

Chapter 15. STREET CONSTRUCTION STANDARDS

15.1 General

The purpose of this section is to set forth the criteria to be used in the construction of all streets and appurtenances within the City of Northglenn.

15.2 Compaction in Utility Trenches

Before street construction will be permitted, all utility trenches within the street Right of Way (including service lines) shall be compacted to ninety-five percent (95%) of maximum standard density at one percent (1%) (plus or minus) optimum moisture, as determined by ASTM D 698-78 or as specified in the approved soils report. This compaction shall extend to the street Right of Way lines as a minimum. Water settlement of trenches shall not be permitted. All water and sewer services, including water and sewer main stub-outs, shall be installed prior to street construction except that curb and gutter and sidewalk shall be installed prior to water service line installation.

15.3 Excavation & Embankment

15.3.1 General

The intent of this section is to specify methods and standards to be used in the construction of embankments or excavations for City streets or for other purposes, as indicated on the accepted drawings or contract documents. The work will include excavation, embankment, grading, compacting, clearing, and grubbing, removal of topsoil, trees, stumps or other vegetation, removal and/or resetting of minor obstructions, subgrade preparations and any other work incidental for the construction of excavations and embankments. All workmanship and materials shall be in accordance with the requirements of the CDOT Standard Specifications for Road and Bridge Construction (Latest Edition) and in conformity with the lines, grades, quantities, and the typical cross-section shown on the plans or as directed by the Engineering Division.

15.3.2 Salvage

All salvageable material shown on the plans shall be removed without unnecessary damage in sections or pieces which may be readily transported and shall be stored by the Contractor in locations approved by the Engineering Division.

The Contractor shall be required to replace any materials lost from improper storage methods or damaged by negligence.

15.3.3 Disposal

The Contractor shall make all necessary arrangements for obtaining suitable disposal locations and the cost involved shall be included in the work. If disposal will be at other than established dump sites, the Engineering Division may require the Contractor to furnish written permission from the property owner on whose property the materials will be placed.

15.3.4 Select Borrow Material

In the event the material found on site is unsatisfactory for constructing subgrade, embankments or filling excavations, the Contractor shall provide material from off-site. The selected borrow material shall be a well-graded mixture of sound mineral aggregate particles containing sufficient quality bonding material to secure a firm stable foundation when placed and compacted on the roadway. The R-value of the borrow material shall be equal to or greater than the design R-value required for the street. The R-value of the borrow shall be provided to the Engineering Division prior to placing borrow. If tests reveal that material being placed is not of suitable quality and structural value, the Contractor shall provide other material as approved by the Engineering Division.

15.4 Subgrade Preparation & Grading

15.4.1 General

The work covered by this section concerns the furnishing of all labor, equipment, supplies, and materials needed to perform preparation of subgrade within the public Right- Of-Way. The bottom of the excavation for the pavement, or top of the fill, will be known as the pavement subgrade and shall conform to the lines, grades, and cross-sections shown on the accepted plans. Prior to the street being excavated, all service cuts shall be checked to see if the backfill meets density requirements. If deficient, they shall be recompact and brought up to the density as specified in **Chapter 14- Trenching, Backfilling & Compacting – Utilities**.

15.4.2 Subgrade Stabilization

Embankment and subgrade soils shall be compacted to ninety-five percent (95%) of maximum standard density at plus or minus two percent (+2%) optimum moisture or as recommended in the approved soils report. Maximum density shall be determined by ASTM D 698-78. Soft and yielding material and other portions of the subgrade which will not compact when rolled or tamped shall be removed as directed by the Engineering Division and replaced with suitable material.

Subgrade surfaces below excavated areas such as cut areas and undisturbed areas shall require additional preparation. Said subgrade shall be scarified to a minimum depth of twelve inches (12"), wetted or aerated as needed and compacted until the required density is obtained, unless otherwise approved by the Engineering Division. No paving, subbase or base shall be placed on soft, spongy, or frozen unstable subgrade which is considered unsuitable by the Engineering Division.

The Contractor, when requested by the Engineering Division, shall furnish the necessary equipment to proof roll, even though density tests may indicate compliance. Heavy construction equipment or loaded trucks acceptable to the City shall be driven over the finished subgrade and deflections noted. Soft and yielding material and portions of the subgrade which show deflection shall be scarified and re-rolled or shall be removed and replaced with subgrade course material and then placed and compacted as specified herein. Subgrade shall not be approved for base course construction or paving until it is uniformly stable and unyielding.

15.4.3 Subgrade Surface Tolerance

The excavation and embankments for the street, intersections and driveways shall be finished to a reasonably smooth and uniform surface. Variations from the subgrade shall not be more than one-half inch (1/2") in solid nor more than one inch (1") above or six inches (6") below in rock.

15.5 Subbase Construction

15.5.1 General

The subbase shall consist of a foundation course composed of granular material constructed on the prepared subgrade in accordance with these STANDARDS AND SPECIFICATIONS and in reasonable conformity to the lines and grades and typical cross-sections as shown on the accepted plans.

15.5.2 Placement & Compaction

Each layer of subbase material shall be placed in layers not to exceed six inches (6") in compacted depth. Each layer shall be wetted or aerated, if necessary and compacted to ninety-five percent (95%) maximum density at plus or minus two percent (+2%) of optimum moisture as determined by ASTM D 698-78. No subbase material shall be placed upon a soft, spongy, or frozen subgrade or other subgrade, the stability of which is unsuitable for the placement thereof.

15.5.3 Subbase Surface Tolerance

The prepared surface of the subbase shall not vary from the approved grade by more than a half inch (1/2").

15.6 Base Construction

15.6.1 General

The intent of this section is to specify methods to be used for the construction, overlaying, sealcoating and pavement rejuvenating of streets, parking lots, walks, drainageways and other miscellaneous work requiring the use of aggregates. The work covered shall include general requirements that are applicable to aggregate base course, bituminous base and pavements of the plant-mix type, bituminous prime coat, bituminous tack coat, rejuvenating applications and asphalt concrete overlay. All workmanship and material shall be in accordance with requirements of these STANDARDS AND SPECIFICATIONS and in conformity with the lines, grades, depths, quantity requirements and the typical cross-section shown on the accepted plans or as directed by the Engineering Division.

15.6.2 Base Course

This item shall consist of a foundation course composed of crushed gravel or crushed stone and filler, constructed on the prepared subgrade or subbase course. Construction shall be in accordance with the requirements of the Colorado Department of Transportation's Standard Specifications for Road and Bridge Construction (Latest Edition) and the accepted pavement design. The composite base course material shall be free from vegetation and lumps or balls of clay.

15.6.3 Placement & Compaction

The base course material shall be deposited and spread in a uniform layer without segregation of size to a compacted depth not to exceed six inches (6"). The material shall be compacted to a minimum ninety-five percent (95%) density as determined by ASTM D 698-78. No base course material shall be placed upon a soft, spongy, or frozen subgrade or subbase with an unsuitable stability. Base material shall not be placed on a dry or dusty foundation where the existing condition would cause rapid dissipation of moisture from the base material and hinder or preclude its proper compaction. Such dry foundations shall have water applied and shall be reworked and recompacted.

Rolling shall be continuous until the base material has been compacted thoroughly in accordance with these STANDARDS AND SPECIFICATIONS. Water shall be uniformly applied as needed during compaction to obtain optimum moisture content and to aid in consolidation. The surface of each layer shall be maintained during the compaction operations in such a manner that a uniform texture is produced and the aggregates are firmly placed.

15.6.4 Base Surface Tolerance

The prepared surface of the base shall not vary from the approved grade by more than one-half inch (1/2").

15.7 Bituminous Construction

15.7.1 Hot Bituminous Pavement

General

All pavements shall be hot bituminous pavement of the plant mix type unless otherwise approved in writing by the Engineering Division. Construction shall be in accordance with the Colorado Department of Transportation's Standard Specifications for Road and Bridge Construction, (Latest edition).

When tack coats, seal coats, rejuvenating agents or the heating and scarifying process are specified on the accepted construction plans or required by the Engineering Division, all materials and construction shall be in accordance with the CDOT Standard Specifications for Road and Bridge Construction (Latest Edition).



The intent of this section is to specify materials and methods to be used for the construction, overlaying, seal coating and pavement rejuvenating of streets, parking lots, walks, and other miscellaneous work requiring the use of aggregates. The work covered shall include general requirements that are applicable to aggregate base course, bituminous base and pavements of the plant mix type, bituminous prime coat, bituminous tack coat, rejuvenating applications, and asphalt concrete overlay. Workmanship and material shall be in accordance with requirements of these Standards and Specifications and in conformity with the lines, grades, depths, quantity requirements, and the typical cross section shown on the plans or as directed by the Engineering Division.

These specifications include general requirements applicable to all types of plant mixed hot mix asphalt (HMA). Also included are requirements for Stone Matrix Asphalt (SMA). Reference to HMA shall also mean SMA is included. This work consists of one (1) or more courses of asphalt mixture constructed on a prepared foundation in accordance with specifications. The design intent is to provide pavement with adequate thickness and quality to provide a serviceable life of at least 20 years. It is also the intent to provide construction in accordance with these specifications with a high standard of practice. This item shall include all labor, equipment, and materials to manufacture, place and compact asphaltic concrete for pavement purposes.

TEST PROCEDURE DEFINITION

- CP-## Colorado Department of Transportation: Field Materials Manual (Colorado Testing Procedures)
- ASTM American Society for Testing & Materials
- AASHTO American Association of State Highway & Transportation Officials
- CP-L ##### Colorado Department of Transportation: Laboratory Manual of Test Procedures (Lab Testing Procedures)

When references to both an AASHTO and either a CP or CP-L and test procedure are given, CP or CP-L shall be used, unless the Engineering Division has stipulated to ONLY use and require AASHTO test procedures.

Materials

Pavement shall be hot mix asphalt plant mix type unless otherwise approved in writing by the Engineering Division. Materials and construction shall be in accordance with the CDOT Standard Specifications, Section 403, and the following requirements:

The hot mix asphalt shall be composed of a mixture of aggregate, filler, hydrated lime and asphalt binder. Some mixes may require polymer modified asphalt binder. Some mixes may allow up to 20% reclaimed asphalt pavement (RAP) as approved by the Engineering Division. All RAP introduced shall meet the requirements of Designing and Constructing SMA Mixtures by National Asphalt Pavement Association. Stone Mastic Asphalt (SMA) mixtures are to be used in the top lift only and are required at intersections in accordance with Federal Highway Administration, Designing and Constructing SMA Mixtures.

Experimental materials such as Warm Mix Asphalt shall be approached as a variance and is subject to the approval of the Engineering Division.

NOTE: SMA specifications are adapted from the CDOT Standard Specifications and incorporated throughout other sections of this specification.

Aggregate

Aggregates for HMA shall be of uniform quality, composed of clean, hard, durable particles of crushed stone, crushed gravel, or crushed slag. Excess of fine material shall be wasted before crushing. The material shall not contain clay balls, vegetable matter, or other deleterious substances and shall meet the following requirements:

Table 15.1: Aggregate Properties

Aggregate Test Property	Coarse: Retained on #4	Fine: Passing the #4
Fine Aggregate Angularity, CP-L 5113 Method A or AASHTO T 304 Note: Fine aggregate angularity does not apply to RAP aggregates		45% Min
Two Fractured Faces, P-45 or ASTM D 5821 SG Mixtures Top and Middle Lifts Bottom Lifts SMA Mixtures	90% Min. 80% Min. 70% Min. 100% required	
LA Abrasion, AASHTO T 96	45% Max.	
Flat and Elongated (Ratio 5:1) %, AASHTO M 283	10% Max.	
Adherent Coating (Dry Sieving) ASTM D 5711	0.5% Max.	
Sand Equivalent. AASHTO-T 176		45% Min.
Micro Deval CP-L 4211 or AASHTO T 327	18% Max	

Reclaimed Asphalt Pavement material (RAP) may be allowed and shall be of uniform quality and gradation with a maximum size no greater than the nominal aggregate size of the mix. Mixes shall not contain more than 20% RAP.

The Proposed Design Job Mix Formula (PDJMF) gradation shall be wholly within the control point gradation range set forth in the following applicable Table 15.2 for dense graded mix designs or Table 15.3 for Stone Matrix Asphalt (SMA). The Allowable Job Mix Formula (AJMF) gradation for production shall be the PDJMF gradation with the tolerances of Section 504.14 B of Designing and Constructing SMA Mixtures by National Asphalt Pavement Association applied. The PDJMF and the final AJMF gradation for production shall report all sieve sizes listed in the applicable Table 15.2 or Table 15.3.

Mineral filler for the Stone Matrix Asphalt pavement shall be limestone dust and shall meet the requirements of this subsection and have a maximum Plasticity Index (AASHTO T90) of four (4) %.

The Contractor shall submit hydrometer analysis (AASHTO T88) for the gradation of mineral filler used in the SMA mixture.

Table 15.2: Dense Graded HMA Gradation Range

Mixture Grading Sieve Size	SX (1/2" nominal)		S (3/4" nominal)		SG (1" nominal)	
	Control Points	Caution Zone*	Control Points	Caution Zone*	Control Points	Caution Zone*
1 1/2"					100	
1"			100		90-100	
3/4"	100		90-100		@	
1/2"	90-100		@		@	
3/8"	@		@		@	
#4	@		@		@	39.5
#8	28-58	39.1	23-49	34.6	19-45	26.8-30.8
#16	@	25.6-31.6	@	22.3-28.3	@	18.1-24.1
#30	@	19.1-23.1	@	16.7-20.7	@	13.6-17.6
#50	@	15.5	@	13.7	@	11.4
#200**	2.0-8.0		2.0-7.0		1.0-7.0	

(% by weight passing square mesh sieves, CP-31, AASHTO T 11 & T 27)

*The caution zone is a guideline only. It is recommended that mix design gradations go above the caution zone boundaries, on the "fine" side.

**These limits shall include the required one (1) % of lime by weight.

@ These sieve sizes used only to determine the final Allowable Job Mix Formula (JMF).

Table 15.3: SMA Aggregate Gradation Range Properties

Sieve Size	Stone Mastic Grading Designation (% by weight passing square mesh sieves)			
	#4 Nominal	3/8" Nominal	1/2" Nominal	3/4" Nominal
1"				100
3/4"			100	90-100
1/2"	100	100	90-100	50-88
3/8"	100	90-100	50-80	25-60
#4	90-100	26-60	20-35	20-28
#8	28-65	20-28	16-24	16-24
#16	22-36			
#30	18-28	12-18	12-18	12-18
#50	15-22	10-15		
#200	12-15	8-12	8-11	8-11

(% by Weight Passing Square Mesh Sieves, CP-31, AASHTO T11 & T27) (Ref: CDOT Table 703-5)

Performance Graded Asphalt Binders

The Contractor shall provide to the Engineering Division acceptable Certifications of Compliance of each applicable asphalt binder grade from the supplier. Upon non-conformance with the specifications, the asphalt binder may be rejected as directed by the Engineering Division. When production begins, the Contractor shall, upon request, provide



to the Engineering Division a one (1) quart can of each specified asphalt binder. Additionally, when requested, the Contractor shall provide the refinery test results that pertain to the asphalt binders used during production.

Asphalt binder shall meet the requirements of the Superpave Performance-Graded Binders (PG) as presented in Table 15.4 below.

Table 15.4: Properties of Performance Graded Binders

Usage for each Binder Grade	PG 58-28	PG 64-22	PG 76-28
Traffic Loading, Total 18 kip ESALs Over Design Life (Usually 20 Years)***	Low Volume (0-100,000)	100,000 to <10.0 Million	3.0 Million to <10 Million
Superpave Compactor Design gyrations Recommended Usage	N _{design} = 50	N _{design} = 75	N _{design} = 100
Property of Binder Grade	PG 58-28	PG 64-22	PG 76-28
Flash Point Temperature, °C, AASHTO T 48	230 Min.	230 Min.	230 Min.
Viscosity at 135 °C, Pas, ASTM D 4402	3 Max.	3 Max.	3 Max.
Dynamic Shear, Temperature °C, where $C^{\circ}/\text{Sin}\delta @ 10 \text{ rad/sec.} \geq 1.00 \text{ KPa}$, AASHTO TP 5	58 °C	64 °C	76 °C
Rolling Thin Film Oven Residue Properties, AASHTO T 240			
Mass Loss, %, AASHTO T 240	1.00 Max.	1.00 Max.	1.00 Max.
Dynamic Shear, Temperature °C, where $G^{\circ}/\text{Sin}\delta @ 10 \text{ rad/sec.} \geq 2.20 \text{ KPa}$, AASHTO TP 5	58 °C	64 °C	76 °C
Elastic Recovery ¹ , 25°C, % Min.*	N/A	N/A	50 Min.
Pressure Aging Vessel Residue Properties, Aging Temperature 100 °C AASHTO PP1			
Dynamic Shear, Temperature °C, where $G^{\circ}/\text{Sin}\delta @ 10 \text{ rad/sec.} \leq 5,000 \text{ KPa}$, AASHTO TP 5	19 °C	25 °C	28 °C
Creep Stiffness @ 60 sec Test Temperature °C, AASHTO TP 1	-18 °C	-12 °C	-18 °C
S, MPa, AASHTO TP 1	300 Max.	300 Max.	300 Max.
m-value, AASHTO TP 1	0.300 Min.	0.300 Min.	0.300 Min.
**Direct Tension Temperature in °C, @ 1.0 mm/min., Where Failure Strain >1.0%, AASHTO TP 3	-18 °C	-12 °C	-18 °C

* Elastic Recovery by Task Force 31, Appendix B Method.

** Direct tension measurements are required when needed to show conformance to AASHTO MP.1.

*** Engineering Division is to determine PG Binder.

*** Use PG Binder 76-28 for all Major Arterial surface course.

Tack Coat

When tack coat is specified on the plans or required by the Engineering Division, the materials and construction shall be in accordance with the requirements of the CDOT Standards Specifications, Section 702. The emulsified asphalt, for Tack Coat shall be CSS-1h or SS-1h and conform to AASHTO M208 or M140.

Reclaimed Asphalt Pavement

- Reclaimed Asphalt Pavement (RAP) may be allowed in the HMA mixture by the Engineering Division.
- It shall be of uniform quality and gradation with a maximum size particle no greater than the maximum size allowed in the HMA mixture.
- HMA mixtures containing RAP shall meet the same gradation requirements as a virgin HMA mix.
- The Engineering Division may allow mixtures with a maximum of 20% RAP of any HMA pavement. RAP is not allowed in Stone Mastic Asphalt Mixtures, except by agreement by the Engineering Division.

The reclaimed asphalt pavement shall meet all the requirements for HMA pavement, as contained herein. The Contractor shall have an approved mix design for RAP to be used prior to placement.

The Engineering Division may require the Contractor to maintain separate stockpiles for each type of RAP material. All processed material shall be free of foreign materials and segregation shall be minimized. Any RAP material that cannot be readily broken down in the mixing process, and/or affects the paving operation, shall be processed prior to mixing with the virgin material.

Fine Aggregate Angularity requirements shall not apply to any RAP aggregate. The RAP will not contain clay balls, vegetable matter, or other deleterious substances.

Verification testing for asphalt content and gradation will be performed on RAP at the frequencies listed in Section 504.2 G of Designing and Constructing SMA Mixtures by National Asphalt Pavement Association, below. The Engineering Division may request the mix supplier’s testing results on RAP at any time. In addition, the mixture shall be tested for properties as listed in Table 15.5.

When the use of RAP is allowed, the following additional conditions shall apply:

The processed RAP must be 100% passing the one and one-fourth inch (1¼) inch sieve. The aggregate obtained from the processed RAP shall be 100% passing the one (1) inch sieve. The aggregate and binder obtained from the processed RAP shall be uniform in all the measured parameters in accordance with the following schedule:

Table 15.5: Rap Aggregate Uniformity Tolerance

Element	Uniformity*
Binder Content	0.5
% Passing ¾”	4.0
% Passing ½”	4.0
% Passing 3/8”	4.0
% Passing #4	4.0
% Passing #8	4.0
% Passing #30	3.0
% Passing #200	1.5

*Uniformity is the Maximum allowable Standard Deviation of test results of processed RAP.

The Contractor shall have an approved RAP Quality Control (QC) Plan that details how the RAP will be processed and controlled. The QC plan must address the following:

- **RAP Processing Techniques.** This requires a schematic diagram and narrative that explains the processing (crushing, screening, and rejecting) and stockpile operation for normal plant operation or a specific project.
- **Control of RAP Asphalt Binder Content:** - Minimum Testing Frequency: 1/1,000 tons of processed RAP material (minimum 3 tests) for recent production of the mix type.
- **Control of RAP Gradation (CP31 or AASHTO T-30):** Minimum Testing Frequency: 1/1,000 tons of processed RAP material (minimum 3 tests) for recent production of the mix type.
- Process Control Charts shall be maintained for binder content and each screen listed, during addition of any RAP material to the stockpile. The Contractor shall maintain separate control charts for each RAP stockpile. The control charts shall be displayed and shall be made available to the Engineering Division upon request.

Example of Rap Quality Control Plan

Initial quality control of the reclaimed asphalt pavement shall be performed prior to and during crushing. Material for reclamation shall be separated by quality and source before being accepted for processing. Reclaimed asphalt must be free of concrete, dirt, and organic materials. These stockpiles shall be built from the ground up, completely mixing all loads as they come in.

Crushing of the reclaimed asphalt pavement shall be accomplished by means of a cone crusher and a screen deck. Oversize material shall be rejected on a three-fourths ($\frac{3}{4}$) inch scalping material, which reprocesses the material through the cone additional times. The processed material shall be stockpiled at the crushing facility and kept in separate piles and separate from other products to prevent intermingling of products, as well as the feed bins to prevent intermingling of the aggregates.

The reclaimed asphalt pavement material shall be sampled during the crushing operations according to AASHTO T 2 at frequencies greater than 1/1000 tons and tested for gradation and asphalt content in accordance with AASHTO T 27 AND T11, and AASHTO T 308. Testing shall be done randomly daily to ensure conformance to specifications.

The reclaimed asphalt pavement material at the asphalt plant shall be again sampled and tested according to the appropriate procedures to ensure that the asphalt content and gradation meet specifications and represent initial quality control data. Once data is collected, a statistical analysis shall be performed to determine the blend for the asphalt mixture design. This analysis shall be provided with the Asphalt Mixture Design submittal. The RAP will meet the Uniformity Specification of Table 15.6 above.

The RAP system at the asphalt plant consists of a feed bin with a variable speed motor controlled by the plant computer, which ensures the proper quantity of RAP material called for by the mix design. Material is delivered to the asphalt-mixing chamber of the asphalt plant by means of conveyor belts. The RAP material falls from one conveyor to another through a shaker screen that serves to break up any RAP material that has recompacted. Any oversize material shall be rejected at the shaker screen. While in production, the front-end loader shall work the full face of the stockpile, to ensure a representative batch is being produced.

Prior to starting a project and at any other time necessary, the RAP feed system shall be calibrated by placing an amount of RAP measured by certified external scales into the feed bin. That measured material is fed from the RAP bin across the belt scales. The weights are compared and, if outside of accepted tolerances for the blending system, adjustments are made by the plant-blending computer. This process is the same for all other components of the mix design.

15.7.2 Mix Design & Plant Produced Mixture Requirements

The mix design materials shall be those listed and used for the project. No substitutions are allowed during production, unless approved by the Engineering Division.



The Contractor shall indicate the project specific criteria concerning mix design method, traffic level, asphalt binder type, mixture grading, and maximum amount of RAP allowed. This information shall be provided on Mix Design, or other construction documents.

Grading SG (1-inch nominal aggregate) shall only be designed using the 150 mm Superpave molds. Hveem Stability and Lottman test are not required for Grading SG mixtures. Grading S and SX shall be designed using 100 mm Superpave molds.

Superpave Mixture Design Method

The Contractor shall submit a Proposed Design Job Mix Formula (PDJMF) for each mixture required by the Contract. The mixture design shall be determined using AASHTO T-312 or Colorado Procedure CP-L 5115 for the Superpave Method of Mixture Design. Guidance is provided in "Superpave Level 1 Mix Design" SP-2 published by the Asphalt Institute. Mixture design and field control testing shall meet the following requirements of Table 15.6: Superpave Mixture Properties for Dense Graded HMA.

Mixture design and field control testing of SMA shall meet the following requirements of Table 15.6.

Table 15.6: Superpave Mixture Properties for Dense Graded HMA

Property or Test	Traffic Levels (ESALs)		
Traffic Loading, Total 18 kip ESALs Over Design Life (Usually 20 Years)	Low (0-100,000)	Medium (100,000 to <3.0 Million)	High (3.0 Million to <30 Million)
Design gyrations, N design (Air Void: 3.5% to 4.5%) (See Note 1,2)	50	75	100
Air Voids in Total Mix (VTM) CPL 5115 or AASHTO T 312	(See Note 1)	(See Note 1)	(See Note 1)
Hveem Stability CP-L 5106 or AASHTO T 246 (Grading S & SX only) (See Note 3)	N/A	28 Min.	30 Min.
Voids Filled with Asphalt (VFA), MS2	70-80	65-78	65-75
Lottman, Tensile Strength Ratio, % Retained, CP-L 5109 or AASHTO T 283, Method B	80 Min.	80 Min.	80 Min.
Lottman, CP-L 5109 or ASHTO T 283 Dry Tensile Strength, psi	30 Min.	30 Min.	30 Min.
See Notes 2,3,4 VMA %. CP-48 or AASHTO PP 19	Minimum VMA criteria applies to the mix design only (Table 500- 7). The minimum VMA criteria shall be linearly interpolated based on actual air voids. See 504.14 B for production tolerances		

Note 1: Select the target Job Mix Optimum Binder Content for HMA gradings as close to 4.0% air voids as possible (3.5% to 4.5% air voids). VTM is also referred to as Pax in CPL 5115, and %Gmmx in T 312

Note 2: Maximum Theoretical Specific Gravity of mix by CP-51 or AASHTO T 209.

Note 3: Refer to Section 504.13 B for production tolerances.



Note 4: VMA shall be based on tests of the Bulk Specific Gravity of the Compacted Mix (CP-L 5103 or AASHTO T 166) and Aggregate (AASHTO T 84 & T 85) and calculated according to CP-48 or AASHTO PP 19. All mixes shall meet the minimum VMA specified in Table 15-9, below.

Table 15.7: Superpave Mixture Properties for Open Graded SMA

Property	Test Method	Value for SMA
Lab compaction (Revolutions) N Design	CPL 5115 or AASHTO T 312	100
Air Voids, % at: N Design (See Note 1)	AASHTO T 312	3.0 – 4.0
Hveem Stability	CP-L 5106 or AASHTO T 246	30 Min.
Accelerated Moisture Susceptibility, Tensile Strength Ratio, (Lottman)	CPL 5109 or AASHTO T 283, Method B	80 Min.
Dry Split Tensile Strength, psi	CPL 5109 or AASHTO T 283, Method B	30 Min.
Grade of Asphalt Binder	n/a	PG 76-28
Voids in the Mineral Aggregate (VMA) %, minimum (see note 2)	CP 48 or AASHTO PP 19	17
Drain down at Production Temperature	AASHTO T 305	0.3 maximum
% VCAMIX (See Note 3)	AASHTO PP 41-02	Less than VCADRC (See Note 4)

General Note: Copies of AASHTO PP 41-02 and MP 8-02 (for designing SMA mixes) can be obtained from the Engineering Division.

Note 1: Select the target Job Mix Optimum Binder Content for SMA grading at 3.0% to 4.0% air voids.

Note 2: VMA shall be based on tests of the Bulk Specific Gravity of the Compacted Mix (CP-L 5103 or AASHTO T-166) and Aggregate (AASHTO T 84 & T 85) and calculated according to CP-48 or AASHTO PP 19. All mixes shall meet the minimum VMA specified in **Table 15-8**, below.

Table 15.8: Minimum Voids in Mineral Aggregate (VMA) for Dense Graded HMA & Open Graded SMA, %

Nominal Maximum* Particle Size	Air Voids **		
	3.5%	4.0%	4.5%
1"	12.2	12.7	13.2
¾"	13.2	13.7	14.2
½"	14.2	14.7	15.2
SMA	17.0	17.0	17.0

* Nominal Maximum Particle Size is defined as one (1) sieve size larger than the first sieve to retain more than 10% but shall not exceed the 100% passing size. The Nominal Maximum Particle Size can vary during mix production even when the 100% passing size is constant.

** Minimum VMA criteria apply to the mix design only. The minimum VMA criteria shall be linearly interpolated based on actual air voids.

15.7.3 Mix Design Submittals

General Requirements

The Contractor shall submit all mixture designs, Certificates of Compliance, and laboratory data to the Engineering Division for approval at least seven (7) calendar days before construction is to begin. The mix design (Proposed Design Job Mix) must be approved by the Engineering Division prior to the start of construction.

Mixture designs shall be performed in a materials laboratory under the direct supervision of and shall be stamped and signed by a Professional Engineer licensed in the State of Colorado and practicing in this field. In addition, the Contractor shall submit, as part of the mixture design, laboratory data documents to verify the following:

- Source of materials.

- Gradation, specific gravity, source and description of individual aggregates and the final blend.
- Aggregate physical properties.
- Source and Grade of the Performance Graded Binder (PG Binder).
- Proposed Design Job Mix: aggregate and additive blending, final gradation shown on 0.45 power graph, optimum asphalt content.
- Mixing and compaction temperatures used.
- Mixture properties determined at a minimum of four (4) asphalt contents and interpolated at optimum and graphs showing mixture properties versus asphalt content.

Engineering Division approval of any mix design for HMA or SMA must be given prior to placement.

The Engineering Division reserves the right to verify the Contractor's mix design for each hot mix asphalt grading utilizing materials produced and stockpiled. If requested, the Contractor shall provide, at no cost, enough quantity of each aggregate, mineral filler, RAP, and additive for the required laboratory tests, by the Engineering Division. The Engineering Division may request a Certificate of Conformance or Certificate of Compliance at any time on any material used. The Engineering Division may request the mix supplier's testing results on RAP at any time.

Change in Source or Grade

Should a change in the source of Lime occur, or more than one temperature grade change on either the high or low end of Performance Graded Asphalt Binders - (PG Binder) occur, a one point verification test (at optimum asphalt content) of the mix must be performed to verify that the applicable criteria shown on Table 15.6 (Dense Graded HMA)) or Table 15.8 (SMA), and Table 15.9 (VMA), is still met. If this testing shows noncompliance, a new Design Job Mix will be established and approved by the Engineering Division before the new Performance Graded Asphalt Binders (PG Binder) or Lime source is used. Any change in aggregate type or source will require a new mix design. The one-point verification test may be performed on lab mixed samples or on plant mixed samples.

Mix Production Verification

Production verification shall occur prior to the start of the project. The production verification shall be performed by LABCAT Level C certified technicians with current Certification to verify the volumetric properties of the mix. If the mix has been produced for another project within the last 90 days, data from that project can be submitted for this verification. Volumetric properties of the mix verification testing shall be within the following tolerances compared to the Proposed Design Job Mix. The mix verification test reports shall be submitted to the Engineering Division prior to mix placement.

Table 15.9: Mix Design Verification Tolerances

Air Voids	+/- 1.2%
VMA	+/- 1.2%
Asphalt Binder Content	+/-0.3%
Stability	Applicable minimum

The tolerances in this table are for mix design verification only. See Section 504.13 for production tolerances.

Prior to Paving Requirements

Engineering Division may require a construction (joint) plan to be submitted at least one week prior to paving, see Section 504.9 and 504.10 of Designing and Constructing SMA Mixtures by National Asphalt Pavement Association for joint requirements.

A minimum of two (2) weeks prior to the proposed use of any Stone Matrix Asphalt pavement on the project, the Contractor shall submit to the Engineering Division, a mix design meeting the appropriate specification requirements for the items in Table 15.8.

15.7.4 HMA Equipment

Mixing Plant

The mixing plant shall be capable of producing a uniform material, have adequate capacity, and be maintained in good mechanical condition. Defective parts shall be replaced or repaired immediately if they adversely affect the proper functioning of the plant or plant units, or adversely affect the quality of the HMA.

Dust, smoke, or other contaminants shall be controlled at the plant site to meet all air quality requirements in the "Colorado Air Quality Control Act," Title 25, Article 7, CRS and regulations promulgated there under.

Acceptable safety equipment, approved by the Engineering Division, shall be provided by the Contractor to accommodate sampling and testing.

Hauling Equipment

Trucks used for hauling HMA material shall have tight, clean, smooth beds, or functional and maintained conveyor belt bottom that is thinly coated with a minimum amount of paraffin oil, lime solution, or other approved release agent.

Petroleum distillates such as kerosene or fuel oil will not be permitted. Each truck shall have a cover of canvas or other suitable material to protect the mixture from the weather and excessive temperature loss or cooled layers of mix in truck as covered in 504.6° C. Hauling, later in this specification.

Bituminous Pavers

Self-propelled pavers shall be provided for full lane width paving capable of spreading and finishing the HMA, material in full lane widths applicable to the typical section and thicknesses shown in the Contract and shall be equipped with:

- Anti-segregation devices.
- A vibratory screed assembly capable of being heated.

Pavers used for shoulders, patching and similar construction, not requiring fine grade control, shall be capable of spreading and finishing courses of HMA material in widths shown in the Contract without segregation.

The paver's receiving hopper shall have enough capacity for a uniform spreading operation and shall have an automatic distribution system that will place and spread the mixture uniformly in front of the screed.

The paver shall be capable of operating at forward speeds consistent with uniform and continuous laying of the mixture. Stop and go operations of the paver shall be avoided. The screed or strike-off assembly shall produce the specified finished surface without tearing, shoving, or gouging the mixture. Self-propelled pavers shall be equipped with automatic screed controls with sensors capable of sensing grade from an outside reference line and maintaining the screed at the specified longitudinal grade and transverse slope. The sensors may be contact or non-contact type

devices. The sensor shall be constructed to operate from either or both sides of the paver and shall be capable of working with the following devices when they are required for the situation:

- Grade control device at least 30 feet in length.
- Joint matching device.
- Adequate length of control line and stakes if no other type of geometric control is present.
- A straight edge at least 10 feet in length will be available to verify the crown on the screed, at the request of the Engineering Division.

The controls shall be capable of maintaining the screed at the specified transverse slope within plus or minus 0.1 %. Automatic mode should be used where possible. If the automatic controls fail or malfunction, the equipment may be operated manually for the remainder of the normal working day, provided specified results are obtained.

If the Contractor fails to obtain and maintain the specified surface tolerances, the paving operations shall be suspended until satisfactory corrections, repairs, or equipment replacements are made.

Placement of HMA on a waterproofed bridge deck shall be accomplished with equipment that will not damage the membrane or protective covering.

Mixing

The dried aggregates and asphalt binder shall be combined in the mixer in the quantities required to meet the design job mix. The materials shall be mixed until the aggregate is completely and uniformly coated, and the asphalt binder is uniformly distributed throughout the aggregate. Baghouse fines shall be fed back to the mixing plant in a uniform and continuous manner to maintain uniformity in the mixture. The Baghouse, fines feeder, auger, and related equipment, shall be in good working condition and operated in accordance with manufacturer's recommendation. If the Engineering Division determines that non-uniform operation of the equipment is detrimental to the mixture, it may suspend all paving operations until the Contractor takes appropriate action.

The minimum temperature of the mixture when discharged from the mixer shall be as shown in the following table:

Table 15.10: Mixture Discharge Temperatures

Asphalt Grade	Minimum Discharge Temperature	Maximum Discharge Temperature
PG 58-28	275° F	310° F
PG 64-22	290° F	325° F
PG 76-28*	318° F	326° F

* Contractor or Binder supplier must supply production temperature as required by their product

The Contractor may provide refinery information that recommends revised discharge temperatures depending on the base binder grade or source being used. HMA mix shall be produced at the lowest temperature within the specified temperature range that produces a workable mix and provides for uniform coating of aggregates (95 % minimum in accordance with AASHTO T 195), and that allows the required compaction to be achieved.

HMA mix may be stored provided that any and all characteristics of the mixture are not altered by such storage. If storing or holding of the mixture causes segregation, excessive heat loss, or adversely affects the quality of the finished product, corrective action shall be taken. Unsuitable mixture shall be disposed of at the Contractor's expense.



When placing hot mix asphalt over bridge decks covered by waterproofing membrane, the minimum temperature of the mixture, when rolling operations begin, shall be 250° F. The job mix temperature may be increased up to 30° F to obtain this temperature.

The mineral filler for SMA shall be stored in a separate silo and added automatically in the correct proportion. The mineral filler addition equipment shall be electronically or mechanically interlocked to the aggregate feed sensors so that the proper amount of mineral filler is added whenever SMA is produced.

The SMA mineral filler shall be added at the same point the asphalt binder is added to the aggregate.

Hauling

Each truck shall use full covers (tarps) to completely protect the mix during transport at all times. The Engineering Division can reject any mix, which shows an excess or deficiency of asphalt cement, damage due to burning or overheating, an improper gradation, or thermal segregation with cold areas 10° F below the minimum discharge temperature. The Engineering Division collects all aggregate, asphalt, concrete and materials tickets and when requested, the Contractor shall provide the tickets within 24 hours.

Tack Coat

Prior to placement of HMA, a tack coat shall be applied to all existing concrete and asphalt surfaces. The material shall be in accordance with 504.2 E. The emulsified asphalt shall be diluted 1:1 with water and applied at 0.10 ± 0.01 gallons per square yard of diluted material. The Engineering Division may direct other application rates to match the age of condition of the surface. The surface prior to receiving the tack coat shall be dry and cleaned by sweeping, or other approved method, until dust, debris, and foreign matter are removed. The tack coat shall then be applied uniformly by squeegee, brooms, or distributor. Prior to paving, all water must have evaporated from the tack coat. Contaminated areas shall be cleaned, and tack coat shall be reapplied.

Prior to placement of SMA, tack coat between the existing pavement and Stone Matrix Asphalt pavement shall be placed at a rate between 0.03 and 0.05 gallons per square yard.

Placement

Hot mix asphalt shall be placed only on approved, properly constructed surfaces that are free from loose material, water, frost, snow or ice. The hot mix asphalt and tack coat shall be placed in accordance with the temperature limitations of Table 500-16 and only when weather conditions permit the pavement to be properly placed and finished as determined by the Engineering Division. Placement temperature as stated shall be increased by 5° F for each 10 miles per hour wind velocity to a maximum increased minimum placement temperature of 70 ° F.

Table 15.11: Minimum Air & Surface Temperatures Limitations or Mix Placement(HMA)

Compaction Layer Thickness	Top Layer of Pavement*		Lower Layers*	
	PG 58-28 PG 64-22	PG 76-28	PG 58-28 PG 64-22	PG 76-28
<2 inches (not recommended)	60° F	75° F	N/A	N/A
2 inches to <3 inches	50° F	65° F	40° F	50° F
> 3 inches	50° F	50° F	40° F	40° F
SG mix only	N/A	N/A	38° F	38° F

* Air temperature is taken in the shade. Surface temperature is taken on the subgrade or base. The Engineering Division may not waive the above temperature limitations for PG 76-28.

The mixture shall not be placed at a temperature lower than 245° F for mixes containing PG 58-28 or PG 64-22 asphalt, and 290° F for mixes containing polymer modified asphalt binder. Mix which is too cold or damaged by weather will be rejected.

The mixture shall be placed on an approved surface, spread, and struck off to obtain the required grade and elevation after compaction. The minimum lift thickness shall be at least three (3) times (preferably four (4) times) the nominal particle size. The un-compacted mixture should be placed approximately 10-25 % thicker than the existing surrounding mat to account for compaction based on the materials being placed. Raking is discouraged and will not be allowed except to correct major problems of grade and elevation. Casting or raking that causes any segregation will not be permitted.

On areas where the use of mechanical spreading and finishing equipment is impracticable, the mixture shall be carefully dumped, spread, raked, screened, and luted by hand tools to the required compacted thickness plus approximately 25 % based on the materials being placed. Carefully move or minimally work the HMA mix with the use of rakes, lutes, or shovels to avoid segregation. Mixtures made with modified asphalt binder require more rapid completion of handwork areas than for normal mixtures. Hauling and placement sequences shall be coordinated so that the paver is in constant motion. Excessive starting and stopping shall not be allowed. A construction joint shall be placed any time the paver stops, and the screed drops enough to cause a surface dip in violation of Section 504.13, Production Tolerances, of Designing and Constructing SMA Mixtures by National Asphalt Pavement Association; or the max temperature falls below that allowed in Section 504.12, Compaction, of the same text. Bituminous pavers shall be used to distribute the mixture either over the entire width or over such partial width as may be practicable. Echelon paving will be permitted.

Longitudinal Joints

The longitudinal joints in both a new pavement and an overlay pavement layer shall offset the joint in the layer immediately below by a minimum of six (6) inches. The joints in any pavement layer shall not fall in a wheel track or path. The joints in the top layer of new pavement, not built on top of an existing pavement, shall be located on lane lines, or as shown on the plans. Longitudinal joints shall be minimized, where feasible, with wide paving pulls or echelon paving. Joints shall be parallel to the flow of traffic and shall not cross any centerline, lane line, or edge line unless approved by the Engineering Division. The Contractor shall submit, prior to paving, a joint plan and pavement marking plan showing locations and the methods to establish a field control line. The Engineering Division must approve such plans prior to paving. The Contractor shall use a continuous string line to delineate longitudinal joints during paving as shown on the joint plan. All string lines shall be removed at the end of each day's paving.

The free edge of the paved pass shall be laid as straight as possible, to the satisfaction of the Engineering Division. This joint, if cold, shall be tack coated prior to placement of adjacent paving.

The new compacted mat shall overlap the previously placed mat no more than one and one-half (1.5) inches. Excess overlap or thickness shall not be raked or cast onto the new mat but shall be wasted by pulling back and removing. The hot edge shall be blocked or bumped in a smooth line consistent with the previous longitudinal edge. Minor raking will only be allowed to correct major grade problems or provide mix around manholes and meter covers. The longitudinal joint shall be rolled from the hot side and overlap the joint by approximately six (6) inches on the cold side.

Transverse Joints

The Contractor shall submit, prior to paving, a joint plan showing location and the methods to be used to construct transverse joints. The Engineering Division must approve such plans prior to paving. Placing of the HMA shall be continuous with a minimum of transverse joints, and rollers shall not pass over the unprotected end of a freshly laid mixture. Transverse joints shall be formed by cutting back on the previous run to expose the full depth of the course. Tack coat material shall be applied to contact surfaces of all joints just before additional mixture is placed against the previously compacted material.

The end of transverse joints shall be located so they will be constructed with a full head of mix in front of the screed. When butt joints are constructed, runoff boards shall be used to support the roller on the downstream side of the joint. All tapered sections, rounded edges and segregated areas shall be removed to achieve a vertical face at the butt joint before paving is restarted. When a temporary tapered joint is required for temporary traffic access, the ramp shall be removed back to a full depth section before paving is restarted.

When restarting paving operations, the paver screed shall be placed on the starter block on the completed side of the transverse joint. The starter block should be approximately 25% greater than the thickness of the existing completed mat, so that adequate grade and compaction can be achieved on starting the paving operation. The screed should be nulled (angle removed) when on starting blocks and an up angle of attack set. Proper head of mix should be introduced into the paver prior to starting. The new compacted (downstream) side of the joint may be up to 3/16 inches higher than the old (upstream) side. Raking of this joint shall not be allowed except to correct major grade problems. The surface tolerance at the transverse joint must be verified by the Contractor with a 10-foot straight edge before the paver is more than 100 feet from the joint. If the surface tolerance is not within 3/16 inches, the Contractor shall make corrections before proceeding.

Segregation

The asphalt mixture shall be transported and placed on the roadway without segregation. All segregated areas shall be removed immediately and replaced with specification material before the initial rolling. If more than 50 square feet of segregated pavement is removed and replaced in any continuous 500 linear feet of paver width laydown, operations shall be discontinued until the source of the segregation has been determined and corrected.

The Engineering Division will visually determine areas that are segregated and may also use density and gradation measures to help in this determination. The Engineering Division will visually determine the extent of the segregation. The Contractor will not be allowed additional compensation for correction of segregated areas.

Compaction

The temperature of the mixture immediately behind the screed shall be sufficient to allow for proper compaction of the HMA layer and at least 245° F for PG 64-22 binder, bottom lift and between 297° F and 305° F for PG 76-28 binder, top lift. The breakdown compaction should be completed as quickly as possible after placement occurs.

The HMA shall be compacted by rolling. The number, weight, and type of rollers furnished shall be sufficient to obtain the required density and surface texture while the mixture is in a workable condition. Compaction shall begin immediately after the mixture is placed and be continued until the required density is obtained. Final compaction shall be obtained using steel wheel rollers.

Pavement operations shall be suspended when density requirements are not met and the surface temperature falls below 185° F, or there is obvious surface distress or breakage, the problem shall be resolved prior to continuing paving operations. The criteria for mixtures containing PG 76-28 asphalt cements shall be 235° F. The minimum compaction temperatures may be adjusted according to the asphalt binder supplier recommendations. Adjusted minimum compaction temperatures must be shown on the approved mix design or on other asphalt binder supplier documents and be available on the job site.

All roller marks shall be removed with the finish rolling. Use of vibratory rollers with the vibrator on will not be permitted on bridge decks.

The Contractor shall establish a rolling pattern or procedure during the beginning of paving operations, which will achieve the required compaction and surface tolerances. This procedure may be re-evaluated by the Contractor and Engineering Division throughout the paving operations.



All HMA paving shall be compacted to $94.0 \pm 2\%$ of Maximum Theoretical (RICE) Density, (CP-51 or AASHTO T-209: Maximum Specific Gravity of Bituminous Paving Mixtures) as determined by ASTM D 2950. RICE values shall be used in calculating Relative Compaction according to CP-44 or AASHTO T 166. The Contractor shall determine the proper RICE value to use for the initial day's placement. Subsequent day's RICE value(s) will be based on the current day's production. The Contractor shall provide the producer's RICE value, which shall be used for production until the actual day's RICE value is determined by the testing firm of record for the project as approved by the Engineering Division.

All joints shall be compacted to $92.0 \pm 2\%$ of RICE, taken fully on each side of joint, every 200 Linear Feet. RICE values shall be used in calculating Relative Compaction according to AASHTO T 166, Cores if needed will be used to verify compaction results.

The Contractor shall core the pavement, as required by the Engineering Division, for field density tests in accordance with Colorado Procedure 44 or AASHTO T 230, Method B, or for field calibration of nuclear density equipment in accordance with the ASTM D 2950. At a minimum, cores for nuclear density equipment calibration shall be taken at the beginning of placement of each pavement layer or change of mixture materials or gradation. Untested areas during placement will also require cores to be taken to verify compaction.

Along forms, curbs, headers, walls, and all other places not accessible to the rollers, the mixture shall be thoroughly compacted with mechanical tampers.

Any mixture that becomes loose and broken, mixed with dirt, or is in any way defective, shall be immediately removed and replaced with fresh hot mixture and compacted to conform to the surrounding area.

Compaction requirements for SMA are covered in Section 504.8 E of Designing and Constructing SMA Mixtures by National Asphalt Pavement Association. Rollers shall not be used in a vibratory mode on SMA unless they are first used successfully in the demonstration control strip. Pneumatic wheel rollers shall not be used on SMA Mix.

Production Tolerances

Top Lift Surface Tolerances

The surface variation between any two (2) contacts shall not exceed three-sixteenths ($3/16$) inch in 10 feet for full lane width paving. For patching surface tolerances, the variation shall not exceed three-eighths ($3/8$) inch in 10 feet.

Irregularities exceeding the specified tolerance shall be corrected at the Contractor's expense. Transverse measurements for variations shall exclude breaks in the crown sections.

Job Mix Formula Tolerances

Production test results that deviate from the design job mix by more than shown in the following table are subject to Section 504.13 C of Designing and Constructing SMA Mixtures by National Asphalt Pavement Association:

Table 15.12: Job Mix Formula Tolerances

Item	Tolerances
Passing No. 3/8" and Larger (Note 1)	± 6%
Passing No. 4 and No.8	± 5%
Passing No. 30 to No. 50	± 4%
Passing No. 200 (Note 2)	± 2%
Air Voids	± 1.2%
VMA (Note 4)	± 1.2%
Hveem Stability	(Note 3)
Asphalt Content	± 0.3%

Note 1: There is one (1.0%) tolerance for the maximum sieve size.

Note 2: Mixes with passing No. 200 sieve material produced over seven (7.0) % are allowed only when the above Air Voids and VMA tolerances are still met.

Note 3: Hveem Stability must meet the minimum value specified in Table 15-8.

Note 4: When calculating VMA, use the most current aggregate specific gravity Gsb.

When disagreements concerning determination of specification compliance occur, only valid tests from both the Engineering Division and Contractor will be considered. The Engineering Division shall determine validity. Generally, valid tests are those in which sampling and testing have been performed according to referenced procedures and the results are within stated precision statements. When disagreements occur with asphalt content and gradation tests results, solvent extracted aggregate testing shall take precedence over burn off oven extracted aggregate, which shall take precedence over cold feed belt testing.

Grinding

Grinding shall consist of milling, grinding, or cold planing the existing pavement surface to establish a new surface profile and cross-section in preparation for a bituminous overlay. After grinding, the surface shall have a grooved or ridged finish, uniform and resistant to raveling or traffic displacement. This textured surface shall have grooves of one-quarter inch (1/4") plus or minus one-eighth inch (+1/8).

Wedge cut grinding shall consist of grinding the existing pavement surface a minimum of four feet (4') wide at the existing concrete gutter. The edge of the gutter end of the finished wedge cut shall be one-and-one-half inches (1-1/2") below the edge of the existing concrete gutter. The centerline of the street edge of the wedge cut will be cut one-eighth inch (1/8"). The depth of cut shall be determined by measuring to the top of the ridges by placing a five-foot (5') straight edge perpendicular to the grooving pattern. Full-width grinding shall consist of grinding the existing pavement surface from edge of gutter to edge of gutter to a minimum depth of two inches (2") unless otherwise directed by the Engineering Division.

In grinding around utility castings, the Contractor may choose to remove the entire existing bituminous pavement around the castings where grinding is not completed and replace it with bituminous surface course placed and compacted in three-inch (3") lifts. The Contractor shall vertically cut the limits of the area to be patched, mechanically compact the existing base course, and prime the bottom and vertical edges before backfilling. The Contractor shall remove the cuttings immediately behind the grind machine by belt loader, end loader, power sweeper and/or by hand. The removed material shall be disposed of as approved by the Engineering Division.

The grinding machine shall be a power-operated, self-propelled machine having a cutting drum with lacing patterns that will attain a grooved surface and produce grinding chips of less than one inch (1") in size. The grinding machine

shall be equipped with a pressurized watering system for dust control. The equipment shall be a type that has successfully performed similar work.

The cleaning equipment shall be a type which will efficiently remove all loosened material and load into trucks for hauling and spreading. Because of the nature of the streets to be ground and the traffic restrictions, a belt loader followed by a power sweeper and manual sweeper is the most desirable method. Flushing into the City's storm sewer system as a means of clean-up will not be allowed.

Grinding shall consist of "milling", "grinding", or "cold planing" the existing pavement surface to establish a new surface profile and cross section in preparation for a bituminous overlay. After grinding, the surface shall have a grooved or ridged finish, uniform and resistant to raveling or traffic displacement. This textured surface shall have grooves of one-fourth ($\frac{1}{4}$) inch plus or minus one-eighth ($\frac{1}{8}$) inch. The existing surface to be ground shall include bituminous pavement, concrete utility patches, and a small amount of concrete pavement.

"Wedge cut" grinding shall consist of grinding the existing pavement surface a minimum of four (4) feet wide at the existing concrete gutter. The edge of the gutter end of the finished wedge cut shall be one and one-half ($1\frac{1}{2}$) inches below the edge of the existing concrete gutter. The center line of street edge of the wedge cut shall be cut one-eighth ($\frac{1}{8}$) inch. The depth of cut shall be determined by measuring to the top of the ridges by placing a five (5) foot straight edge perpendicular to the grooving pattern. "Full width" grinding shall consist of grinding the existing pavement surface from edge of gutter to edge of gutter to a minimum depth of two (2) inches, unless otherwise directed by the Engineering Division.

Grinding around utility castings to the depth of cut before and after encountering the castings shall be included in the area of the pavement surface ground. The Contractor may choose to remove the entire existing bituminous pavement around the castings where grinding is not completed and replace it with bituminous surface course placed and compacted in three (3) inch lifts. The Contractor shall vertically cut the limits of the area to be patched, mechanically compact the existing base course, and prime the bottom and vertical edges before backfilling.

The grinding machine shall be a power operated, self-propelled machine, having a cutting drum with lacing patterns that shall attain a grooved surface and produce grinding chips of less than one (1) inch in size. The grinding machine shall be equipped with a pressurized watering system for dust control. The equipment shall be a type that has successfully performed similar work.

The Contractor shall remove the cuttings immediately behind the grind machine by belt loader, end loader, power sweeper and/or by hand. The removed material shall be disposed of as approved by the Engineering Division.

The cleaning equipment shall be a type which shall efficiently remove loosened material, load it into trucks for hauling and spreading, and utilize a watering system for dust control. Because of the nature of the streets to be ground and the traffic restrictions, a belt loader followed by a power sweeper and manual sweeper is the most desirable method.

Flushing into the City's storm sewer system as a means of cleanup shall not be allowed.

15.8 Portland Cement Concrete Pavement

15.8.1 General

Furnishing all tools, transportation, labor, equipment, accessories, services and material, and in performing all operations in constructing a single course of air-entrained Portland cement concrete pavement constructed on a prepared subgrade shall be in accordance with the CDOT Standard Specifications for Road and Bridge Construction (Latest Edition). Portland Cement Concrete Pavements will only be allowed if approved in writing by the Engineering Division.

15.8.2 Concrete Pavement

The installation of concrete pavement, including materials, equipment, foundation, and construction methods shall be in conformance with Section 412, "Portland Cement, Concrete Pavement" of the CDOT Standard Specifications, except as modified herein or as modified by the approval of the Engineering Division.

Concrete pavements shall only be designed where approved by the Engineering Division. It shall be installed as shown on the accepted plans. When concrete pavement is constructed on a curve, flexible forms shall be used having a radius of 200 feet or less, unless otherwise directed by the Engineering Division. The Contractor shall furnish steel pins to use in setting grades for concrete pavement.

This material shall consist of a mixture of coarse and fine aggregates, Portland cement, fly ash, water and other materials or admixtures as required. CDOT Class "D" mix shall be used.

- Portland cement shall comply with the CDOT requirements. The type of cement shall be Type II or Type II Modified unless sulfate conditions dictate otherwise. Table 2.2.3 in Chapter 2.2 of ACI 201 indicates recommendations for sulfate resistance.
- Fine aggregates shall meet CDOT Standard Specifications, Section 703.01 requirements.
- Coarse aggregates shall meet CDOT Standard Specifications, Section 703.02 requirements.
- Fly Ash shall comply with CDOT Standard Specifications, Section 701.02 if use is approved by Engineering Division.
- Water shall meet the requirements of CDOT Standard Specifications, Section 712.01.
- Air entraining and chemical admixtures shall meet the requirements of CDOT Standard Specifications, Section 711.02 and 711.03. No chloride containing additives shall be permitted.
- Curing materials shall be white pigmented liquefied membrane curing compound and meet the requirements of AASHTO M 148.
- Reinforcing steel shall meet the requirements of CDOT Standard Specifications, Section 709.01, grade 40 minimum.
- Minimum compressive strength shall be 4000 psi; minimum modulus of rupture or flexural strength shall be 600 psi.

15.8.3 Aggregate Base Course Material

This material shall consist of hard, durable particles or fragments of stone or gravel, crushed to required sizes, containing an appropriate quantity of sand or other finely divided mineral matter which conform to the requirements of AASHTO M 147, and to Section 703.03, CDOT Standard Specifications. In addition, the material shall have an R-value of 78 or greater or a CBR of 80 or greater and shall be moisture stable. Moisture stability is determined by R-value testing which shows a drop of 12 points or less in R-value between exudation pressures of 300 psi and 100 psi.

Only aggregate from approved sources shall be used. Approval of sources shall be at the discretion of the Engineering Division and submissions shall, at a minimum, consist of supplying documented gradation, Atterberg limits and CBR/R-value testing on an annual basis. Only two (2) types of crushed aggregate base course are acceptable. The gradation specifications for these two types of base course are listed below:

Table 15.13: Aggregate Base Course Materials & CDOT Specification

Sieve Designation	% Passing by Weight	
	Class 5	Class 6
1½"	100	---
1"	95-100	---
¾"	---	100
No. 4	30-70	30-65
No. 8	---	25-55
No.200	3-15	3-12
Liquid Limit (LL)	30, Maximum	30, Maximum

15.9 Materials & Construction Practices

15.9.1 Curing

Finishing and consolidation shall be performed per CDOT Standard Specifications. Immediately after the finishing operations have been completed and as soon as marring of the concrete will not occur, the entire surface of the newly placed concrete shall be covered and cured in accordance with the following methods. In all cases in which curing requires the use of water, the curing shall have prior right to all water supply or supplies. Failure to provide sufficient cover material or lack of water to adequately take care of both curing and other requirements shall be cause for immediate suspension of concreting operations. The concrete shall not be left exposed for more than one-half (1/2) hour between stages of curing or during the curing period.

Impervious Membrane Method

The entire surface of the pavement shall be sprayed uniformly with an accepted white pigmented curing compound immediately after the finishing of the surface and before the set of the concrete has taken place. Curing compound shall be applied under pressure at the rate of one (1) gallon to not more than one hundred-and-fifty (150) square feet by mechanical sprayers. The spraying equipment shall be the fully atomizing type equipped with a tank agitator. At the time of use, the compound shall be in a thoroughly mixed condition with the pigment uniformly dispersed throughout the vehicle. During application, the compound shall be stirred continuously by effective mechanical means. Hand-spraying of odd widths or shapes and concrete surfaces exposed by the removal of forms will be permitted. Curing compounds shall not be applied to the inside faces of joints yet to be sealed.

Membrane-curing compounds shall be wax base Protex DW3 or equal and meet the requirements of AASHTO M 148, Type 2, latest edition. Should the film become damaged from any cause within the required curing period, the damaged portions shall be repaired immediately with additional compound. Upon removal of side forms, the side of the slabs exposed shall be protected immediately to provide a curing treatment equal to that provided for the surface.

Wet Burlap Curing

After completion of the finishing operations, the surface of the concrete shall be entirely covered with burlap mats. The mats used shall be in such length or width that as laid they will extend at least twice the thickness of the concrete beyond the edges of the slab or structure. They shall be placed so the entire structure and all edges of the concrete, when forms are removed, are completely covered. This covering shall be placed as soon as the concrete has set sufficiently to prevent marring of the surface. After being placed, the mats shall be thoroughly saturated with water by spraying with a mist spray. The burlap shall be placed and weighted down so it remains in contact with the surface covered and covering shall be maintained fully wetted and in position for seven (7) days after the concrete has been placed. If it becomes necessary to remove the burlap for any reason, the concrete shall not be exposed for a period of more than one-half (1/2) hour. This method of curing shall not be used when the outside air temperature is below thirty-two degrees Fahrenheit (32o F) unless heated enclosures are provided.

Plastic Sheet Curing

As soon after the completion of the finishing operation as the concrete has set sufficiently to prevent marring of the surface, the top surface and sides shall be entirely covered with plastic sheet materials. The plastic sheet as prepared for use shall have dimensions such that each unit as laid will extend beyond the edges of the concrete at least twice the thickness of the concrete. The units as used shall be lapped at least twelve inches (12") and the laps of plastic sheet shall be secured in such a manner that they do not open or separate. The plastic shall be placed and weighted so it remains in contact with the surface covered during the entire curing period of seven (7) days.

Waterproof Paper Curing

The procedures used for plastic sheet curing shall be used when waterproof paper is used in curing concrete.

Insulation Pad

Insulation pads or other thermal devices may be used to protect concrete in cold weather.

Other

Other acceptable curing methods may be used upon review and acceptance by the Engineering Division.

15.9.2 Curing in Cold Weather

When the air temperatures may be expected to fall below thirty-five degrees Fahrenheit (35o F), the Contractor's written, detailed proposal for protecting the concrete must be accepted by the Engineering Division before commencement of the paving operation. A sufficient supply of straw, hay, grass or other suitable material shall be provided along the work. The methods and materials used shall be such that a minimum temperature of forty-degree Fahrenheit (40o F) will be maintained at the surface of pavement. Acceptance of the Contractor's proposed method shall not relieve the Contractor of the responsibility for the quality and strength of the concrete placed during cold weather. Any concrete damaged by frost action shall be removed and replaced at the Contractor's expense. During paving operations, day or night, when the air temperature reaches thirty-five degrees Fahrenheit (35o F) and is falling, placement of concrete shall cease, and the previously approved protection method shall be initiated. All concrete placed within the previous seventy-two (72) hours shall be protected for a minimum of five (5) days after initial placement of the concrete.

Admixtures for curing or temperature control may be used only when permitted by the Engineering Division.

When concrete operations have been completed, the Contractor shall be responsible for the clean-up and removal of all leftover or waste materials resulting from any of his activities. All curbs shall be properly backfilled, and the adjacent ground left in an acceptably neat and presentable condition.

15.9.3 Protection Against Rain

In order that the concrete may be properly protected against the effects of rain before the concrete is sufficiently hardened, the Contractor shall be required to have materials available at all times for the protection of the edges and surface of the unhardened concrete. Such protective materials shall consist of standard metal forms or wood plank having a nominal thickness of not less than two inches (2") and a nominal width of not less than the thickness of the pavement at its edge for the protection of the pavement edges and covering material such as burlap or cotton mats, curing paper, or plastic sheeting material for the protection of the surface of the pavement. When rain appears imminent or when requested by the Engineering Division, all paving operations shall stop, forms shall be placed against the sides of pavement and protective covering shall be placed over the surface of unhardened concrete.

15.9.4 Opening to Traffic

Opening to traffic, including the Contractor's vehicles, shall not be permitted until the flexural strength of the concrete, as indicated by the modules of rupture of beams tested in conformity with the latest ASTM Standard Method of Test for "Flexural Strength of Concrete Using Simple Beam With Third-Point Loading." Designation C-78 is at least five hundred (500) pounds per square inch or the compressive strength of six-inch by 12-inch (6" x 12") cylinders, tested in conformity with the latest ASTM Standard Method of Test for "Compressive Strength of Molded Concrete Cylinders." Designation C-39 is at least three thousand (3000) pounds per square inch. These tests shall be performed when the concrete is seven (7) days old unless otherwise requested by the Contractor. If permanent shoulders are not in place, a six-foot (6') wide temporary earth shoulder shall be placed against the outside pavement edges before traffic is allowed on the pavement. Opening to traffic shall not constitute a final acceptance of the pavement.

15.9.5 Defects

The City will allow either flexural or compressive Quality Control Testing at the Contractors expense. The Contractor shall be responsible for process control testing of all elements of the project. Before final inspection and acceptance, tolerances and smoothness shall be tested by means of surface-testing machine or a straightedge applied to each separate lane of pavement. All surface variations of one-eighth inch (1/8") or more in ten feet (10') shall be ground off. Brush-hammering shall not be permitted. Sections of pavement containing depressions with a depth in excess of one-eighth inch (1/8") in ten feet (10') shall be removed and replaced at the Contractor's expense. Such removed sections shall not be less than full-lane width and full distance between joints in length. Slabs containing excessive cracking, fractures, spalling or other defects shall be removed and replaced as above, when directed by the Engineering Division.

15.10 Utility Pothole Repair

15.10.1 General

Contractor shall be required to restore all utility potholes in a timely fashion as determined by the Engineering Division or designee. Potholes located in pavement sections must be backfilled with approved Controlled Low Strength Material (refer to Section 9.3.4). Potholes located in concrete pavement sections require replacement of entire concrete panel section. Potholes located in asphalt pavement sections require replacement of a minimum of 2 foot by 2-foot section. Refer to Section 5.8 for pavement depth requirements.

15.11 Bridges & Major Drainage Structures

15.11.1 General

- All culvert pipe, box culverts, and bridges which will ultimately be maintained by the City of Northglenn shall conform to the following:
- AASHTO "Standard Specifications for Highway Bridges," latest edition, and applicable interims.
- Colorado Department of Transportation's "Standard Specifications for Road and Bridge Construction," latest edition.
- Colorado Department of Transportation's "Bridge Manual," Volumes I and II
- All structures shall be designed to an HS-20 loading.
- All box culverts and bridges shall have the year of construction permanently indentured on the downstream headwall face in legible numbers. The numbers shall be three inches (3") high by one-and-one-half inches (1-1/2") deep in the headwallface.
- All box culvert and bridge designs shall be certified by a Professional Engineer registered in the State of Colorado who is competent to perform such designs.

15.12 Material Specifications

15.12.1 Subbase

Subbase material, if allowed, shall be composed of granular material consisting, essentially, of sand, gravel, rock, slag, disintegrated granite or a combination of such materials. The coarse portions of the material shall be sound fragments of the crushed or uncrushed materials enumerated above. Supplied material shall be a well-graded mixture containing sufficient soil mortar, crushed dust or other proper quality binding material which, when placed and compacted in the roadway structure, will result in a firm, stable foundation. Material composed of uniform size particles or which contains pockets of excessively fine or excessively coarse material, will not be acceptable for use.

This material need not be crushed but shall be graded within the following limits:

Table 15.14: Classification Table for Subbase

Sieve Size	% Passing
2-1/2 Inch Screen	100
2-Inch Screen	95-100
#4 Mesh Sieve	30-60
#200 Mesh Sieve	5-15

Note: Liquid Limit -- 35 Maximum
Plasticity Index -- 6 Maximum

15.12.2 Base

Base material, if allowed, shall consist of a foundation course composed of crushed gravel or crushed stone and filler constructed on the prepared subgrade or subbase course. Materials and construction shall be in accordance with the requirements of the Colorado Department of Transportation's "Standard Specifications for Road and Bridge Construction," Section 703. Gradation shall be Class 6 (3/4-inch maximum) in accordance with the following gradation:

Table 15.15: Classification Table for Aggregate Base Course

Sieve Size	% Passing
3/4 Inch Screen	100
#4 Mesh Sieve	30-65
#8 Mesh Sieve	25-55
#200 Mesh Sieve	3-12

Note: Liquid Limit -- 30
Maximum Plasticity Index -- 6
Maximum R- Value Minimum -- 78

15.13 Bituminous Materials & Pavements

15.13.1 Prime Coat

Materials shall be in accordance with the requirements of the Colorado Department of Transportation's "Standard Specifications for Road and Bridge Construction."

15.13.2 Hot Bituminous Pavement

All pavements shall be hot bituminous pavement of the plant mix type unless otherwise approved in writing by the Engineering Division. Materials shall be in accordance with the Colorado Department of Transportation's "Standard

Specifications for Road and Bridge Construction”, Sections 702 and 703, and the following exceptions and/or requirements:

- The asphalt cement shall be Superpave Performance Graded Binders and shall conform to the requirements listed in table 702-2 of the Colorado Department of Transportation’s “Standards and Specifications for Road and Bridge Construction” (Taken from AASHTO Provisional Standard MP1) and the following:
 - On arterial streets the grade of asphalt cement for the top layer shall be PG 76-28 (Polymer Modified). The bottom layers may be PG 64-22.
 - On all other street classifications, the grade of asphalt cement for the top layer shall be PG 64-28 (Polymer Modified). The bottom layers may be PG64-22.
- The top layer of asphalt shall be a stone matrix asphalt (SMA) or hot bituminous pavement (HBP) Grading SX. The lower layers may consist of HBP Grading SG or HBP Grading S. SMA mixes will only be required as determined by the Engineering Division. The minimum layer thickness shall be 1.5 inches and each layer should be a minimum of two times the maximum aggregate size.

15.13.3 Tack Coat

When is specified on the accepted plans or required by the Engineering Division, all materials shall be in accordance with the requirements of the Colorado Department of Transportation’s Standard Specifications for Road and Bridge Construction. Bituminous material shall be SS-1h emulsion.

15.13.4 Seal Coat

When seal coat is required, all materials shall be in accordance with the requirements of the Colorado Department of Transportation’s Standard Specifications for Road and Bridge Construction. The type of bituminous material cover aggregate and rates of application will be as shown on the accepted construction plans.

15.13.5 Rejuvenating Agent

When a rejuvenating agent is specified on the accepted construction plans or required by the Engineering Division, all materials shall be in accordance with the requirements of the Colorado Department of Transportation’s Standard Specifications for Road and Bridge Construction. The rejuvenating agent shall be as shown on the accepted construction plans or as specified by the Engineering Division.

15.13.6 Appurtenant Structures Concrete

Concrete used in the construction of curb, gutter, sidewalk, drive cuts and other appurtenant roadway concrete structures shall be in accordance with **Chapter 6 – Earthwork & Erosion Control** of these STANDARDS AND SPECIFICATIONS.

15.13.7 Structure Backfill Material

Structure backfill shall comply with Colorado Department of Transportation’s specifications for Class I material. Flowfill may be required in lieu of Class 1 backfill as determined by the Engineering Division. The requirements for flowfill are described in **Chapter 14 – Trenching, Backfilling, & Compacting – Utilities**.

15.14 Portland Cement Concrete Pavement -- Materials

15.14.1 General

Concrete materials, including fine aggregates, coarse aggregates, Portland cement, forms, reinforcing steel, water, joints, metal supports, expansion tubes, curing materials, admixtures and bonding agents shall comply with the

Colorado Department of Transportation’s Standard Specifications for Road and Bridge Construction (Latest Edition). Fly ash may be used in the concrete pavement mixtures.

15.14.2 Test Specimens

The Contractor shall furnish the concrete necessary for casting test cylinders. See Table 15.16 for the cylinders test requirements.

Table 15.16: Concrete Cylinder Test Requirements

Type of Test	Frequency
Gradation (aggregate)	1 per 2500 sq. yard or fraction thereof for each size aggregate
Moisture Content, fine aggregate	1 per day or as often as needed for quality control
Moisture Content, coarse aggregate	1 per day minimum where moisture content is +0.5 percent from SSD condition
Slump	1 per set of cylinders and as often as needed for quality control
Air Content	1 per set of cylinders and as often as needed for quality control
Yield and Cement Factor	1 per set of cylinders and as often as needed for quality control
Compressive Strength	1 set of four (4) cylinders per 5000 sq. yards or major fraction thereof on each day pavement is placed, with two (2) cylinders to be field cured. One additional set shall be made if the Contractor intends to open early for traffic
Thickness	1 per 1250 linear feet each traffic lane on freshly finished concrete and as often as needed for quality control

The degree and frequencies of all concrete testing beyond normal specified frequencies, if necessary, to assure quality control, shall be determined by the Engineering Division at the time of concrete construction. All concrete testing necessary beyond normal specified frequencies to assure quality control shall be paid for by the Contractor.

15.15 Portland Cement Concrete Pavement -- Equipment

15.15.1 General

All equipment necessary for the proper preparation of the subgrade, placing, finishing and curing of the concrete pavement shall be on the project in good working condition and shall have been inspected by the Engineering Division or designed before the Contractor will be permitted to begin paving operations. Throughout construction, the Contractor shall maintain sufficient, adequate equipment to assure the proper execution of the work.

15.15.2 Roller

Final subgrade compaction shall be by means of a self-propelled roller having a weight on the rear wheels of the roller of not less than two-hundred-and-fifty (250) pounds per inch of tread. Vibratory rollers may be used with the permission of the Engineering Division. The use of rubber-tired rollers is encouraged.

15.15.3 Subgrade Planer

The subgrade planer shall have an adjustable cutting edge which shall be set to leave the subgrade at the elevation necessary to produce pavement of the thickness shown on the plans. Each end of the planer shall be supported on the

forms by means of two rollers with enough spacing to maintain stability. The planer shall be of enough weight to maintain contact with the forms during planning operations. Wheels or rollers on previously placed concrete shall be rubber-faced and shall be adjusted so that bearing on concrete shall not be less than three inches (3") from the edge of a pavement.

15.15.4 Forms

Side forms shall be made of metal except on curves of less than an one-hundred-foot (100') radius where wooden forms may be used. Forms shall have base width of not less than eight inches (8") for all forms more than eight inches (8") in height. All side forms less than eight inches (8") in height shall have a base width of not less than six inches (6"). The minimum length of each section of form used shall be ten feet (10'). Each section of form shall be straight and free from bends or warps.

The maximum deviation of the top surface of any section shall not exceed one-eighth inch (1/8"). The inside face shall not deviate more than one-fourth inch (1/4") from a straight line. The method of connection between sections shall be such that the joint thus formed shall be free from movement in any direction. Forms shall be of such cross-section and strength and so secured as to resist the pressure of the concrete when placed and the impact and vibration of any equipment which they support without springing or settlement.

Each ten-foot (10') length of form shall have at least three (3) form braces and pin sockets which shall be spaced at intervals of not more than five feet (5'), having the end brace and socket not less than six inches (6") from the end of the form.

Forms that are not required to support a mechanical finishing machine, subgrade planer or other similar heavy equipment may, upon approval of the Engineering Division, be made of wood. They shall have sufficient stiffness and be so staked to remain vertical and true to lines and grade during the placing and finishing of the concrete. Straight wood forms shall have a thickness of not less than one-and-one-half inches (1-1/2"). Wood forms used at intersection radius points may be one-fourth inch (1/4") thick. All wood forms shall be dressed on the side supporting the concrete and on their upper edge.

Curb forms, if used, shall be made of steel, except where returns of small radius or other special sections make the use of steel forms impractical. Back forms for curbs shall be rigidly attached to the side forms for the pavement slab using all the fastening provided by the manufacturer of the forms. Slip forms or curb mules may be used.

15.15.5 Vibrators

Vibratory units shall be capable of frequencies of not less than ten thousand (10,000) vibrations per minute in air and shall produce vibration in vertical and horizontal planes and ensure a downward vibration of intensity as great as in other directions to provide thorough vibration through the full depth of the concrete. The unit shall be adjustable to approximately the cross-section of the finished surface. Vibration shall not be used to cause concrete to flow or run into position in lieu of placing and shall not be prolonged to the point where segregation occurs.

15.15.6 Finishing Equipment

A screed or template shall be used to roughly strike off the first layer of concrete to permit placing of required reinforcement in the specified position.

The Contractor shall furnish an approved mechanical finishing machine of the screening and troweling type. It shall be designed and operated both to strike off and to consolidate. The finishing machine shall be of adequate strength to withstand severe use and shall be fully and accurately adjustable to make the pavement conform to the required cross-section shown on the plans. If it is necessary to operate one or both sets of wheels on previously placed concrete, they

shall be rubber-faced and shall be adjusted so that bearing on concrete will not be less than three inches (3") from the edge of the pavement.

Such additional hand equipment -- including but not limited to wooden floats, straightedges, bridges, edgers, etc. required for proper finishing -- shall be furnished by the Contractor.

15.15.7 Concrete Saw

When sawing joints, the Contractor shall provide sawing equipment adequate in number of units and power to complete the sawing with a water-cooled diamond-edge saw blade or an abrasive wheel to the required dimensions and at the required rate. The Contractor shall provide at least one stand-by saw in good working order and meeting the same requirements as stated above. An ample supply of saw blades shall always be maintained at the site of the work during sawing operations. The Contractor shall provide adequate artificial lighting facilities for night sawing. All of this equipment shall be on the job both before and continuously during concrete placement.

15.16 Portland Cement Concrete Paving -- Mixing

15.16.1 General Mixing

Concrete may be mixed in a central mix plant, or in truck mixers. The mixer shall be of an approved type and capacity. Mixing time shall be measured from the time all materials, except water, are placed in the drum.

The time elapsing from the time water is added to the mix (or cement comes in contact with aggregate) until the concrete is deposited in place at the site of the work shall not exceed forty-five (45) minutes when the concrete is hauled in non-agitating trucks nor ninety (90) minutes when hauled in truck mixers or agitating trucks. The Contractor may use approved mixes utilizing admixtures which conform to AASHTO M 194, latest edition, Types A, B, and D. The use of AASHTO M 194 admixtures Types C and E may be used only when specifically provided for in the contract or upon written permission from the Engineering Division.

15.16.2 Stationary Mixing

When mixing or in a central mixing plant, the mixing time shall not be less than fifty (50) seconds nor more than ninety (90) seconds. Four (4) seconds shall be added to the specified mixing time if timing starts the instant the skip reaches its maximum raised position. Mixing time ends when the discharge chute opens. Transfer time in multiple drum mixers is included in mixing time. The contents of an individual mixer drum shall be removed before a succeeding batch is emptied therein.

The volume of concrete mixed per batch may exceed the mixer's nominal capacity in cubic feet, as shown on the manufacturer's standard rating plate on the mixer, up to ten percent (10%) provided concrete test data for strength, segregation, and uniform consistency are satisfactory and provided spillage of concrete does not occur.

The batch shall be charged into the drum such that a portion of the mixing water shall enter in advance of the cement and aggregates. The flow of water shall be uniform, and all water shall be in the drum by the end of the first fifteen (15) seconds of the mixing period. The throat of the drum shall be kept free of accumulations that may restrict the free flow of materials into the drum.

The timing device on stationary mixers shall be equipped with a bell or other suitable warning device adjusted to give a clearly audible signal each time the lock is released. In case of failure of the timing device, the Contractor will be permitted to operate while it is being repaired, provided he furnishes an approved timepiece equipped with minute and second hands. If the timing device is not placed in good working order within twenty-four (24) hours, further use of the mixer will be prohibited until repairs are made.

15.16.3 Ready-Mixed Concrete

The use of ready-mixed concrete in no way relieves the Contractor or developer of the responsibility for proportion, mix, delivery or placement of concrete. All concrete must conform to all requirements of these STANDARDS AND SPECIFICATIONS and ASTM C-94 and AASHTO M 157.

The City shall have free access to the mixing plant at all times. The organization supplying the concrete shall have sufficient plant and transportation facilities to assure continuous delivery of the concrete at the required rate. (The Contractor will collect delivery or batch, tickets from the driver for all concrete used on the project and deliver them to the Engineering Division.)

Batch tickets shall provide the following information:

- Weight and type of enforcement
- Weights of fine and coarse aggregates
- Volume (in gallons) of water, including surface water on aggregates.
- Quantity (cubic yards) per batch
- Times of batching and discharging of concrete.
- Name of batch plant
- Name of Contractor
- Type of mixture (mix designations code)
- Name and amount of admixture
- Date and truck number

15.16.4 Mixing Proportions of Concrete Materials

Proportioning shall conform to the requirements set forth in the Colorado Department of Transportation's Standard Specifications for Road and Bridge Construction (Latest Edition).

15.16.5 Limitations of Mixing

Concrete shall be mixed, placed, and finished only when the natural light is enough unless an adequate and approved artificial lighting system is provided. Unless authorized in writing by the Engineering Division, mixing and concreting operations shall be discontinued when a descending air temperature in the shade and away from artificial heat reaches forty degrees Fahrenheit (40° F) and not resumed until an ascending air temperature in the shade and away from artificial heat reaches thirty-five degrees Fahrenheit (35° F).

When concreting is authorized during cold weather, the aggregates may be heated by either steam or dry heat prior to being placed in the mixer. The apparatus used shall heat the mass uniformly and shall be arranged to preclude the possible occurrence of overheated areas which might injure the materials. Unless otherwise authorized by the Engineering Division, the temperature of the mixed concrete shall not be less than fifty degrees Fahrenheit (50° F) and not more than eighty degrees Fahrenheit (80° F) at the time of placing it in the forms.

If the air temperature is thirty-five degrees Fahrenheit (35° F) or less at the time of placing concrete, it will be required that the water and/or the aggregate be heated to not less than seventy degree Fahrenheit (70o F) nor more than one-hundred-fifty degrees Fahrenheit (150° F). Concrete shall not be placed on frozen subgrade nor shall frozen aggregates be used in the concrete. In concreting operations during the summer months, maximum temperature of the mixed concrete shall not exceed ninety degrees Fahrenheit (90° F).

In cold weather, aggregates and water may be heated as part of the batching operation but they shall not be heated beyond a temperature of one-hundred-fifty degrees Fahrenheit (150°F). Aggregates shall not be heated directly by gas or oil flame or on sheet metal over direct flame. Materials containing frost or lumps of frozen material shall not be used in the mix and their presence in the concrete shall be cause for rejection of that batch.

15.17 Concrete for Sidewalk & Crosspans

15.17.1 General

This specification enumerates the requirements for the materials, storage, transportation, measuring, mixing, placing and curing of Portland cement concrete. This specification applies to all Portland cement concrete used in sidewalks, driveways, approaches, patches, manholes, inlets and other structures constructed in the City of Northglenn.

Specifications for Portland cement concrete pavement are in this chapter of these STANDARDS AND SPECIFICATIONS. Engineering plans, licenses, permits, inspection, warranty and acceptance shall be as detailed in these STANDARDS AND SPECIFICATIONS for the applicable type of construction involved. Permits shall be obtained before work begins. The Contractor shall contact the Public Works Department twenty-four (24) hours in advance of concrete placement when the form work is ready to receive the concrete. Where required, compaction test results shall verify the adequacy of all ground upon which concrete is to be placed.

15.17.2 Design Standards

Design criteria for the various elements using concrete are specified in other chapters of this document. Design specifications for sidewalks, curb and gutter, driveways, inlets, sidewalk and concrete paved streets are in **Chapter 11- Roadways & Pavements**. Design specifications for concrete pipe, manholes, inlets and other drainage and wastewater concrete structures are in **Chapter 8 - Water System, Chapter 7 - Sanitary Sewer System** and **Chapter 9 - Storm Drainage & Other Concrete Facilities**. Design specification relative to traffic signals and traffic control items is in **Chapter 16- Temporary Traffic Control**.

15.17.3 Placing Concrete

Preparation

Before depositing concrete, debris shall be removed from the space to be occupied by the concrete and the forms. Concrete shall not be placed until all forms and reinforcing steel have been inspected and approved by the Engineering Division. The soil receiving the concrete shall be moist, but not wet, and shall not contain frost or frozen material. Specifications for subgrade preparation are in **Chapter 11- Roadways & Pavements**.

Timing

Concrete which has developed initial set or does not have workable consistency shall not be used. Concrete shall be continuously mixed or agitated from the time the water is added until the time of use and shall be completely discharged from the truck mixer or truck agitator within one-and-one-half (1-1/2) hours after it comes in contact with the mixing water or with the aggregates. Re-tempered concrete will not be allowed.

Concrete Temperature

At the time of concrete placement, the mix temperature shall be between fifty degrees Fahrenheit (50° F) and ninety degrees Fahrenheit (90° F). In cold weather, aggregates and water may be heated as part of the batching operation but they shall not be heated beyond a temperature of one-hundred-and-fifty degrees Fahrenheit (150° F). Aggregates shall not be heated directly by gas or oil flame or on sheet metal over direct flame. Materials containing frost or lumps of frozen material shall not be used in the mix and their presence in the concrete shall be cause for rejection of that batch.

Handling

Concrete shall be handled from the mixer to the place of final deposit as rapidly as possible by methods which prevent separation or loss of ingredient. The concrete shall be deposited in the forms as nearly as practicable in its final position to avoid rehandling. Concrete shall be deposited in continuous layers, the thickness of which generally shall not exceed twelve inches (12"). Concrete shall be placed in one continuous operation, except where keyed construction joints are shown on the plans or as approved by the Engineering Division. Delays in excess of thirty (30) minutes may require removal and replacement of that pour, as determined by the Engineering Division.

Concrete shall be placed in a manner that will avoid segregation and shall not be dropped freely more than five feet (5'). If segregation occurs, the Engineering Division may require the concrete to be removed and replaced at the Contractor's expense. Necessary hand spreading shall be done with shovels and not with rakes.

Concrete shall be thoroughly compacted or vibrated. All concrete shall be compacted by internal vibration using mechanical vibrating equipment, except that concrete in floor slabs, sidewalks, or curb and gutter, not poured against form linings, shall be either tamped or vibrated. Care shall be taken in vibrating the concrete to vibrate only long enough to bring a continuous film of mortar to the surface. Vibration shall stop before any segregation of the concrete occurs. Mechanical vibrators shall be an approved type as specified in ACI Publication 309, Chapter 5 (Latest Edition). Vibrators shall not be used to move or spread the concrete. Any evidence of lack of consolidation or over consolidation will be regarded as sufficient reason to require the removal of the section involved and its replacement with new concrete at the Contractor's expense. The Contractor shall be responsible for any defects in the quality and appearance of the completed work. A 2nd vibrator must be onsite.

Workability

The consistency of concrete shall be kept uniform for each class of work and shall be checked by means of a slump test. The workability of the concrete will be varied as directed by the Engineering Division. At all times, concrete shall have a consistency such that it can be worked into corners and angles of the forms and around joints, dowels and tie bars by the construction methods which are being used without excessive spading, segregation or undue accumulation of water or laitance on the surface. If, through accident, intention or error in mixing, any concrete that fails to conform to the proportions of the approved mix design, such concrete shall not be incorporated in the work but shall be discarded off the project site as waste material at the Contractor's expense. NO WATER MAY BE ADDED AT THE JOB SITE WITHOUT PERMISSION OF THE ENGINEERING DIVISION or his representative. If approval is obtained and water is added at the job site, slump tests shall be run and test cylinders cast following the addition of the water. Any expense incurred in excess of ordinary tests will be borne by the Contractor.

Weather Restrictions

- **Hot Weather:** Except by written authorization, concrete will not be placed if the temperature of the plastic concrete cannot be maintained at ninety degrees Fahrenheit (90° F) or lower. The placement of concrete in hot weather shall comply with ACI 305 (Latest Edition).
- **Cold Weather:** During extreme weather conditions, placing of concrete will be permitted only when the temperature of the concrete placed in the forms will not be less than fifty degrees Fahrenheit (50° F), nor more than ninety degrees Fahrenheit (90° F). To maintain this temperature range, the Contractor shall provide acceptable heating apparatus for heating the aggregates and the water. Concrete slabs shall not be placed, regardless of temperature conditions, if the supporting ground is frozen or contains frost. Use of salt or other additives to prevent concrete from freezing will not be allowed. Concrete which has been frozen shall be completely removed and replaced as directed by and to the satisfaction of the Engineering Division.

Concrete may be placed when the air temperature in the shade is at least forty degrees Fahrenheit (40° F) and rising. No concrete shall be placed, regardless of the present temperature, when the weather forecast promises freezing weather before final set of the concrete unless special means of heating and protection are used. Protection against freezing is

the Contractor's responsibility regardless of the weather forecast or climatic conditions at the time of placing. During cold weather conditions, concrete less than seventy-two (72) hours old shall be protected as follows:

Table 15.17: Concrete Placement Temperature Protection Requirements

Forecast Low Temperatures (per National Weather Service)	Protection
Between 40 and 32 Degrees	One layer of plastic or burlap
Between 31 and 25 Degrees	One layer of plastic and one layer of burlap, or two layers of burlap
Below 25 Degrees	Six inches (6") of hay or straw and two layers of plastic or burlap in addition to regular curing method, or equivalent commercial insulating material in addition to regular curing method

These coverings must remain in place until the concrete is at least five (5) days old. When straw is required on concrete and the concrete is cured with only curing compound, the fresh concrete shall be covered with a layer of burlap or plastic before application of straw. Heated enclosures may be utilized in lieu of protection requirements cited above. If used, such enclosures shall be maintained for seven (7) days.

Jointing

EXPANSION JOINTS:

Expansion joint material shall be provided at the following locations and shall be in place prior to the placing of concrete:

- Between new concrete and existing masonry buildings
- As shown on the drawings
- As directed by the Engineering Division

CONTRACTION JOINTS:

Transverse joints shall be placed at maximum intervals of ten feet (10') to control random cracking. Joints shall be formed, sawed or tooled to a minimum depth of one-third (1/3) of the total thickness, but no less than 1.5 inches. Contraction joints shall be placed as follows:

- Not more than ten feet (10') nor less than six feet (6') apart in curb and gutter and combination curb-walk.
- Not more than the walk width in non-monolithic concrete sidewalk.
- At least two joints equally spaced at not greater than ten-foot (10') intervals as applicable in driveways.
- As accepted and shown on the plans for special concrete structures.

Finishing & Curing

In addition to the curing techniques unique to hot and cold weather placement, adequate attention shall be given to finishing and curing the fresh concrete. Exposed faces of curbs and sidewalks shall be finished to true line and grade, as shown on the plans. The surface shall be floated to a smooth, but not slippery finish. The addition of surface water to assist in the finishing process is prohibited. Sidewalk and curb shall be broomed or combed and edged, unless otherwise indicated by the Engineering Division. After completion of brooming and before concrete has taken its initial set, all edges in contact with the forms shall be tooled with an edger having a three-eighths inch (3/8") radius. No dusting or topping of the surface or sprinkling with water to facilitate finishing will be permitted.

Immediately following the removal of the forms, all fins and irregular projections shall be removed from all surfaces except from those which are not to be exposed or are not to be waterproofed. On all surface's cavities produced by form ties, honeycomb spots, broken corners or edges and other defects shall either be thoroughly cleaned, moistened with water, and carefully pointed and trued with a mortar consisting of cement and fine aggregate or removed and replaced at the direction of the Engineering Division. The surface shall be left sound, smooth, even and uniform in color. Mortar used in pointing shall not be more than thirty (30) minutes old. All construction and expansion joints in the completed work shall be left carefully tooled and free of all mortar and concrete. The joint filler shall be left exposed for its full length with clean and true edges.

Fresh concrete shall be adequately protected from weather damage and mechanical injury during the curing periods. The selected curing process shall be started as soon as it can be done without injury to the concrete surface. The use of a membrane-curing compound is recommended. The following curing procedures may be used subject to the approval of the Engineering Division.

WET BURLAP CURING:

After completion of the finishing operations, the surface of the concrete shall be entirely covered with burlap mats. The mats used shall be in such length or width that as laid they will extend at least twice the thickness of the concrete beyond the edges of the slab or structure. They shall be placed so that the entire structure and all edges of the concrete, when forms are removed, are completely covered. This covering shall be placed as soon as the concrete has set sufficiently to prevent marring of the surface. After being placed, the mats shall be thoroughly saturated with water by spraying with a mist spray. The burlap shall be so placed and weighted down so it remains in contact with the surface covered, and the covering shall be maintained fully wetted and in position for seven (7) days after the concrete has been placed. If it becomes necessary to remove the burlap for any reason, the concrete shall not be exposed for a period of more than one-half (1/2) hour. This method of curing shall not be used when the outside air temperature is below thirty-two degrees Fahrenheit (32° F) unless heated enclosures are provided.

PLASTIC SHEET CURING:

As soon after the completion of the finishing operation as the concrete has set sufficiently to prevent marring of the surface, the top surface and sides shall be entirely covered with plastic sheet materials. The plastic sheet as prepared for use shall have such dimensions that each unit as laid will extend beyond the edges of the concrete at least twice the thickness of the concrete. The units as used shall be lapped at least twelve inches (12"), and the laps of plastic sheet shall be secure such that they do not open up or separate. The plastic shall be placed and weighted, so it remains in contact with the surface covered, curing the entire curing period of seven (7) days.

WATERPROOF PAPER CURING:

The procedures used for plastic sheet curing shall be used when waterproof paper is used in curing concrete.

LIQUID CURING MEMBRANE:

Immediately after the surface water has disappeared from the concrete surface, the liquid membrane curing compound (white pigmented) shall be sprayed under pressure to the concrete surface at a rate not less than one (1) gallon per one-hundred-fifty (150) square feet with a spray nozzle or nozzles, so it covers the entire pavement with a uniform water-impermeable film. If the forms are removed within seven (7) days, the exposed sides and edges shall be sprayed in the above-described manner or the backfill completed immediately.

INSULATION PAD:

Insulation pads or other thermal devices may be used to protect concrete in cold weather.

Wax base and resin base solutions shall not be used if linseed oil protection is to be applied to the concrete surface. If linseed oil protection is to be utilized, the method of curing shall be either linseed oil base curing compound, wet burlap, plastic sheet or waterproof paper curing.

Testing of Concrete

The requirements of this section shall apply to testing services for all concrete curb and gutter, sidewalk, slope paving, retaining walls, structures and for all miscellaneous concrete testing. Testing for concrete pavement shall be in accordance with this chapter of these STANDARDS AND SPECIFICATIONS.

The contractor shall furnish the concrete necessary for casting test cylinders. See Table 15.18 for the cylinders test requirements.

Table 15.18: Concrete Cylinder Test Requirement

Type of Test	Frequency
Gradation (aggregate)	1 per 2500 sq. yard or fraction thereof for each size aggregate
Moisture Content, fine aggregate	1 per day or as often as needed for quality control
Moisture Content, coarse aggregate	1 per day minimum where moisture content is +0.5 percent from SSD condition
Slump	1 per set of cylinders and as often as needed for quality control
Air Content	1 per set of cylinders and as often as needed for quality control
Yield and Cement Factor	1 per set of cylinders and as often as needed for quality control
Compressive Strength	1 set of four (4) cylinders per 50 cubic yards or major fraction thereof on each day pavement is placed, with two (2) cylinders to be field-cured and 1 additional set shall be made if the Contractor intends to open early for traffic
Thickness	1 per 1250 linear feet each traffic lane on freshly finished concrete and as often as needed for quality control

Repairs

After stripping of the forms, if any concrete is found to be not formed as shown on the drawings or is out of alignment or level or shows a defective surface, it shall be considered as not conforming with the intent of these STANDARDS AND SPECIFICATIONS and shall be removed and replaced by the Contractor at his expense unless the Engineering Division gives written permission to patch the defective area. In this case, patching shall be done as described in the following paragraphs. Defects that require replacement or repair are those that contain honeycomb, damage due to stripping of forms, loose pieces of concrete, bolt holes, tie-rod holes, uneven or excessive ridges at form joints and bulges due to movement of the forms and other deficiencies identified in the acceptance and warranty inspection. Ridges and bulges shall be removed by grinding. Honeycombed and other defective concrete that does not affect the integrity of the structure shall be chipped out and the vacated areas shall be filled in a manner acceptable to the Engineering Division. The repaired area shall be patched with a non-shrink, non-metallic grout with a minimum compressive strength of five thousand (5000) psi in twenty-eight (28) days. All repair areas treated with an epoxy bonding agent shall have the approval of the Engineering Division before the repair filling is placed.

Bolt holes, tie-rod holes and minor imperfections as accepted by the Engineering Division shall be filled with

dry-patching mortar composed of one (1) part Portland cement to two (2) parts of regular concrete sand (volume measurement) and only enough water so that after the ingredients are mixed thoroughly the mortar will stick together on being molded. Mortar repairs shall be placed in layers and thoroughly compacted by suitable tools. Care shall be taken in filling rod and bolt holes so that the entire depth of the hole is completely filled with compacted mortar. The mortar mix proportions described above are approximate.

An approved mix shall be prepared by a commercial testing laboratory to ensure that grout has a twenty-eight (28) day compressive strength equal to that of the area on which it is placed. All costs for mix design and testing shall be paid by the Contractor. Those areas with excessive deficiencies as determined by the Engineering Division shall be removed and replaced at the Contractor's expense. Where repairs are made in existing sidewalks, all edges of the old sidewalk allowed to remain shall be saw-cut to a minimum depth of two inches (2"). No rough edges will be permitted where new construction joins the old section. Unless directed by the Engineering Division, no section less than five feet (5') in length shall be placed or left in place. Where new sidewalk construction abuts existing sidewalks, the work shall be accomplished so that there is no abrupt change in grade between the old section and the new work.

15.18 Underground Facilities for Traffic Signals

15.18.1 Foundations

- **Concrete Foundations.** All foundations shall be Portland cement concrete conforming to the applicable requirements of construction specifications of the City of Northglenn, except as herein provided.
- **Stable Subgrade.** The bottom of concrete foundations shall rest on firm ground. Cast-in-place foundations shall be poured monolithically where practicable. The exposed portions shall be formed to present a neat appearance.
- **Foundation Grades.** Forms shall be true to line and grade. Tops of foundations, except as noted on plans, shall be finished to curb or sidewalk grade or as ordered by the Engineering Division. Forms shall be rigid and securely braced in place and inspected prior to the pouring of concrete. Conduit ends and anchor bolts shall be placed in proper position and in a template until the concrete sets.
- **Anchor Bolts.** Anchor bolts shall conform to the specifications and each individual bolt shall have two (2) flat washers, one (1) lock washer and two (2) nuts. Shims or other similar devices for plumbing or raking will not be permitted.
- **Moistened Ground.** Both forms and ground which will be in contact with the concrete shall be moistened before placing concrete. Forms shall not be removed until the concrete has thoroughly set.
- **Abandoned Foundations.** All abandoned foundations shall be removed and disposed of by the contractor. All conduit runs associated with an abandoned foundation shall be extended or abandoned as called for on the plans. When a foundation is removed, the hole shall be backfilled in accordance with State of Colorado and City of Northglenn standard practices.

15.18.2 Conduit

- **PVC Conduit.** All cables and conductors not shown on the plans as aerial cable shall be installed in conduit unless installed in poles, pedestals, or mast arms. All metal conduit referred to in the specifications and shown on the plans shall be rigid and adequately galvanized. All PVC conduit will be of Schedule 80 or greater.
- **Tracer wire.** Tracer wire shall be installed on all conduits.
- **Ream Conduits.** The end of all metal conduit, existing or new, shall be well reamed to remove burrs and rough edges. Field cuts of existing or new conduit shall be made square and true, and the ends shall butt together for the full circumference thereof. Slip joints of running thread will not be permitted for coupling metal conduit. When a standard coupling cannot be used, an approved threaded union coupling shall be used. All couplings shall be screwed up until the ends of the metal conduits are brought together.

- **Stub Out.** Where a "stub out" is called for on the plans, a sweeping ell shall be installed in the direction indicated and properly capped. The locations of ends of all conduits in structures or terminating at curbs shall be marked by a "Y" at least three inches (3") high cut into the face of the curb, gutter, or wall directly above the conduit.
- **Conduit Bends.** Conduit bends, except factory bends, shall have a radius of not less than six (6) times the inside diameter of the conduit. Where factory bends are not used, conduit shall be bent without crimping or flattening, using the longest radius practicable.
- **Depth.** Conduit shall be laid at a depth of not less than twenty-four inches (24") below the top of curb grade in sidewalk or grass areas and to a depth of not less than thirty inches (30") below the finished grade in all other areas. Conduit under railroad tracks shall be not less than forty-eight inches (48") below the bottom of the tie.
- **Trench Size.** Trench excavations for conduit shall be two inches (2") wider than the outside diameter of the conduit. Backfilling of conduit trenches shall be accomplished by placing concrete or approved flow-fill up on the bottom surface of the existing or new roadway surface material. The remaining portion of the excavation shall be backfilled with the same type of material used to construct the existing roadway surface.
- **Conduit Run.** Conduit shall always enter a foundation, pull box or any other type structure from the direction of the run only.
- **Termination.** Conduits terminating in a pole shall extend approximately two inches (2") vertically above the foundation.
- **Nylon Line.** All conduit runs that exceed ten feet (10') in length shall have a continuous nylon line pulled into the conduit along with the specified electrical cables. The line shall be firmly secured at each end of the conduit run with a minimum slack of three feet (3'). The purpose of this line is to be able to pull future electrical cable through the existing conduit runs.
- **Clean Conduit.** Existing underground conduit to be incorporated into a new system shall be cleaned with a mandrel or blown out with compressed air.
- **Locate Wire.** Install a #12 locate wire inside the conduit throughout the length of the installation.
- **Spare Conduits.** New conduit runs shown on the plans are for bidding purposes only and may be changed with approval of the Engineering Division. The City may request the installation of spare conduits.

15.18.3 Pull Boxes

- Pull box shall always be installed in combination with a steel strain pole and at all other locations shown on the plans and at such additional points as ordered by the Engineering Division. The Contractor may install, at his own expense, any additional pull box that he may desire to facilitate the work.
- **Special Pull Boxes.** Special pull boxes which are required shall be fabricated and installed in general conformance with the size and details shown on standard drawings.
- **Design.** Pull boxes installed in concrete or similar finished areas shall be designed for such installations and shall be stackable and manufactured of a Precast polymer concrete material such as Quazite or an approved equal. Unless otherwise noted, pull box lids shall have the word "Traffic" cast into them. Pull boxes shall be installed so that the covers are level with curb or sidewalk grade or level with the surrounding ground when no grade is established. The bottoms of all pull boxes shall be bedded in crushed rock.
- **Conduit.** When a new conduit run enters an existing pull box, the contractor shall remove the pull box or tunnel under the side at no less than eighteen inches (18") and enter from the direction of the run. No new conduit will be allowed to enter a new or existing pull box in any other manner than that shown on standard drawings.

- **Loop Detector.** Loop detector pull boxes installed in the street shall be placed according to the plans or as directed by the Engineering Division. The lids shall have the word "Traffic" cast into them.

15.18.4 Detector Loop Wire Installation

The use of detector loops instead of cameras must be approved by the Engineering Division. If approved, each individual detector loop is to be terminated within a water valve housing as specified on the construction drawing, and each loop shall consist of one continuous wire, without splicing to this termination point. Any required series or parallel connections are to be at the termination point.

All loops shall have a tag attached to the leading clockwise lead of the loop. This tag shall be marked to indicate the relative location of the loop. This marking shall correspond directly to the loop designations on the intersection drawing provided in the contract.

Detector loop roadway slots shall be cut in asphalt that has a 6-inch minimum depth and sealed one-fourth inch (1/4") below the surface level of the roadway with 3M or approved equal. This sealer is to be used whether or not the roadway is to be overlaid.

The contractor shall include cost for loop wire, saw cutting, sealant, splice and test for a complete installation of the loop to the termination point for the pay item price.

15.18.5 Conductor & Cable

Wiring shall conform to appropriate articles of the National Electric Code. Wiring within cabinets, junction boxes, etc., shall be neatly arranged.

Powdered soap stone, talc or other approved lubricant shall be used in placing conductors in conduit.

A common neutral conductor, separate from the signal light circuit neutral, shall be used for all low-voltage circuits, including the detectors and pedestrian push-button circuits.

Splicing of cable will not be permitted in conduit or pull boxes or outside of signal heads, standards, or foundations.

In no case shall any shellac compounds be used. Wire nut type connectors shall be used on all splices made above ground level. Detector loop lead-in splices in underground systems shall be waterproofed with 3M splice kits or City approved equivalent. A minimum of twelve inches (12") of slack shall be left at each splice except within hand-holes where twenty-four inches (24") shall be left.

When conductors and cables are pulled into the conduit, all ends of conductors and cables shall be taped to exclude moisture and shall be so kept until the splices are made or terminal appliances attached. Ends of spare conductors shall be taped and marked.

Cable shall be stranded. For span wire type installations, cable shall be installed where specified on the plans and secured to messenger cable with cable rings in accordance with standard practices. Aerial cable shall be supported by strand vices of proper size and strength as well as insulators used where necessary.

A small permanent tag on which the direction and phase is printed, in the order named, using the codes given in "Cable Schedule," shall be securely attached near the end of each conductor at each controller, standard, or pull box where conductors are separated. Where direction and phase are not clearly indicated by conductor insulation, additional tags shall be used.

Inboard and outboard heads, mounted on mast arms, are to be wired separately from head to base of pole. Seven conductors for outbound and side-of-pole signal heads required.

15.18.6 Bonding & Grounding

Metallic cable sheaths, conduit, metal poles and foundations shall be made mechanically and electrically secure to form a continuous system and shall be effectively grounded. Bonding and grounding jumpers shall be copper wire, No. 8 AWG, for all systems. Beldon cable sheath for loop detectors to be grounded in control cabinet only. The other end of the sheath to be left ungrounded.

Bonding of standards shall be by means of a bonding wire attached to a bolt or a three-sixteenths inch (3/16") or larger bolt installed in the lower portion of the shaft.

At each pull box the ground electrode shall be a one-piece copper ground rod of five-eighths inch (5/8") diameter and eight feet (8') in length, driven into the ground so that the top is two inches (2") above the bottom of the pull box. The ground rod connector will be placed so that the bare copper wire, No. 8, can be pulled into a pole, foundation, or attached to the control cabinet ground buss.

15.18.7 Maintenance

Contractor Responsibility

The Contractor shall have full maintenance responsibility of the traffic signal from the date of the written notification by the Engineering Division to the final inspection and date of written approval of the work performed. Continuous maintenance and emergency service shall be provided by the Contractor 24 hours each day during the time frame outlined above. The Contractor shall provide and maintain a 24-hour a day continuous one number telephone answering service.

Emergency

All malfunctions of a controller and its accessory equipment shall be considered an emergency unless otherwise identified by the City. Equipment malfunctions and/or damage, which in the opinion of Northglenn's Engineering Division or other authorized person, constitutes a serious hazard or inconvenience to the public shall be considered an emergency. Such malfunctions or damage may include, but not necessarily be limited to, situations where:

- all indications are out including bulbs and lenses, for any one traffic movement;
- signal heads give conflicting indications to any intersection approach;
- a signal has been knocked down;
- an overhead red indication is out.

Response Time

Contractor shall undertake each such emergency repair no later than one hour after Northglenn notifies Contractor of the emergency.

Reimbursement

In instances of repairs that are not of an emergency nature, such repairs shall be undertaken at the site within one working day after Northglenn notifies Contractor of the needed repair. Northglenn shall pay the Contractor for the materials, parts and/or supplies actually used by the Contractor in making any such repair in the amount of the Contractor's cost-plus five percent (5%). Labor and equipment rates associated with work performed due to vandalism or vehicle accident damage will be reimbursed at the rate set forth in the City's Traffic Signal Maintenance Contract.



Failure to Work

Should the Contractor fail to perform any maintenance responsibilities within the prescribed time periods, the Engineering Division or other authorized person shall employ the services of the City's designated Traffic Signal Maintenance Contractor to perform said maintenance work. The Contractor shall reimburse the City for labor and equipment charges associated with the utilization of the City's designated Traffic Signal Maintenance Contractor plus a fifteen percent (15%) administration fee.

Field Testing

Prior to completion of the work, the Contractor shall cause the following tests to be made on all traffic signals in the presence of the Engineering Division.

Each circuit shall be tested for continuity. Each circuit shall be tested for grounds.

A functional test shall be made in which it is demonstrated that each and every part of the system functions as specified or intended herein. The functional test for each traffic signal system shall consist of not less than fourteen (14) days of continuous, satisfactory operation commencing with full operation of all electrical facilities. During the fourteen-day period, the contractor will maintain the system or systems. The cost of any maintenance necessary, except electrical energy and maintenance due to damage by public traffic, shall be borne by the contractor and will be considered as included in the price paid for the contract item involved and no additional compensation will be allowed.