be copper and conform to Specification 19-5 of the IMSA except that conductors shall be seven, wire, stranded.

Pull rope shall be 3-mm (1/8 inch) nylon.

Messenger cable (span wire) shall be 9.5-mm (3/8 inch)

diameter (minimum), seven wire stranded, common galvanized, utilities grade, rated at 51.2 kN (11,500 pounds), in accordance with ASTM A 475.

Grounding and bonding wires, straps and electrodes shall be copper and conform to NEC Article 250.

Adjustable face vehicle traffic control signal heads and associated equipment shall conform to the general specifications and definitions contained in the latest issue of Technical Report No. 1, prepared by the ITE, and as shown on the plans.

Adjustable face pedestrian signal heads and associated equipment shall conform to the general specifications and definitions contained in the latest issue of Technical Report No. 5, prepared by the Institute of Traffic Engineers, and as shown on the plans.

Traffic signal lamps shall conform to the general specifications and definitions contained in the latest issue of Technical Report No. 6, prepared by the Institute of Traffic Engineers. Lamps shall be rated for operation at 120 volts AC. Lamp wattages shall be 60-69 Watts for all 200 mm (8 inch) traffic signals, 150 Watts for all 300 mm (12 inch) traffic signals, 116 Watts for all 400 mm (16 inch) pedestrian signals, or as otherwise specified by the manufacturer.

LED Traffic Signal Section optical units shall meet or exceed ITE Adjustable Face Vehicular Traffic Control and Pedestrian Signal Head Standards. In addition to this, LED optical units shall conform to the following requirements:

Wattage

Max. 35 watts for 300 mm (12 inch) ball
Max. 30 watts for 200 mm (8 inch) ball
Max. 15 watts for 300 mm (12 inch) arrow
Max. 15 watts for PED hand symbol

Maximum total harmonic current distortion (THD) shall be < 20%.
Power factor shall be > 90%.

Note: THD and power factor requirements shall be waived for products designed to operate at less than 14 watts.

Voltage

Operating shall be between 85 and 130 VAC. Electronic circuitry shall assure proper operation of the load switch and monitor in the control cabinet.

Circuit Configuration

The LEDs shall be connected to form multiple series circuits. All series circuits shall be interconnected at intervals, forming subcircuits not exceeding 15 LEDs for the ball and arrow signals, and 10 LEDS for the pedestrian hand symbol. In the event of an LED failure, these subcircuits shall limit the number of extinguished LEDs to no more than 4% of the total on the ball and pedestrian hand signal lamps, and 6% of the total on the arrow lamp.

Enclosure

Shall be dust and water resistant

Operating Temperature

Between -40 ºC (-40 º F) and 85 ºC (+185 º F)

Lens

Shall be replaceable, polycarbonate (UV stabilized "Lexan") convex lens; meet ITE color standards; minimum of 3 mm (1/8 inch) thickness; and minimum light transmittance of 92%, free from bubbles, flaws and other imperfections. Non-polycarbonate tinted lenses will be accepted provided that these meet ITE color stan-

dards. Chromacity shall be measured uniform across the face of the lens. Non-polycarbonate lenses shall also meet 1 m (3-1/2 foot) drop tests.

Candlepower Distribution

Shall meet minimum ITE specifications. Intensity shall be measured uniform across the face of the lens. Brightness shall be maintained in the event of voltage fluctuations or voltage drops.

Beam Spread

30 degrees to each side.

Manufacturer's Warranty

Repair or replacement guarantee of five years covering all but accidental damage.

Foundations for poles, pedestals, posts, and cabinets shall conform to the requirements of Section 601.

Bonding and grounding jumpers shall be copper wire or copper strap of the same cross sectional area; the wire size shall be No. 10 AWG for all systems except the ground terminal of controllers, which shall be No. 8 AWG.

All exterior parts of the signal heads requiring paint shall be painted Federal Yellow 595B No. 13538 unless otherwise specified.

Traffic signal faces, which are rigidly supported on the top and bottom, may be of an approved polycarbonate type unless otherwise shown on the plans.

713.12 Thermoplastic Marking Material. Thermoplastic marking material shall conform to AASHTO M 249 except for the following:

(1) In paragraph 3.1.2 of the AASHTO specifications, delete the first two sentences and replace with the following: The material manufacturer shall have the option of formulating the material according to its own specifications. However, the binder shall be composed of alkyd resins wherein a minimum of 70 percent (by weight) of the binder shall be maleic modified glycerol ester of rosin. The physical and chemical properties contained in this specification shall apply regardless of the type of formulation used.

(2) In paragraph 4.3 of the AASHTO specifications, add the following physical characteristics: The infra-red spectra of the extracted binder will be compared to the characteristic absorption bands of maleic modified glycerol ester of rosin.

(3) In paragraph 6.1 of the AASHTO specifications, delete the second sentence and replace with the following: The containers of thermoplastic material shall weigh approximately 23 kg (50 pounds).

713.13 Preformed Plastic Material. Preformed plastic pavement marking material shall conform to ASTM D 4505, Type I, Class B, C, D or E, and shall have a minimum thickness of 1.5 mm (60 mils).

713.14 Preformed Thermoplastic Material.

(a) *General.* Preformed Thermoplastic markings shall be composed of aggregates, pigments, binders and glass beads, and shall conform to AASHTO designation M 249 with the exception of the relevant differences due to the fact that the material is supplied in a preformed state. The material shall be either alkyd, hydrocarbon, or ester modified resin

based. Only preformed thermoplastic pavement marking material listed on the Department's approved products list may be used.

(b) *Physical Requirements.*

1. *Graded Glass Beads.* The material shall contain a minimum of 30 percent graded glass beads by weight. The beads shall be clear and transparent. Twenty percent or less shall consist of irregular, fused spheroids, or silica. The refractive index shall be at least 1.50.

2. *Pigments.* White - Sufficient titanium dioxide pigment shall be used to insure a color similar to Federal Highway White, Color Number 17886, conforming to Federal Standard 595. Yellow - Sufficient yellow pigment shall be used to insure a color similar to Federal Highway Yellow, Color Number 13655, conforming to Federal Standard 595. The yellow pigment shall be organic and contain no lead chromate.

3. *Skid Resistance.* The surface of the preformed thermoplastic markings shall provide a minimum resistance value of 45 BPN when tested according to ASTM E 303.

4. *Thickness.* The material shall be supplied at a minimum thickness of 3.15 mm (125 mils).

5. *Environmental Resistance.* The preformed thermoplastic material shall be resistant to deterioration due to exposure to sunlight, water, oil, gasoline, salt and adverse weather conditions.

713.15 Pavement Marking Tape.

(a) *Description.* The marking tape shall consist of weather and traffic resistant yellow or white colored reflective material. The material shall consist of conformable (metal foil) backing with a pressure sensitive adhesive designed for adhesion to asphalt or concrete surfaces.

(b) *Requirements.*

1. *Color.* The color of the visible or outer surface shall closely match the white or yellow traffic marking paint specified for highway delineation. Glass beads shall be strongly adhered to the tape.

2. *Reflectance.* The white and yellow tapes shall have the following initial minimum reflectance values at 0.20° and 0.50° observation angles and 86.00° entrance angle as measured in accordance with the testing procedures of Federal Test Method Standard 370. The photometric quantity measured is specific luminance (SL), and is expressed as millicandelas per square meter per lux.

Color	White		Yellow	
Observation Angle	0.2°	0.5°	0.2°	0.5°
Specific Luminance	1360	760	820	510

3. *Adhesive.* The striping tape shall be supplied in rolls ready for application and have a precoated pressure sensitive adhesive which shall not have a protective liner nor require a solvent activator.

4. *Adhesion.* The material shall adhere to asphalt and concrete surfaces when applied at surface tempera

tures of 2 °C (35 °F) and above. Once applied, the tape shall adhere to the pavement at subfreezing temperatures.

5. *Conformability.* The material shall be thin, flexible, conformable, and show no cracking, flaking, or bead loss. Following application, the tape shall remain conformed to the texture of the pavement surface. The thickness of the material shall not be less than 430 micrometers (17 mils).

6. *Removability.* The tape shall be removable by following manufacturers' recommendations so long as the material is substantially intact. Removal shall not require sandblast, solvents, or grinding methods.

7. *Durability.* The striping material applied in accordance with manufacturers' recommended procedures shall be weather resistant and show no appreciable fading, lifting, or shrinkage during the useful life of the line.

8. *Packaging and Delivery.* The striping material as supplied shall be of good appearance and free from cracks. The edges shall be true, straight, and unbroken. The material shall be supplied in rolls with no more than one splice per 50 m (50 yards) of length.

The striping material shall be packaged in accordance with accepted commercial standards to prevent damage during shipment and storage. The tape as supplied shall be suitable for use for a period of at least one year following delivery when stored at temperatures of 38 °C (100 °F) or below.

713.16 Pavement Marking Tape (Removable). Pavement marking tape designated in the pay item as removable shall conform to ASTM D 4592, Type I, and shall be 100 ± 2 mm (4 ± 0.1 inches) wide.

713.17 Epoxy Pavement Marking Material. Only epoxy pavement marking material that has been preapproved by the CDOT Product Evaluation process may be used. Approved products will be accepted on the project by certificate of compliance (COC). The COC shall confirm that the material meets all CDOT requirements and is the same material that was preapproved in the product evaluation process. To determine whether an epoxy pavement marking material has been evaluated and preapproved call the Central Lab (757-9432).

(a) *Formulation.* Epoxy pavement marking material shall be a two component, 100 percent solids, material formulated to provide simple volumetric mixing ratio of two volumes of component A and one volume of component B unless otherwise recommended by the material manufacturer.

(b) *Composition.* The component A of both white and yellow shall be within the following limits:

	White:	Yellow:
Pigments	Min % by weight 18% Titanium Dioxide, (ASTM D 476, Type II)	% by weight 21-27%
Epoxy Resin	75-82%	73-79%

The pigment for yellow epoxy shall contain no lead or other material such that the cured epoxy could be considered a hazardous waste under EPA or CDPHE regulations. The Contractor shall submit to the Engineer

a manufacturer's certification of compliance with this requirement.

(c) *Epoxide Number.* The epoxy number of the epoxy resin shall be 0.38 ± .05 as determined by ASTM D 1652 for white and yellow component A on pigment free basis.

(d) *Amine Number.* The amine number on the curing agent (component B) shall be 410 ± 50 per ASTM D 2071.

(e) *Toxicity.* Upon heating to application temperature, the material shall not produce fumes which are toxic or injurious to persons or property.

(f) *Color and Weather Resistance.* The mixed epoxy compound, both white and yellow, when applied to 75 mm by 150 mm (3 inch x 6 inch) aluminum panels at 380 ± 10 micrometers (15 ±½ mils) of thickness with no glass beads and exposed in the Q.U.V. Environmental Testing Chamber as described in ASTM G 53, shall conform to the following minimum requirements. (The test shall be conducted for 75 hours at 50°C, 4 hours humidity, and 4 hours U.V., in alternating cycles. The prepared panels shall be cured at 25°C for 72 hours prior to exposure.) The color of the white epoxy system shall not be darker than Federal Standard No. 595B-17778. The color of the yellow epoxy system shall conform to Federal Standard No. 595B-13538. The gloss values of both samples shall not be less than 70° after the test.

(g) *Drying Time.* The epoxy pavement marking material shall have a setting time to a no-tracking condition of not more than 10 minutes at a temperature of 23 °C (73 °F) and above.

(h) *Curing.* The epoxy material shall be capable of fully curing under the constant surface temperature condition of -4 °C (25 °F) and above.

(i) *Adhesion to Concrete.* The catalyzed epoxy pavement marking material, when tested according to ACI Method 503, shall have such a high degree of adhesion to the specified (30 MPa [4000 psi] minimum) concrete surface that there shall be a 100 percent concrete failure in the performance of this test.

(j) *Hardness.* The epoxy pavement marking materials, when tested according to ASTM D 2240, shall have a Shore D Hardness between 75 and 100. Samples shall be allowed to cure at room temperature, 24 ± 1 °C (75 °F ± 2 °F) for a minimum of 12 hours and a maximum of 48 hours prior to performing the indicated test.

(k) *Abrasion Resistance.* The abrasion resistance shall be evaluated on Taber Abrader with a 1000 gram load and CS-17 wheels. The duration of the test shall be 1000 cycles. The wear index shall be calculated based on ASTM test method C-501 and the wear index for the catalyzed material shall not be more than 70. The tests shall be run on cured samples of material which have been applied at film thickness of 380 ± 10 micrometers (15 ± ½ mils) to code S-16 stainless steel plates. The samples shall be allowed to cure at 24 ± 1 °C (75 °F ± 2 °F) for a minimum of 48 hours prior to performing the indicated tests.

(l) *Tensile Strength.* When tested according to ASTM D 638, the epoxy pavement marking materials shall have a tensile strength of not less than 42 MPa (6000 psi). The Type IV Specimens shall be cast in a suitable mold and pulled at the rate of 6 mm (¼ inch) per minute by a suitable dynamic testing machine. The samples shall be allowed to cure at room temperature (24 ± 1 °C [75 °F ± 2 °F]) for a minimum of 12 hours and a maximum of 48 hours prior to performing the indicated tests.

(m) *Compressive Strength.* When tested according to ASTM D 695M (D 695), the catalyzed epoxy pavement marking materials shall have a compressive strength of not less than 83 MPa (12,000 psi). The cast sample shall be conditioned at room temperature, 24 ± 1 °C (75 °F ± 2 °F), for a minimum of 12 hours and a maximum of 48 hours prior to performing the tests. The rate of compression of these samples shall be no more than 6 mm (¼ inch) per minute.

713.18 Raised Pavement Marker. Raised pavement marker shall be not less than 90 mm (3.5 inches) nor more than 115 mm (4.5 inches) in the major dimension and not more than 19 mm (0.75 inch) in height. The marker shall contain a retroreflective element not less than 250 mm² (0.38 square inch) in area. The color of the marker and the retroreflective element shall match the color of the pavement marking line. The reflective quality requirements shall be at least equal to the following minimum values:

Observation Angle Degrees	Entrance Angle Degrees	Specific Intensity Candela per Lux	
		White	Yellow
0.1	0	0.09	0.06
0.1	20	0.04	0.02

The marker shall be ceramic or plastic and shall be secured to old or new pavement using an adhesive approved by the marker manufacturer.

713.19 Methyl Methacrylate Pavement Marking. The Methyl Methacrlyate material shall be preapproved by the Department.