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**SECTION 01 57 28  
TEMPORARY FLOW CONTROL**

**PART 1 GENERAL**

**1.1 REFERENCES**

- A. The following is a list of standards which may be referenced in this section: Institute of Inspection, Cleaning, and Restoration Certification (IICRC): S500, Standard and Reference Guide for Professional Water Damage Restoration.

**1.2 DEFINITIONS**

- A. Bypass Pumping: Temporary flow control accomplished by diverting flow away from the Work area using one or more pumps.
- B. Temporary Flow Control: Reducing, limiting, or excluding flow in or to a sanitary sewer, storm sewer, pump station, force main, or other facility as required for performing the Work under the Contract. Draining, handling, and disposal of sanitary sewage and storm water from pipelines and other facilities as required for performing the Work under the Contract is also part of temporary flow control.
- C. Temporary Flow Control Plan: Plan prepared by Contractor containing complete information on how Contractor proposes to perform temporary flow control in accordance with specified requirements.

**1.3 SYSTEM DESCRIPTION**

- A. Provide facilities and controls required to intercept, convey, and discharge flow to be controlled; include redundant standby and emergency equipment.
- B. Conform to regulatory requirements.
- C. Protect water resources and other natural resources.
- D. Temporary flow control shall be done in a manner that will not interfere or disrupt airport or tenant operations, property, or create a nuisance or public menace. Flow shall be conveyed in enclosed pipes that are adequately protected from traffic or other hazards.
- E. Sanitary Discharge:
  - 1. To downstream sanitary sewer manhole. Refer to drawings for general manhole locations and configuration.
  - 2. Dumping or free flow on property, airfield, gutters, streets, or sidewalks is strictly prohibited.
  - 3. Discharge of sanitary sewage to storm sewers or onto the ground, is strictly prohibited.

**1.4 SITE CONDITIONS**

- A. Obtain approval and secure permits for placement of temporary flow control facilities within airfield and near public roadways.

- B. Depth of flow and velocity vary and are subject to change at manholes and pipes where sewage must be rerouted to allow for rehabilitation. Some manholes include a drop pipe varying in size from 11 to 15 inches. Flow through drop pipe and main line will need to be temporarily bypassed for rehabilitation of the manhole or adjacent pipe.
- C. The use of temporary flow-through plugs is acceptable provided adequate access to the manhole bench and invert is provided for rehabilitation as described on the Drawings. Where access cannot be provided with flow-through plugs, flow shall be bypassed from an upstream manhole to a downstream manhole and redundant bypass pumping equipment is required for the duration of the bypass.

#### 1.5 SUBMITTALS

- A. Informational Submittals:
  - 1. Emergency Cleanup Plan.
  - 2. Special permits required for temporary flow control.

#### 1.6 QUALITY ASSURANCE

- A. Qualifications: Temporary Flow Control System Designer: Professional engineer who has at least five (5) years of experience in design of such systems and who is registered in the State of Colorado.
- B. Regulatory Requirements: Comply with City and County of Denver and Colorado Department of Public Health and Environment (CDPHE) temporary sanitary flow bypass requirements.

### **PART 2 PRODUCTS (NOT USED)**

### **PART 3 EXECUTION**

#### 3.1 GENERAL REQUIREMENTS

- A. Install temporary flow control facilities in a location acceptable to Airport Operations and Facility Maintenance.
- B. Operate and maintain temporary flow control 24 hours per day, 7 days per week, including without limitation, holidays, as required to control flows.
- C. Promptly remove temporary flow control facilities as soon as they are no longer needed.

#### 3.2 REQUIRED TEMPORARY FLOW CONTROL

- A. Eliminate flow from pipe segment for point repair or manhole for manhole rehabilitation. Flow must either be rerouted from an upstream manhole to a downstream manhole, or the flow shall be temporarily plugged such that the backup of flow does not cause adverse effects upstream.

### 3.3 EQUIPMENT AND MATERIALS

- A. General:
1. Provide materials and equipment that will ensure continuous and successful operation of temporary flow control systems.
  2. Repair or modify systems as necessary.
  3. Unless otherwise shown or specified, materials and equipment may be new or used at Contractor's option.
- B. Plugs:
1. Provide with taps for connection of pressure gauges and air hoses, and flow-through capability.
  2. Pipe Diameters 24 Inches and Smaller: Use mechanical plugs with rubber gaskets or pneumatic plugs with rubber boots.
  3. Pipe Diameters Larger than 24 Inches:
    - a. Use inflatable bag stoppers made in two or more pieces.
    - b. Manufacturers:
      - 1) Lansas.
      - 2) Cherne Industries.
- C. Pumps:
1. Fully automatic, self-priming units that do not require use of foot valves or vacuum pumps in priming system.
  2. Solids handling design with ability to pump minimum three (3)-inch diameter sphere.
  3. Able to run dry for long periods of time to accommodate cyclical nature of flows.
  4. Engine: Equipped to minimize noise. Noise levels shall not exceed 86 dBA at a distance of fifty (50) feet from source.
- D. Electric Power Generators:
1. Be able to simultaneously start and run electric powered pumps required for flow to be controlled.
  2. Equipped to minimize noise. Noise levels shall not exceed 86 dBA at a distance of fifty (50) feet from source.
  3. Include automatic transfer switch if flow control system is to operate unattended.
- E. Standby Equipment:
1. Standby Pump: One of each size to be available onsite at all times.
  2. Electric Power Generators: Minimum of one if temporary flow control system contains electric powered pump. Able to simultaneously start and run electric powered pumps required for flow to be controlled.

### 3.4 TEMPORARY FLOW CONTROL PLAN

- A. Prepare and submit Temporary Flow Control Plan at least ten (10) days before starting the Work requiring temporary flow control; include following information:
1. Drawings indicating location of temporary sewer plugs and bypass discharge lines.
  2. Airfield Construction Phasing Plan or Traffic Control Plan as appropriate for location:
    - a. Airfield Construction Phasing Plan specifically applicable to the temporary flow control adhering to the requirements of airfield operations and detailing closure requirements, equipment locations, and alternate traffic patterns.
    - b. Traffic Control Plan specifically applicable to temporary flow control adhering to requirements of applicable agencies and as may be specified in Contract Documents.

3. Locations where flow will be intercepted and discharged.
4. Complete descriptions and performance characteristics of pumps, electric power generators, and standby equipment.

### 3.5 EMERGENCY CLEANUP PLAN

- A. Prepare and submit an emergency cleanup plan. As a minimum plan shall include the following:
  1. Procedures for removal of water.
  2. Procedures for determining nature and extent of damage and required restoration where restoration is possible.

### 3.6 BLOCKING FLOW

- A. Flow control may consist of blocking flow with mechanical or pneumatic plugs if adequate storage is available.
- B. Use primary and secondary plugs for each flow control location.
- C. When blocking flow is no longer needed for performance and acceptance of the Work, remove plugs in a manner that permits sewage flow to slowly return to normal without surcharging or causing other major disturbances downstream.
- D. Remove temporary plugs at end of each working day and restore normal flow. If downstream work is not or cannot be completed during workday provide, operate, and maintain bypass pumping system or other method of flow control to accommodate flows.

### 3.7 PIPING

- A. Minimize disturbance of existing utilities. Contractor is responsible for locating any utilities and other restrictions prior to piping placement.

## PART 4 MEASUREMENT AND PAYMENT

- 4.1 Contractor shall provide all labor, materials, equipment, and tools necessary to install, maintain, and remove flow management devices. Rehabilitation work will assume live flows. Flow management is not required as long as concrete surfaces within each manhole, to springline depth in flow channel, meets dryness requirements specified by rehabilitation coating/lining product manufacturer. Flow-through plugs may be utilized at the Contractor's option to manage flow level variability. Bypass pumping may be required for manhole rehabilitation work on this project. Flow management shall be paid at the percentage milestone based upon the installation, maintenance, rental or purchase, and removal of all wastewater flow management equipment in each manhole.

<b>Pay Item</b>	<b>Pay Unit</b>
015728.A Wastewater Flow Management	Lump Sum

**END OF SECTION**

## SECTION 31 23 16 EXCAVATION

### PART 1 GENERAL

#### 1.1 DEFINITIONS

- A. Excavation is unclassified: Perform all excavation regardless of water, rock, type, nature, or condition of material encountered. In paved areas, saw cut, remove and dispose of (regardless of thickness) pavement and concrete, curbs, gutters, and sidewalks before excavating.

#### 1.2 QUALITY ASSURANCE

- A. Provide adequate survey control to avoid unauthorized overexcavation.
- B. Locate all utilities prior to excavation.

#### 1.3 WEATHER LIMITATIONS

- A. Material excavated when frozen or when air temperature is less than 32 degrees F shall not be used as fill or backfill until material completely thaws.
- B. Material excavated during inclement weather shall not be used as fill or backfill until after material drains and dries sufficiently for proper compaction.

#### 1.4 SEQUENCING AND SCHEDULING

- A. Demolition: Complete applicable Work specified in Section 33 01 30.80 Manhole Rehabilitation.

### PART 2 PRODUCTS (NOT USED)

### PART 3 EXECUTION

#### 3.1 GENERAL

- A. Excavate to lines, grades, and dimensions as necessary to accomplish Work. Allow for forms, working space, backfill, topsoil, and similar items, wherever applicable. Trim to neat lines where concrete is to be deposited against earth.
- B. Do not overexcavate without written authorization of DEN Project Manager.
- C. Remove or protect obstructions near excavations.
- D. Comply with all laws for sloping, sheeting and shoring of excavations including 29 CFR 1926-Subpart P.

### 3.2 STOCKPILING EXCAVATED MATERIAL

- A. Stockpile excavated material that is suitable for use as fill or backfill until material is needed.
- B. Confine stockpiles to within approved work areas as approved from the DEN Project Manager and Airport Operations. Do not obstruct roads, streets, or airside movement areas.
- C. Do not stockpile excavated material adjacent to trenches and other excavations, unless excavation side slopes and excavation support systems are designed, constructed, and maintained for stockpile loads.
- D. Do not stockpile excavated materials near or over existing facilities, adjacent property, or completed Work, if weight of stockpiled material could induce excessive settlement.

### 3.3 DISPOSAL OF SPOIL

- A. Clean soils shall to disposed of in the DEN North or South Soil Stockpiles.
- B. Clean concrete or asphalt shall go to the DEN North or South Rubble Yards.
- C. Debris shall be disposed offsite at DADS.

## PART 4 MEASUREMENT AND PAYMENT

- 4.1 No measurement for payment is associated with this specification section.

**END OF SECTION**

**SECTION 31 23 23  
BACKFILL AND SURFACE RESTORATION**

**PART 1 GENERAL**

1.1 REFERENCES

- A. The following is a list of standards that may be referenced in this section:
1. ASTM International (ASTM):
    - a. D698, Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft<sup>3</sup> (600 kN-m/m<sup>3    - b. D1557, Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft<sup>3</sup> (2,700 kN-m/m<sup>3    - c. D4253, Standard Test Methods for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table.
    - d. D4254, Standard Test Method for Minimum Index Density and Unit Weight of Soils and Calculation of Relative Density.</sup></sup>
  2. Colorado Department of Transportation Standard Specifications for Road and Bridge Construction (2011).
  3. Denver Public Works Wastewater Capital Projects Management Standard Construction Specifications (2016).

1.2 DEFINITIONS

- A. Relative Compaction:
1. Ratio, in percent, of as-compacted field dry density to laboratory maximum dry density as determined in accordance with ASTM D698.
  2. Apply corrections for oversize material to either as-compacted field dry density or maximum dry density, as determined by DEN.
- B. Optimum Moisture Content:
1. Determined in accordance with ASTM Standard specified to determine maximum dry density for relative compaction.
  2. Determine field moisture content on basis of fraction passing 3/4-inch sieve.
- C. Relative Density: Calculated in accordance with ASTM D4254 based upon maximum index density determined in accordance with ASTM D4253 and minimum index density determined in accordance with ASTM D4254.
- D. Prepared Ground Surface: Ground surface after completion of required demolition, clearing and grubbing, scalping of sod, stripping of topsoil, excavation to grade, and subgrade preparation.
- E. Completed Course: A course or layer that is ready for next layer or next phase of Work.
- F. Lift: Loose (uncompacted) layer of material.
- G. Well-Graded:
1. A mixture of particle sizes with no specific concentration or lack thereof of one or more sizes.



2. Does not define numerical value that must be placed on coefficient of uniformity, coefficient of curvature, or other specific grain size distribution parameters.
  3. Used to define material type that, when compacted, produces a strong and relatively incompressible soil mass free from detrimental voids.
- H. Native Fill Material: Materials available onsite that DEN determines to be suitable for specific use.

### 1.3 SUBMITTALS

- A. Informational Submittals:
1. Native Fill, Aggregate Base, Superpave Asphalt Mix:
    - a. Manufacturer's data sheets for compaction equipment.
    - b. Certified test results from independent testing agency.
  2. CLSM: as specified in Item P-162 Controlled Low-Strength Material (CLSM).

### 1.4 QUALITY ASSURANCE

- A. Notify DEN Project Manager when:
1. Structure is ready for backfilling, and whenever backfilling operations are resumed after a period of inactivity.
  2. Soft or loose subgrade materials are encountered wherever embankment or site fill is to be placed.
  3. Fill material appears to be deviating from Specifications.
  4. Excavation will occur in paved, concrete, or airfield areas.

### 1.5 SEQUENCING AND SCHEDULING

- A. Complete applicable Work specified in 33 01 30.80 Manhole Rehabilitation and 33 01 31 Pipe Rehabilitation.
- B. Backfill around manholes only after manhole is set in position, securely anchored, and ready to be backfilled.
- C. Backfill shall not be placed until required inspections are performed by the DEN Project Manager or designated representative and the Work approved for backfill.

## PART 2 PRODUCTS

### 2.1 NATIVE FILL FOR TOP 2 FEET OF UNIMPROVED AREAS

- A. Excavated material from required excavations free from rocks larger than three (3) inches, from roots and other organic matter, ashes, cinders, trash, debris, and other deleterious materials.
- B. Material containing more than 10 percent gravel, stones, or shale particles is unacceptable.

### 2.2 CONTROLLED LOW STRENGTH MATERIAL (CLSM)

- A. Per DEN's Item P-162 Controlled Low-Strength Material (CLSM).

### 2.3 AGGREGATE BASE COURSE

- A. Class 6 per Table 703-3 and Paragraph 703.3 Colorado Department of Transportation Standard Specifications for Road and Bridge Construction.

### 2.4 SUPERPAVE PAVEMENT

- A. Tack coat per paragraph 25.7 of Denver Public Work Wastewater Capital Projects Management Standard Construction Specification.
- B. PG 64-22 Superpave asphalt mix per Section 25, Hot Mix Asphalt Pavement, of Denver Public Work Wastewater Capital Projects Management Standard Construction Specification, including Tables 25.2.2, 25.6.2.1., and 25.8.

### 2.5 WATER FOR MOISTURE CONDITIONING

- A. Potable water free of hazardous or toxic contaminates, or contaminants deleterious to proper compaction.

### 2.6 CONCRETE

- A. Landside: Concrete patching in accordance with Colorado Department of Transportation Standard Specifications for Road and Bridge Construction Section 601 Structural Concrete including Subsection 601.17 Acceptance and Pay Factors for Testing and Acceptance Requirements.
- B. Airside: Concrete placement in accordance with DEN standard specification P-501 Portland Cement Concrete Pavement.

## PART 3 EXECUTION

### 3.1 GENERAL

- A. Keep placement surfaces free of water, debris, and foreign material during placement and compaction of fill and backfill materials.
- B. Place and spread fill and backfill materials in horizontal lifts of uniform thickness, in a manner that avoids segregation, and compact each lift to specified densities prior to placing succeeding lifts. Slope lifts only where necessary to conform to final grades or as necessary to keep placement surfaces drained of water.
- C. Unimproved areas are to be backfilled with CLSM and native materials for the top two (2) feet to grade. Point repairs and manhole excavations in paved or concrete areas are to be backfilled entirely with CLSM.
- D. During filling and backfilling, keep level of fill and backfill around each manhole even.
- E. Do not place fill or backfill, if fill or backfill material is frozen, or if surface upon which fill or backfill is to be placed is frozen.

- F. Tolerances: Blend into existing grades, establish and maintain slopes to drain away from manhole cover. Reverse slopes are not permitted.
- G. Settlement: Correct and repair any subsequent damage to structures, pavements, curbs, slabs, piping, and other facilities, caused by settlement of fill or backfill material.

### 3.2 BACKFILL UNDER AND AROUND MANHOLES

- A. Unimproved areas: Backfill with native or imported fill to restore existing grades. Place in lifts of six (6)-inch maximum thickness and compact each lift to minimum 95 percent relative compaction as determined in accordance with ASTM D 1557.
- B. Paved or concrete areas: Place CLSM material as shown on the Drawings.
- C. Submit independent testing firm test records of the material and the compaction demonstrating compliance of both for each manhole. Finished compacted road base surface shall be one (1)-inch below bottom of existing asphalt concrete. Before applying tack coat, use a straight beam to verify top of manhole frame is flush with top of adjacent existing pavement.
- D. Apply tack coat per paragraph 25.7 of Denver Public Work Wastewater Capital Projects Management Standard Construction Specification. Apply to sawcut edges of existing asphalt concrete, compacted road base surface, grade rings, grout and manhole frame.
- E. Place and compact PG 64-22 Superpave asphalt mix to existing asphalt thickness plus one (1)-inch. Perform all work per Denver Public Work Wastewater Capital Projects Management Standard Construction Specification, including, more specifically, paragraph 25.8 and Table 25.2.2, respectively. Before commencing work, submit and obtain DEN Project Manager acceptance of data demonstrating that Superpave asphalt mix complies with specifications. Submit testing and inspection records for each manhole showing compliance with paragraph 25.15 of Denver Public Work Wastewater Capital Projects Management Standard Construction Specification.
- F. After backfill and surface restoration is complete, a concrete collar per the Drawings is to be installed on all manholes in unimproved areas. Manholes that are located in the obstacle free area shall have concrete collars installed per the detail for obstacle free area collars. Concrete collars shall be subject to the CDOT standard specification 601.17 for acceptance, both landside and airside.

### 3.3 SITE TESTING

- A. In-Place Density Tests: In accordance with ASTM D1557. During placement of materials, test as follows:
  - 1. Native: two (2) tests per manhole.
  - 2. CLSM: per Item P-162 Controlled Low-Strength Material (CLSM).
  - 3. Aggregate Base: two (2) tests per manhole.
  - 4. Superpave asphalt: in compliance with paragraph 25.15 of Denver Public Works Wastewater Capital Projects Management Standard Construction Specification.

## PART 4 MEASUREMENT AND PAYMENT

### 4.1 Measurement and payment are as follows:

- A. Asphalt
  - 1. Asphalt replacement will be measured by the square foot compacted in place and includes furnishing all equipment, labor, and materials necessary for installation of the pavement shown on the Drawings including importing material, aggregate, asphalt cement, asphalt, additives, hauling, placing, preparation, tack coat, compaction, and all other work necessary to complete the installation per the Drawings and as specified.
  - 2. A six (6)- foot by six (6)- foot area was assumed for asphalt replacement for each manhole as identified on the manhole summary sheets. Actual area required for replacement may vary. Contractor will not be paid for an area larger than thirty-six (36) square feet without prior approval by the DEN project manager or authorized representative.
  
- B. Concrete
  - 1. Concrete replacement will be measured by the square foot compacted in place and includes furnishing all equipment, labor, and materials necessary for installation of the pavement shown on the Drawings including importing material, aggregate, asphalt cement, asphalt, additives, hauling, placing, preparation, tack coat, compaction, and all other work necessary to complete the installation per the Drawings and as specified.
  - 2. A six (6)- foot by six (6)- foot area was assumed for concrete replacement for each manhole as identified on the manhole summary sheets. Actual area required for replacement may vary. Contractor will not be paid for an area larger than thirty-six (36) square feet without prior approval by the DEN Project Manager or authorized representative.
  
- C. Airfield Concrete Panels
  - 1. Airfield concrete panel replacement will be measured by each airfield concrete panel that needs to be removed for manhole rehabilitation and replaced per FAA requirements. Three (3) panels were estimated per point repair and excavation required rehabilitation. Actual number of panels for replacement may vary. Pay item includes furnishing all equipment, labor, and materials necessary for installation of the concrete panel shown on the Drawings including demolition, removal, and hauling of the existing concrete panel. Pay item includes all other work necessary to complete the installation per the Drawings and as specified.
  
- D. Flowfill Backfill
  - 1. Flowfill will be measured on a cubic yard basis to be used as backfill in paved and concrete areas. Bid item to include furnishing all equipment, labor, and materials necessary for installation of the flowfill as shown on the Drawings including the imported flowfill. Bid item also includes the removal and haul of excavated native material to the disposal area as identified in the Specifications. Bid item includes all other work necessary to complete the installation per the Drawings and as specified.
  - 2. A total volume of eleven (11) cubic yards was assumed for flowfill in paved (asphalt) and concrete areas for each manhole as identified on the manhole summary sheets. Actual volume required for backfill may vary. Contractor will not be paid for a volume greater than eleven (11) cubic yards without prior approval by the DEN project manager or authorized representative.

- E. Concrete Collar and Unimproved Surface Restoration
1. Concrete collar and surface restoration will be measured by each needed in unimproved areas. Bid item to include furnishing all equipment, labor, and materials necessary for installation of the collars and restoration to existing conditions as shown on the Drawings including but not limited to imported concrete and rebar and gravel and seeding. Bid item includes all other work necessary to complete the installation per the Drawings and as specified.
- F. Object Free Area – Concrete Collar and Unimproved Surface Restoration
1. Concrete collar and surface restoration will be measured by each needed in unimproved areas in the airside object free area. Bid item to include furnishing all equipment, labor, and materials necessary for installation of the collars and restoration to existing conditions as shown on the Drawings including but not limited to imported concrete and rebar and gravel and seeding. Bid item includes all other work necessary to complete the installation per the Drawings and as specified.

<b>Pay Item</b>		<b>Pay Unit</b>
312323.A	Asphalt Replacement	Square Feet
312323.B	Concrete Replacement	Square Feet
312323.C	Airfield Concrete Panel Replacement	Each
312323.D	Flowfill Backfill	Cubic Yards
312323.E	Concrete Collar and Unimproved Surface Restoration	Each
312323.F	Object Free Area – Concrete Collar and Unimproved Surface Restoration	Each

**END OF SECTION**

## SECTION 32 92 00 - TURF AND GRASSES (CDOT)

### PART 1 - GENERAL

#### 1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

#### 1.2 SUMMARY

- A. This work shall follow the latest version of the Colorado Department of Transportation (CDOT) Standard Specifications for Road and Bridge Construction Section 623 Seeding, Fertilizer, Soil Conditioner and Sodding.
- B. All materials and construction shall follow the latest version of the CDOT Standard Specifications for Road and Bridge Construction and the latest version of the CDOT Standard Plans M&S Standards and all referenced sections therein.
- C. CDOT General Provisions consisting of Section 100 through 109 of the above referenced "Standard Specifications" do not apply to this specification Section except where specifically added.
- D. The following shall apply to this specification Section:
  - 1. Section 101 Definitions and Terms.
  - 2. Section 105 Control of Work with the following exceptions:
    - a. If there are any conflicts with the City and County of Denver's General Provisions, General Conditions, Special Conditions or Technical Specifications and this specification Section, those documents will take precedence.
    - b. Any reference to incentives shall be disregarded. No Incentives will be paid as a result of these specifications. References to disincentives, corrective work or removal and rejections of work and/or materials shall apply.
    - c. Section 105.21 Acceptance shall not apply.
    - d. Section 105.22 through 10.24 shall not apply.
  - 3. Section 106 Control of Material.
  - 4. Section 109.1 Measurement of Quantities.
- E. Related Requirements:
  - 1. Section 329300 "Plants" for trees, shrubs, ground covers, and other plants as well as border edgings and mow strips.
  - 2. Section 334600 "Subdrainage" for below-grade drainage of landscaped areas.

### 1.3 REFERENCES

- A. All references to “CDOT or the Department” shall be changed to “City and County of Denver” unless otherwise noted.
- B. All references to the CDOT Project Engineer and CDOT Regional Transportation Director shall mean DEN Project Manager and DEN Director.
- C. Any and all reference to incentives or positive pay factors within any documents pertaining to these specifications shall not apply. No incentives or increase pay factors will be paid on this Project. References to disincentives, negative pay factors, corrective work or removal and rejection of work and/or materials shall apply.

### 1.4 PREINSTALLATION MEETINGS

- A. N/A

### 1.5 INFORMATIONAL SUBMITTALS

- A. Certification of Grass Seed: From seed vendor for each grass-seed monostand or mixture, stating the botanical and common name, percentage by weight of each species and variety, and percentage of purity, germination, and weed seed. Include the year of production and date of packaging.

### 1.6 CLOSEOUT SUBMITTALS

- A. N/A

### 1.7 DELIVERY, STORAGE, AND HANDLING

- A. Seed and Other Packaged Materials: Deliver packaged materials in original, unopened containers showing weight, certified analysis, name and address of manufacturer, and indication of compliance with state and Federal laws, as applicable.
- B. Bulk Materials:
  - 1. Do not dump or store bulk materials near structures, utilities, walkways and pavements, or on existing turf areas or plants.
  - 2. Provide erosion-control measures to prevent erosion or displacement of bulk materials; discharge of soil-bearing water runoff; and airborne dust reaching adjacent properties, water conveyance systems, or walkways.
  - 3. Accompany each delivery of bulk materials with appropriate certificates.

1.8 FIELD CONDITIONS

- A. Planting Restrictions: Plant during one of the following periods. Coordinate planting periods with initial maintenance periods to provide required maintenance from date of planting completion.
  - 1. Seeding Seasons. Seeding in areas that are not irrigated shall be restricted to the time table and specifications as identified in CDOT Standard Specification Subsection 212.03 Seeding Seasons.
- B. Weather Limitations: Proceed with planting only when existing and forecasted weather conditions permit planting to be performed when beneficial and optimum results may be obtained. Apply products during favorable weather conditions according to manufacturer's written instructions.

1.9 CONSTRUCTION WASTE MANAGEMENT

- A. Construction waste shall be managed in accordance with provisions of Section 017419 "Construction Waste Management and Disposal". Documentation shall be submitted to satisfy the requirements of that Section.

**PART 2 - PRODUCTS**

2.1 MATERIALS

- A. All materials including concrete mix designs shall be currently listed on the CDOT Approved Products List or as approved by the DEN Project Manager.

Table 329200-2: Non-Saline Upland Seed Mix for Shoulder Areas

Scientific Name:	Common Name	Variety	Pounds PLS/acre*	% of mix**
<b>GRASSES</b>				
Bouteloua curtipendula	Sideoats Grama	Vaughn	0.8	10
Bouteloua gracilis	Blue Grama	Bad River	0.05	2.5
Bouteloua gracilis	Blue Grama	Hachita	0.05	2.5
Buchloe dactyloides	Buffalograss	Cody	0.7	2.5
Buchloe dactyloides	Buffalograss	Native -VNS~	0.7	2.5
Distichlis spicata v. stricta	Inland Saltgrass	Native -VNS~	0.3	5
Elymus lanceolatus v. lanceolatus	Thickspike Wheatgrass	Critana	1.1	11
Elymus lanceolatus v. psammophilus	Steambank Wheatgrass	Sodar	1.0	10
Elymus trachycaulus	Slender Wheatgrass	Primar 0.5	0.5	5
Nasella viridula	Green Needlegrass	LoDorm	0.8	5
Pascopyrum smithii	Western Wheatgrass	Arriba	3.6	25
Poa secunda	Sandberg Bluegrass	Native -VNS~	0.5	5
Sporobolus cryptandrus	Sand Dropseed	Native -VNS~	0.01	4



Stipa comata	Needleandthread Grass	Native -VNS~	0.7	5
Grass Species Subtotal			10.8	100
	<b>TOTAL</b>		<b>10.8</b>	<b>100</b>

Table 329200-3: Saline Upland Area Mix, Denver International Airport

Scientific Name	Common Name	Variety	Pounds PLS/acre*	% of mix**
Buchloe dactyloides	Buffalograss	Cody	1.4	5
Buchloe dactyloides	Buffalograss	Native	1.4	5
Distichlis spicata v. stricta	Inland Saltgrass	Native	0.8	25
Sporobolus airoides	Alkali Sacaton	Salado	0.2	20
Pascopyrum smithii	Western Wheatgrass	Arriba	2.1	15
Puccinellia distans	Alkaligrass	Fults	0.2	15
Puccinellia airoides	Nuttall Alkaligrass	Native	0.1	12
<b>Grass species subtotal</b>			<b>6.1</b>	<b>97</b>
<b>SHRUBS</b>				
Atriplex gardneri	Gardner Saltbush	Native	0.4	3
Shrub species subtotal			0.4	3
	<b>TOTAL PLS RATE</b>		<b>6.5</b>	

\* PLS means Pure Live Seed; rates shown are for drill seeding, if broadcast, rates should be doubled.

\*\* Percent by seed number

\*\*\* Wetland mixes to be used only where wetland hydrology exists. Check with DEN Environmental Services.

~VNS = Variety Not Stated

### PART 3 - EXECUTION (Not Used)

### PART 4 - MEASUREMENT

#### 4.1 METHOD OF MEASUREMENT

- A. The quantities of native seeding will not be measured. The native seeding shall include soil preparation, fertilizer, soil conditioner, and seed applied, completed, and accepted.
- B. The Contractor shall furnish the DEN Project Manager with seed certifications and analysis, fertilizer analysis, and bag weight tickets prior to placing any seed or fertilizer.

### PART 5 - PAYMENT

#### 5.1 METHOD OF PAYMENT

- A. No separate payment will be made for work under this Section. The accepted quantities of native seeding shall be included in the surface restoration of unimproved areas, as described in Section 31 23 23 Backfill and Surface Restoration.

- B. Soil preparation, water, seed, fertilizer, and soil conditioner, incorporated into the seeding sodding, or soil conditioning will not be paid for separately but shall be included in the work.
  
- C. Adjusting or readjusting seeding or fertilizing equipment will not be paid for separately but shall be included in the work.

END OF SECTION 32 92 00

**SECTION 33 01 30.16**  
**TELEVISION INSPECTION OF SEWER PIPELINES**

**PART 1 GENERAL**

**1.1 REFERENCES**

- A. The following is a list of standards that may be referenced in this section: National Association of Sewer Service Companies (NASSCO): Pipeline Assessment Certification Program (PACP).

**1.2 SUBMITTALS**

- A. Action Submittals:
1. Catalog and manufacturer's data sheets for television equipment.
  2. Acceptance Standard closed-circuit television (CCTV) video; one copy on flash drive.
- B. Informational Submittals:
1. Certification that staff to be used for the Work is properly trained in confined space entry and hazardous atmospheres.
  2. Training and inspection plan, seven (7) days prior to manual inspection.
  3. Confined space entry procedures.
  4. CCTV Inspection:
    - a. After the point repair has been completed. CCTV prior to the excavation is required to verify repair. However, only the post rehabilitation video is required for submittal to DEN.
    - b. Include the following with each inspection submitted:
      - 1) Inspection media.
      - 2) Inspection reports.
  5. Log of cable footage counter calibration checks.
  6. Listing of actual measured flow depth and times.
  7. Project-specific Safety Plan.
  8. Confined space entry permit.

**1.3 QUALITY ASSURANCE**

- A. Prestartup Meeting: Contractor to coordinate with Airport Operations when completing CCTV in airside locations.
- B. Acceptance Standard CCTV Video:
1. DVD format showing example quality of work that Contractor proposes for Project.
  2. Submittal shall also include examples that demonstrate camera advancement speeds, picture clarity, environment condition, lighting, panning as well as focus on defects, title frame, and screen labels for images, and sample stills.
  3. Picture quality and definition shall be to satisfaction of DEN Project Manager.

**1.4 SEQUENCE AND SCHEDULING**

- A. Contractor shall coordinate scheduling with Airport Operations prior to airside inspections.

- B. Contractor shall complete CCTV prior to excavation and rehabilitation for point pipeline repairs.
- C. Contractor shall complete CCTV after all excavation and rehabilitation for point pipeline repairs.

## **PART 2 PRODUCTS (NOT USED)**

## **PART 3 EXECUTION**

### **3.1 GENERAL**

- A. Complete closed-circuit television (CCTV) inspection for pipe segments as indicated on Drawings C-1 through C-2 prior and post to any excavation and rehabilitation work.
  - 1. Label assets and structures in inspection records using same identification nomenclature as shown on on Drawings G-6 through G-19.
- B. Complete applicable Work specified in Section 01 57 28, Temporary Flow Control prior to starting CCTV inspection work.
- C. Record GPS latitude and longitude (decimal degrees) coordinates using portable global positioning system (GPS) device in field for manholes and pipeline access locations used during inspection; include them in inspection information in database and summary report. Datum is to be NAD83 and NAVD88. Coordinates are to be in DEN Low Distortion Projection (LDP).
- D. Traffic Control:
  - 1. Airside traffic control shall be coordinated with Airport Operations prior to any work and shall conform to the minimum requirements identified on the Drawings.
  - 2. Landside traffic control shall conform to the minimum requirements identified on the Drawings and approved by Terminal Operations and Landside Engineering Manager.
- E. Measure and record flow depths and times of measurement at a sufficient number of locations to indicate flow depths that could be expected during inspection work. A minimum of one (1) flow depth measurement shall be recorded for each line section.

### **3.2 NOTIFICATIONS**

- A. DEN Project Manager:
  - 1. A minimum of five (5) days prior to the anticipated commencement of inspections landside. Airside must be coordinated with Airport Operations.
  - 2. When obstruction, restricting flow in pipeline, is discovered.
  - 3. If depth of flow in pipeline exceeds 25 percent of pipe diameter.
  - 4. If conditions for CCTV inspection are found to be unsafe or impractical.
  - 5. Pipe configuration in field is different than shown on maps; include diagram clearly indicating location of structure in relation to immediately adjacent structures.

### 3.3 EQUIPMENT

- A. Inspection Vehicle:
1. Equipped with monitoring equipment specifically compatible with sewer inspection equipment and meet DEN Security requirements.
  2. Equipped with a safety backup alarm and traffic warning flashers.
  3. Clearly marked with the inspection company name and phone number.
- B. Inspection Equipment:
1. Inspection equipment that fails to produce satisfactory inspection quality shall be removed from the Work.
  2. Transport Platform:
    - a. Self-propelled, mounted on skid, or mounted on float.
    - b. Sized for each pipe diameter in accordance with manufacturer's recommendations.
    - c. Cables: 1,000 feet long, minimum.
    - d. Equipped with tag line suitable for pulling camera backwards.
    - e. Equipped with winch, power winch, TV cable, powered rewind, or other devices used to move camera through pipe.
      - 1) When powered and controlled winches are used to pull television camera through line, provide telephones, radios, or other means of communication between the two (2) manholes to ensure communications exist between crewmembers.
    - f. Remote Reading Footage Counter:
      - 1) Accuracy: 0.20 foot over length of section being inspected.
      - 2) Counter display.
      - 3) Marking on cable will not be allowed.
      - 4) Calibration: Perform each day prior to setup.
    - g. Secure cable, chains, and other devices used with camera so as not to obstruct camera view or otherwise interfere with proper documentation of sewer conditions.
  3. Television Camera:
    - a. Closed-circuit color television camera.
    - b. Sufficient for 8–inch through 24–inch diameters and in accordance with manufacturer's recommendations.
    - c. Mounted on transport platform.
    - d. Operative in 100 percent humidity conditions without lens fogging.
    - e. Operative in hazardous and corrosive environment and specifically designed for pipeline inspection.
    - f. Camera Lighting:
      - 1) Mounted on and turned in direction of camera head.
      - 2) Light Sensitivity: Greater than 1.5 lux minimum.
      - 3) Minimize reflective glare.
      - 4) Remote variable intensity control.
      - 5) Provide clear, in-focus picture of entire inside periphery of pipe.
      - 6) Ability to achieve proper balance of tint and brightness.
    - g. Resolution:
      - 1) Horizontal Resolution: 460 lines minimum.
      - 2) Vertical Resolution: 400 lines minimum.
      - 3) Meet or exceed monitor resolution.
    - h. Rotation: 360 degrees.
    - i. Pan and Tilt: 270 degrees, with adjustable supports designed for operation in connection with pipe inspection.

- j. Viewing Angle: 65 degrees, minimum.
- k. Focus and Iris Controls:
  - 1) Automatic or remote.
  - 2) Remote control adjustment for focus and iris.
- l. Focal Distance: Adjustable through range from 6 inches to infinity.
- m. Zoom: Capable of 40:1 (10x optical, 4 times digital).

### 3.4 INSPECTION

- A. Video Recording:
  - 1. CCTV inspection is represented by one manhole-to-manhole pipe segment or other access-to-access point; not multiple manhole-to-manhole segments.
  - 2. Prior to beginning CCTV inspection, complete initial screen text step and position camera at center of manhole and with axis at centerline of pipe.
  - 3. Before camera enters pipe, inspection shall provide internal video of manhole. Video recording shall begin by facing pipe segment to be televised and then pan/tilt/zoom as necessary to point camera up towards manhole opening.
  - 4. Show continuous footage reading on inspection image. Place on screen where it is clearly visible (if black font, do not place on dark background, if white font, do not place on light background).
  - 5. Viewing shall be in direction of flow, except while camera is being used in a reverse setup. Inspection shall proceed from upstream to downstream, unless prohibited by obstruction.
  - 6. If during inspection operation television camera will not pass through entire line segment due to obstruction, set up equipment so inspection can be performed from opposite manhole.
  - 7. If upstream (reverse) setup, is required, establish new inspection run separate from downstream (normal) setup.
  - 8. Keep camera lens clean and clear. If material or debris obscures image or causes reduced visibility, clean or replace lens prior to proceeding with recording operation.
  - 9. Camera lens shall remain above visible water level and may submerge only while passing through clearly identifiable line sags or vertical misalignments. If flow exceeds 25 percent of diameter, such that camera lens becomes obscured, stop inspection until flow subsides. If necessary, reschedule CCTV operation. Surcharging and flooding of camera lens is not an excusable condition if it has been artificially created upstream (for example, placement of flow plugs or freshwater flushing in pipe).
  - 10. Recordings shall clearly show defects and observations, and their severity, in addition to obvious features, such as laterals and joints.
  - 11. Immediately report to DEN Project Manager, any obstructions that restrict flow and cause inspection to be interrupted. Document condition with still photographs, and begin inspections of other pipelines.
  - 12. Camera Operation:
    - a. Speed: 30 feet per minute, maximum, during inspection.
    - b. Stop, for a minimum of 5 seconds, at every lateral, or other defect or adversity.
    - c. Pan entire diameter or area of pipe at each defect and lateral connection.
    - d. Readjust lens, lighting, and focus in order to ensure clear, distinct, and properly lighted image of defect.
  - 13. Loss of color or severe red or green color will be cause for rejection of inspection.
  - 14. Recordings shall be without distortion or outside interference.

15. Televising line segments from structure-to-structure on same DVD in continuous run.
    - a. Video shall clearly show camera starting and ending at structure, unless defects do not allow it.
    - b. Do not perform partial televising on one DVD and then complete run on another DVD.
    - c. If line is partially televised, as a result of an excusable condition, (for example, collapsed line), televised length shall be viewed by DEN Project Manager for acceptability.
    - d. If portion of line is unacceptable, entire segment shall be deemed unacceptable and shall be retelevised.
  16. DEN Project Manager may accept physical inspection that does not adhere to minimum standards if adverse conditions are encountered and reinspection is not advised. In such a case, enough data shall be provided to permit accurate assessment.
- B. Measurement:
1. Record in English units.
  2. Obtain pipe diameter by physical measurement in upstream (or downstream) access structure.
  3. Verify pipe material (such as, RCP, VCP, CMP) and surface lengths between manholes.
  4. Use calipers or measuring rod to determine diameter of inlet and outlet pipe.
  5. Footage measurements shall begin at centerline of upstream manhole, unless DEN Project Manager approves otherwise.
  6. Continuous Footage Readings:
    - a. Use to identify location of defects.
    - b. Accurate to within plus or minus 0.20 feet tolerance.
    - c. Defect identifications are to be called out and recorded to nearest 0.10 feet.
    - d. Line segment recording will be unacceptable if continuous footage meter is inaccurate, or identified defects or features leave doubt as to accuracy of locations or total length.
  7. Measurement shall be zeroed after each segment inspected.

### 3.5 RECORDING OF DOCUMENTATION

- A. Upon completion of CCTV inspection post rehabilitation, transfer inspection data to DVD of sufficient capacity and compatibility with DEN's equipment; include code required for proper playback of video file.
1. Labeling:
    - a. Provide printed label on outside of DVD that indicates the following:
      - 1) Denver International Airport (DEN)
      - 2) 2017 Manhole Rehabilitation Project.
      - 3) Date of inspection.
      - 4) Inspection company.
      - 5) Range of pipe structure identification numbers included.
- B. Media:
1. Video:
    - a. Inspections completed, with a unique filename per inspection.
    - b. Encoded in .WMV, .MPG, or .AVI format.
    - c. Opening Screen: The following is an example of required on-screen text display fields:
      - 1) Date and Time: (YYYY/MM/DD), (military time hh:mm).

- 2) Surveyor's Name/Company: John Doe/ABC Company.
- 3) Project Name: XYZ project.
- 4) Location: 1 Example Street.
- 5) Location Code: B – Example Highway.
- 6) Upstream MH No: ### (Feature\_ID or Facility\_ID).
- 7) Upstream MH depth: ##.# (nearest tenth of a foot).
- 8) Downstream MH No: ### (Feature\_ID or Facility\_ID).
- 9) Pipe Segment Ref. ##### (Feature\_IDs).
- 10) Starting Footage: ###(nearest tenth of foot).
- 11) Inspection Direction: Downstream or upstream.
- 12) Pipe Material: Example, ductile iron.
- 13) Pipe Diameter/Height/Width: Diameter: ##/Height: ##/Width: ## (as measured in field).
- 14) Weather: Example, snow.
- 15) Precleaning: Example, jetting.
- 16) Additional Information: Additional important information/comments.
- d. Continuous View: Following is list of required on-screen text display fields:
  - 1) Inspection date and time.
  - 2) Continuous forward and reverse readout of cameral distance from center of manhole reference (tape counter footage).
  - 3) Pipe structure identification number.
  - 4) Defect/observation code(s) (when encountered).
2. Audio:
  - a. Embedded in video file.
  - b. Operator shall include description of inspection setup, including related information from log form and unusual conditions.
  - c. Operation changes (for example, remove roots and restart inspection at footage prior to root removal).
  - d. Verbal description and location of each defect.
  - e. Verbal description and location of each service connection.
3. Still Photographs:
  - a. Provide digital photographs showing inspection image whenever observation or defect is recorded.
  - b. Each with unique filename.
  - c. Encoded in .jpg format.
  - d. Minimum 640 by 480 resolution.
  - e. Provide label on front of photograph with structure identification number, footage (if not visible on photograph), and defect code.
- C. Inspection Reports:
  1. Provide .PDF inspection reports including:
    - a. Summary of inspections completed. An example summary inspection report is shown as a supplement at the end of this section.
    - b. Pipe graphs of each inspection showing asset information and defects/observations.
  2. Field Maps:
    - a. Corrected to reflect actual field conditions.
    - b. Illustrate changes in pipe routing that differ from anticipated network on Drawings and in the Mapbook.
    - c. Neatly strike out incorrect data using green pencil and clearly mark in correct data, using red pencil. Show notes that clarify changes in blue pencil.



3.6 FIELD QUALITY CONTROL

- A. Review videos and reports to resolve inconsistent and conflicting data and to improve accuracy of data prior to submittal.
- B. If minimum level of accuracy is not met between videos and reports after review by DEN Project Manager, perform reinspection of pipes that do not meet requirements.
- C. Quality control procedures shall be in accordance with method attached as a supplement at the end of this section.

3.7 SUPPLEMENTS

- A. The supplements listed below, following “End of Section,” are a part of this specification.
  - 1. Inspection Summary Sheet.
  - 2. NASSCO PACP Quality Control.

**END OF SECTION**

**INSPECTION SUMMARY SHEET**

Deliverable ID	Basin	Pipe ID	US MH	DS MH	Pipe Mat'l	Pipe Size	Length	Date Insp.	Insp. Length	Reverse (Y/N)	Condition Score

## NASSCO PACP QUALITY CONTROL PROCEDURE

### General Method

CCTV contracting companies shall have a Random Number Quality Control procedure in place that is then audited by client. A random number is one of a series of numbers that have no detectable pattern, so that each and every item in a known population has an equal chance of being selected based upon random number. A minimum of 5 percent of CCTV contractor's data shall be checked using a Random Number Quality Control procedure as basis of selecting inspections for review. Intent is for Client to actually audit CCTV contractor's QC procedure rather than performing their own QC. If there is doubt about results then Client can ask for another differing set of Random Numbers to be created and be applied to CCTV operator in question, thereby generating another different set of inspections to be checked. Create QC history for each CCTV operator and not for each contract.

### Generating Random Numbers

A Random Number list, based upon population and selection percentage, is available from many web sites. This site generates a list of random numbers that can be sorted in numerical order and printed. Each CCTV operator shall have a different set of Random Numbers.

### Selection of Inspections to be Checked

In the field, CCTV operator inspects each sewer segment and enters PACP information into a computer database. In the office, QC employee/operator counts through inspections, for each separate CCTV operator, in the order in which they were inspected. When inspection coincides with a Random Number a copy of inspection is made from HD/DVD onto CCTV operator's master QC HD/DVD. A copy of corresponding CCTV report is also printed from computer. These are then kept in CCTV operator's QC folder until QC is carried out by qualified QC employee/operator. By using the Random Number sampling system CCTV operator will not be able to "abuse" system. Client can ask for the set of Random Numbers for each CCTV operator at start of Project, or Client can provide a set of Random Numbers to be used for each operator associated with Project.

### Quality Control of Inspection

It is expected that accuracy of Header record exceeds 90 percent as most field contents are based upon facts. The simplest method for QC of Header record is as follows:

Each field completed, and those that are not but should have been, is counted, producing a "number of fields checked", say 32 (ignoring unused fields).

Then fields with mistakes are counted, irrelevant of level of the mistake, creating an "error count" say for this example, 2.

Therefore, calculation is:

$(\text{error count}/\text{number of fields checked}) * 100 = \text{percentage error}$   
 $100 - \text{error percentage} = \text{accuracy percentage}$

$(2 / 32) * 100 = 6.25\%$

$100\% - 6.25\% = 93.75\%$  accuracy level

This percentage accuracy level is then entered onto a graph so that ongoing accuracy can easily be seen, again, for each CCTV operator.

### Detail Information

It is expected that accuracy of Observation/Defect codes exceed 90 percent.

As with Header records, each field that has been completed in the Detail records is added up, irrelevant of whether it is a Clock At/To, the Continuous Defect field or Distance/Video digits. Each entry is treated as equally important. From this number of entries made in the Detail section, a figure is arrived. A qualified QC employee/operator then looks through the same inspection and checks accuracy of each field and reaches two values, the number of entries that should have been made and an error count. No attempt should be made to create a new inspection from scratch, just check what has already been reported on. If a defect is not recorded then number of fields that support the missed defect is added to Error Count, for instance, if CCTV operator misses an EMJ then error count increases by at least five errors:

Video Digit, Distance, Code, Clock At and To and the percent

The five errors must also be added to number of entries that should have been made as well as any other errors to reach a total number of entries. Therefore at the end each inspection there are two values, the number of entries that should have been made and the error count. Calculation for Quality Control of each inspection is as follows:

$(\text{Error Count} / \text{Number of entries that should have been made}) * 100 = \text{Percentage Error}$

$100 - \text{Percentage Error} = \text{Accuracy Level}$

Assume number of entries made should have been 122 Assume Error Count is 8:

$(8 / 122) * 100 = 6.5\%$

$100\% - 6.5\% = 93.5\% \text{ Accuracy Level}$

This percentage Accuracy Level is then entered onto a graph so that ongoing level can be easily seen for each CCTV Operator.

### Summary

QC inspection information for each sewer segment checked is entered into QC forms so that an Audit trail can be established. There must be hard copies of each inspection checked with Errors and Omissions clearly marked. Accuracy Level calculations must also be entered into QC logs. Random Number must be entered against each aspect of QC procedure. A continuing Accuracy Level Graph must be kept up to date for each CCTV operator; it is acknowledged that results could be as much as 1 month behind time of inspection.

**SECTION 33 01 30.70  
PIPE REHABILITATION**

**PART 1 GENERAL**

**1.1 SECTION INCLUDES**

- A. Repair of sanitary sewers by replacing short lengths of failed pipe with new pipe.
- B. Repair of sanitary sewers with mechanical point repair system.
- C. Cured in place pipe lining.

**1.2 REFERENCES**

- A. The following is a list of standards that may be referenced in this section:
  - 1. American Association of State Highway and Transportation Officials (AASHTO).
  - 2. ASTM International (ASTM):
    - a. D543, Standard Practices for Evaluating the Resistance of Plastics to Chemical Reagents.
    - b. D2122, Standard Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings.
    - c. F1216, Standard Practice for Rehabilitation of Existing Pipelines and Conduits by the Inversion and Curing of a Resin-Impregnated Tube.
    - d. F1743, Standard Practice for Rehabilitation of Existing Pipelines and Conduits by Pulled-in-Place Installation of Cured-in-Place Thermosetting Resins Pipe (CIPP).
    - e. F2019, Standard Practice for Rehabilitation of Existing Pipelines and Conduits by the Pulled-in-Place Installation of Glass Reinforced Plastic (GRP) Cured-in-Place Thermosetting Resin Pipe (CIPP).
    - f. F2599, Standard Practice for the Sectional Repair of Damaged Pipe by Means of an Inverted Cured-In-Place Liner.
    - g. ASTM F3110, Standard Practice for Proper Use of Mechanical Trenchless Point Repair Sleeve with Locking Gear Mechanism for Pipes of Varying Inner Diameter and Offset Joints.
  - 3. Occupational Safety and Health Administration (OSHA).

**1.3 PERFORMANCE REQUIREMENTS**

- A. Determine the location of point repairs by closed circuit television (CCTV) inspection of the failed pipe location per Section 33 01 30.16 Television Inspection of Sewer Pipelines.
- B. The options for completing the point repairs are cured-in-place pipe, mechanical repair sleeve inserts, and excavation to replace portions of damaged pipe. The Contractor is responsible for reviewing the CCTV information and developing the approach to completing the repair. The contractor is to confirm with the manufacturer of the point repair system that the repair approach selected will provide a water-tight, leak-free, and fully structural repair of the damaged pipe. If the Contractor selected repair approach and materials do not provide a fully structural and water-tight repair, the Contractor shall replace at no cost to DEN.

## 1.4 SUBMITTALS

- A. Action Submittals:
1. Product data for each pipe product, fitting and jointing material.
  2. Product data for mechanical repair sleeve inserts.
  3. Post-Inspection video in accordance with Section 33 01 30.16 Television Inspection of Sewer Pipelines.
  4. Cured-in-Place Lining: Manufacturer's technical literature on proposed lining system. Resin: Specifications, Characteristics, Properties, and Itemize exceptions and deviations to Specification. Annular space sealant. Service connection fittings.
  5. Installation Plan: Access manhole locations; site plan sketch showing dimensions of access within work limits and utilities, installation duration, appropriate excavation/backfill/resurfacing procedures, and discussion of bypass pumping requirements.
- B. Informational Submittals:
1. Cured-in-Place Lining:
    - a. Liner Thickness Design Calculations: Signed and sealed by Professional Engineer in the State of Colorado. Manufacturer certification of material to values used in calculations.
    - b. Qualifications:
      - 1) Installer: List of past projects, including references for selected curing method. Manufacturer's written certification of approval.
      - 2) Superintendent: List of past projects, including references. Manufacturer's written certification of approval.
      - 3) Testing Laboratory: Qualifications, experience history, and references.
    - c. Manufacturer's Certificate of Compliance that resin material is appropriate for intended application and in conformance with specification.
    - d. Certified test reports on physical properties and chemical resistance of proposed resin.
    - e. Manufacturer's instructions for materials requiring special shipping, storage, or handling requirements.
    - f. Manufacturer's printed installation instructions. Installation method statement shall include but not be limited to the following:
      - 1) Details concerning curing methods.
      - 2) Inversion pressures necessary for proper installation.
      - 3) Minimum pressure required to hold tube tight against existing host pipe, and maximum allowable pressure that will not damage tube.
      - 4) Type of insertion.
      - 5) Defect Repair:
        - a) Methods of repairing in conjunction with manholes, joints, laterals, and active infiltration.
        - b) Quality control/quality assurance plan.
        - c) Repair material test results.
    - g. "Wet-out" Plan: For each proposed lining section, method for "wet-out" of flexible tube together with specific insertion and curing schedule.
    - h. Field Report, After Completion of Each Section:
      - 1) Process control sheet; include temperature/time log information, tap cut information, and curing cycle.

- 2) Pre-CCTV and post-CCTV inspection DVDs as specified in Section 33 01 30.16, Television Inspection of Sewer Pipelines.
  - 3) CIPP manufacturer's Certificate of Proper Installation.
  - 4) Certified test reports of CIPP samples obtained during installation.
2. Mechanical Repair Sleeve Insert:
- a. Installer Qualifications: Manufacturer's written certification of approval.
  - b. Manufacturer's standard data including: Literature, illustrations, specifications, product data sheets, storage requirements, installation requirements, and repair instructions.
  - c. Manufacturer's Certificate of Compliance, that mechanical sleeve insert is appropriate for intended application and in conformance with specification.

## 1.5 DELIVERY, STORAGE, AND HANDLING

- A. Cure-in-Place Lining:
1. Resin: Shipped directly to wet-out facility from resin manufacturer.
  2. Store water-cured or steam-cured resin-impregnated tubes in refrigerated truck trailers at a temperature below 45 degrees F to prevent premature curing.
  3. If liner tube is impregnated with resin at factory, transport, install, and cure before expiration of shelf life.
  4. No cuts, tears, or abrasions shall occur to liner tube during handling.
  5. Prior to beginning installation, do not subject resin-impregnated liner to sunlight or ultraviolet radiation.
    - a. UV liner may be stored for three (3) months maximum before installation.
    - b. Remove resin-impregnated tubes with signs of premature curing from Site.

## 1.6 SPECIAL GUARANTEE

- A. Material Warranty: A written guarantee of one (1) year(s) shall be provided by manufacturer against breakdown of material effectiveness of structural repair elements.
- B. Workmanship Warranty: A written guarantee of one (1) year(s) minimum shall be provided by Contractor against defects of workmanship.
- C. Warrantee Inspection: A warranty inspection shall be conducted in the eleventh (11<sup>th</sup>) month following final acceptance of the Work. Contractor and liner manufacturer representative shall participate in inspection. Deficiencies related to material and workmanship shall be repaired by Contractor to satisfaction of DEN Project Manager and DEN Asset Manager at no cost to the DEN. Inspection shall be conducted by designated representative of DEN Project Manager and DEN Asset Manager.

## PART 2 PRODUCTS

### 2.1 CURED-IN-PLACE LINER DESIGN CRITERIA

- A. Design liner thickness using the following criteria:
1. Design Life: 50 years.
  2. Pipe Diameters: Per Contract Drawings.
  3. Ovality: 2 percent.

4. Pipe Condition: Fully deteriorated.
5. External Water: Ground surface.
6. Flexural Strength: 4,500 psi.
7. Short-Term Flexural Modules: 250,000 psi.
8. Reduction Factor: 50 percent.
9. Long-Term Flexural Modules: 125,000 psi.
10. k Enhancement Factor: 7.
11. Soil Modules: 1,000 psi.
12. Soil Density: 120 pcf.
13. Highway Live Load: AASHTO HS20-44.
14. Safety Factor: 2 minimum.
15. Minimum Thickness:
  - a. Pipe 10 Inches and Smaller: 6 millimeters.
  - b. Pipe Larger than 10 Inches: 7.5 millimeters.
  - c. If calculations require thicker wall, round to next higher multiple of 0.5 millimeter.
16. Poisson's Ratio: 0.3.
17. Liner shall be watertight.

## 2.2 MATERIALS

### A. Resin:

1. General purpose, unsaturated, polyester, epoxy, isophthalic neopentyl glycol, or thermosetting vinyl ester resin, catalyst system, initiators, or hardeners that provide specified cured physical strengths and properties, and compatible with reconstruction inversion process.
2. Resistant to municipal wastewater environment; immersion in septic sewage at temperatures up to 75 degrees F.
3. Curing:
  - a. Designed to cure properly within selected curing method.
  - b. Initiation Temperature: 180 degrees F, maximum.
4. Resistant to ultra-violet light (sunlight) prior to installation.
5. PET resins, resin filters, resin additives, and resin enhancement agents are prohibited. Only neat resins are acceptable. Old resins and reworked resins are prohibited, regardless of whether or not they are mixed with new resin.
6. Chemical resistance of resin system shall have been tested by resin manufacturer in accordance with ASTM D543. Exposure to chemical solutions listed below at temperatures of up to 75 degrees F shall be conducted for a minimum period of one (1) month and shall result in a loss of not more than 20 percent of initial structural properties.
  - a. Minimum Chemical Solution Concentration, ASTM F1216:
    - 1) Tap Water, pH 6 to 9: 100 percent.
    - 2) Nitric Acid: 5 percent.
    - 3) Phosphoric Acid: 10 percent.
    - 4) Sulfuric Acid: 10 percent.
    - 5) Gasoline: 100 percent.
    - 6) Vegetable Oil: 100 percent.
    - 7) Detergent or Soap: 0.1 percent.
7. Produce cured tube resistant to shrinkage, not to corrode or oxidize, and resistant to abrasion from solids, grit, and sand in wastewater.
8. Bond between tube layers shall be strong and uniform.
9. Layers, after cure, shall be saturated with resin.



10. Manufacturers and Products:
  - a. Reichhold; PolyLite #33420 or DION 9800-20.
  - b. Interplastic Corporation; #COR72-AA-455HV, #COR72-AA-656, or #CORVE8190.
  - c. Ashland Specialty Chemical Company; #AROPOL MR12018 or HETRON Q6405.
  - d. AOC; 701 or 102NA.
  - e. Vipel; L704NET-11 or L704AAP-12.
  
- B. Catalyst:
  1. Primary: 1 percent maximum of resin by volume.
  2. Secondary: 1/2 percent of resin by volume.
  3. Manufacturers and Products:
    - a. Primary Catalyst:
      - 1) Akzo; Perkadox 16, Perkadox BTW-50, or Norox 600.
    - b. Secondary Catalyst:
      - 1) Akzo; Trigonox C or Norox TBPB.
      - 2) Puritan Products; N, N-dimethyl aniline (DMA).
  
- C. Flexible Liner Tube:
  1. Consist of layers of flexible nonwoven and absorbent polyester felt manufactured under quality controlled conditions set by manufacturer and applicable requirements set forth in ASTM F1216 and ASTM F1743.
  2. Capable of stretching to fit irregular pipe sections.
  3. Fabricated and sized for each section to ensure snug and firm fit inside existing sewer; produce required thickness after resin is cured.
  4. Inside layer of tube shall be coated with an impermeable material compatible with resin and felt.
  5. Fit length and diameter of manhole with allowance for longitudinal and circumferential stretching or shrinkage.
  6. Maximum Stretching Allowance: In accordance with ASTM F1216.
  7. Fabricate in lengths, that when installed, liner occupies length of pipeline between launch and reception manholes.
  8. Lining shall be correct diameter; after installation there shall be no wrinkles or form permanent fins.
  9. Contain no intermediate layers that may delaminate after resin curing. Not capable of separating layers with a probe or knife blade such that layers separate cleanly or probe or knife blade moves freely between layers.
  10. Where several layers of felt are required, inner layer shall be stitched to form a tube.
    - a. Each successive layer shall be individually wrapped around previous one and stitched together.
    - b. Outer layer of felt shall have an installation tube prebonded to it, or a sheet of this material shall be wrapped around completed felt tube.
    - c. Where a prebonded material is used, bond a covering strip over seam to form airtight joint.
  11. Fabricated from materials that when cured will be chemically resistant to reagents as defined in ASTM D543.
  12. Preliner:
    - a. If required by DIA Project Manager, apply to tube on what will become interior wall of finished CIPP.
    - b. Polypropylene compatible with resin system and shall not adversely affect adhesive properties of resin used in mainline or lateral liners.

13. Interior Pipe Wall Color: Shall not be a dark or nonreflective nature that could inhibit proper closed circuit television (CCTV) inspection.
14. Manufacturers:
  - a. Applied Felts.
  - b. Insituform Technologies.
  - c. Liner Products.
  - d. National Liner.

D. Annular Space Sealant, Hydrophilic Rubber Joint Seal: Greenstreak, Inc.; Hydrotite.

### 2.3 SOURCE QUALITY CONTROL

- A. At time of manufacture, each lot of liner shall be inspected and certified to be free of defects.
- B. Mark inside of tube in at least one location per setup. Mark shall include manufacturer of liner at regular intervals, not to exceed five (5) feet, along full length.

### 2.4 PVC PIPE

- A. 15-Inch Diameter and Smaller:
  1. In accordance with ASTM D3034.
  2. Joints: Integral bell and spigot, in accordance with ASTM D3212.
  3. Minimum SDR: 26.
  4. Cell Classification: 12454-B or 12454-C, as defined by ASTM D1784.
  5. Fittings: SDR 35 minimum wall thickness.
  6. Gaskets: Factory fabricated rubber compression type with solid cross section in accordance with ASTM F477. Lubricant for joining pipe as approved by pipe manufacturer.
- B. 18-Inch through 36-Inch Diameter:
  1. In accordance with ASTM F679.
  2. Joints: Integral bell and spigot, in accordance with ASTM D3212.
  3. Minimum Pipe Stiffness: 46 psi when tested in accordance with ASTM D2412.
  4. Cell Classification: Minimum 12454-C, as defined by ASTM D1784.
  5. Fittings: Wall thickness no less than wall thickness of equivalent size of pipe.
  6. Gaskets: Factory fabricated rubber compression type with solid cross section conforming to ASTM F477.

### 2.5 MECHANICAL REPAIR SLEEVE

- A. In accordance with ASTM F3100. Stainless steel structural body with seamless EPDM compression seal.
- B. Manufacturer/Product: Rausch QuickLock sleeve.

### 2.6 JOINTING MATERIALS

- A. Use flexible adapters secured with 1/2-inch stainless steel bands, as manufactured by Fernco, or approved equal.

## PART 3 EXECUTION

### 3.1 TEMPORARY FLOW BYPASS AND DIVERSION PUMPING

- A. In accordance with Section 01 57 28, Temporary Flow Control.

### 3.2 OVERFLOWS OR SPILLS

- A. Schedule and perform the Work in a manner that does not cause or contribute to incidence of overflows or spills of sewage from sewer system.
- B. In the event Contractor's work activities contribute to overflows or spills, take appropriate action to contain and stop overflow, clean up spillage, disinfect area affected by spill and notify DEN Project Manager in a timely manner.

### 3.3 PROTECTION

- A. Provide barricades, warning lights and signs for excavations created by point repairs as identified on the traffic control sheets for landside. Airside traffic control is to be coordinated with DEN Airport Operations via DEN Project Manager.
- B. Do not allow soil, sand, debris or runoff to enter sewer system during repair.

### 3.4 TYPICAL SEQUENCE OF POINT REPAIR

- A. Perform pre-installation video inspection as specified in Section 33 01 20.16 Television Inspection of Sewer Pipeline to verify the location of sewer line point repairs.
- B. Identify the point repair methodology to be utilized: CIPP, Mechanical Repair Sleeve, or replacement of damaged section. Provide manufacturer compliance information as identified in Part 1 of this specification.
- C. Complete the point repair and perform a post-installation video inspection as specified in Section 33 01 20.16 Television Inspection of Sewer Pipeline. Perform television survey in accordance with Section 33 01 30.16, Television Inspection of Sewer Pipelines. Conduct finished inspections continuous over entire length of sewer between manholes. Point repairs that show offset joints, non-uniform grade, incorrect alignment, excessive deflection or similar conditions are considered defective work. Repair as required to correct defective work.

### 3.5 CIPP POINT REPAIR

- A. Preinstallation Procedures
  - 1. Complete the following activities, unless approved otherwise by DEN Project Manager:
    - a. Perform operations in accordance with OSHA Standards.
    - b. Before Work commences, required preinstallation submittals shall be approved by DEN Project Manager, including traffic management measures, safe pedestrian passage, provision of vehicular access to property, bypass/diversion pumping, and emergency measures.
    - c. Notify DEN Project Manager prior to beginning preinstallation activities.
    - d. Preinsertion Cleaning:
      - 1) Clean sewer pipe before preinsertion television inspection.

- 2) Debris removed from sewer during cleaning shall be transported in watertight containers and disposed of in accordance with local, State, and Federal Regulations.
  - e. Preinsertion CCTV Inspection:
    - 1) In accordance with Section 33 01 30.16, Television Inspection of Sewer Pipelines.
    - 2) Inspect sewer pipe before insertion of resin impregnated tube to ensure pipe is clean and existing pipe conditions are acceptable for lining.
  - f. Line Obstructions: If preinsertion video CCTV inspection reveals obstruction in existing pipe that cannot be removed by sewer cleaning equipment, with approval of DEN Project Manager, perform point repair using flexible coupling.
  - g. Ensure proper sequence of work occurs between mainline and lateral lining activities.
  - h. Confirm accurate location and serviceability of existing lateral or service connection (tap). Serviceability shall be confirmed by flowing water, dye testing, or visually with CCTV inspection.
  - i. When service connections protrude into existing pipe more than 1/2 inch, as measured from inside pipe wall, remove protruding portion of service connection to within 1/2 inch of inside pipe wall.
- B. Installation
1. Verify lengths in field before cutting liner to length.
  2. Wet-Out:
    - a. Tube shall be vacuum impregnated with resin (wet-out) under controlled conditions.
      - 1) Designate vacuum-impregnated location prior to CIPP installation.
      - 2) If requested, allow DEN to inspect materials and procedures used to vacuum impregnate tube.
      - 3) If Contactor uses an alternative method of resin impregnation, method shall produce the equivalent results of a roller system. An alternative resin impregnation method shall be documented to DEN's satisfaction that saturation of CIPP is sufficient.
      - 4) Handle resin impregnated tube to retard or prevent settling until it is ready for insertion.
    - b. Use roller system to uniformly distribute resin throughout tube.
    - c. Volume:
      - 1) Resin shall fill voids in tube material at nominal thickness and diameter; no air spaces or pockets allowed.
      - 2) Adjust by adding excess resin to change resin volume because of polymerization and to allow for migration of resin into cracks and joints in original pipe.
    - d. Complete wet-out process control sheet for every lining completed. Control sheet shall provide the following information:
      - 1) Liner manufacturer.
      - 2) Liner diameter.
      - 3) Number of layers.
      - 4) Resin manufacturer.
      - 5) Resin amount.
      - 6) Resin type.
      - 7) Batch number.

- 8) Catalyst and accelerator name/type.
  - 9) Hardener name/type.
  - 10) Filler name/type, if any.
  - 11) Percent of filler, if any.
  - 12) Mixing ratios.
  - 13) Vacuum pressure of impregnation process.
  - 14) Wet-out start time and date.
3. Insertion:
- a. Install CIPP in accordance with practices outlined in ASTM F1216 for direct inversion installations and ASTM F1743 for pull-in installations.
  - b. Dewater existing host pipe for CIPP installation that does not use an inversion method to expand tube against pipe wall.
  - c. If vacuum impregnation process is used, point of vacuum shall be no further than 25 feet from point of initial resin introduction. After vacuum in tube is established, vacuum point shall be no further than 75 feet from leading edge of resin. Leading edge of resin slug shall be as near to perpendicular to longitudinal axis of tube as possible.
  - d. Insert wet-out tube through existing manhole or approved access point by means of an inversion process or pulled in method and application of hydrostatic head sufficient to extend tube to next designated manhole or termination point.
  - e. Alternately, tube may be pulled into place and expanded with inflation bladder. Insertion method shall not result in abrasion or scuffing of the tube.
  - f. Once installation has begun, maintain pressure between minimum and maximum pressures until installation has been completed. Pressure shall be sufficient to hold tube tight against host sewer pipe.
  - g. Place temperature gauges between tube and host pipe's invert position to monitor temperature during cure cycle.
  - h. CIPP shall be continuous over entire length from manhole to manhole.
  - i. Complete installation process control sheet for every lining completed. Control sheet shall provide the following information:
    - 1) Liner length.
    - 2) Hydrostatic head at point of inversion.
    - 3) Hydrostatic head at termination point.
    - 4) Time inversion process started.
    - 5) Time cutting ends started.
    - 6) Time cutting laterals started.
    - 7) Number of laterals cut.
4. Inflation Bladder Removal: For pulled-in-place installation techniques where inflation bladder is designed not to bond to CIPP, remove bladder material from CIPP.
5. Curing:
- a. Complete curing process control sheet for every lining completed.
  - b. Control sheets shall provide required temperatures and time for the different steps of curing process; initial cure, post cure, and cooling as outlined in ASTM F1216. Initial cure may be considered completed when exposed portions of flexible tube pipe take a hard set and temperature is adequate, as recommended by manufacturer.

- c. After installation, apply steam, hot water, or ultraviolet (UV) light as recommended by liner manufacturer.
- 1) Steam:
    - a) Provide safety system specifically structured for use of steam.
    - b) Thermoset Resin: Designed to cure properly when using steam.
    - c) CIPP Tube Thermoplastic Coating:
      - (1) Formulated from material designed specifically to withstand high temperature curing process utilizing steam.
      - (2) Polypropylene/polyethylene blend or equal.
    - d) Equipment:
      - (1) Heat source shall be capable of delivering steam throughout section and uniformly raising steam temperature above temperature required to affect cure of resin.
      - (2) Install temperature gauges in the following areas:
        - (a) Incoming steam supply.
        - (b) Outgoing steam supply.
        - (c) Between impregnated tube and pipe invert at lining termination point.
    - e) Steam Temperature: 230 degrees F, minimum.
    - f) Minimum Interface Temperature between Liner and Tube: 120 degrees F.
    - g) Pressure Required to Keep Tube Inflated: Per manufacturer's instructions.
    - h) Time: Per manufacturer's instructions.
    - i) Cool Down:
      - (1) Send air through steam cured CIPP liner until liner cools down to 120 degrees F interface temperature.
      - (2) Once 120 degrees F has been reached, water may be introduced to finish cooling line down to 90 degrees F.
      - (3) During release of water, prevent vacuum that could damage newly installed CIPP.
  - 2) Hot Water:
    - a) Equipment:
      - (1) Heat source shall be capable of delivering hot water throughout section and uniformly raising water temperature above temperature required to affect cure of resin.
      - (2) Install temperature gauges in the following areas:
        - (a) Incoming water supply.
        - (b) Outgoing water supply.
        - (c) Between impregnated tube and pipe invert at lining termination point.
    - b) Minimum Interface Temperature between Liner and Tube: 120 degrees F, minimum.
    - c) Time: 3 hours, minimum.

- d) Cool Down:
    - (1) Introduce cool water into CIPP to replace water being drained from small hole made in downstream end.
    - (2) Cool liner to temperature below 90 degrees F before relieving hydrostatic head.
    - (3) During release of water, prevent vacuum that could damage newly installed CIPP.
  - 3) UV: If this method of curing is selected, material shall be a polyester needle felt or fiberglass based CIPP liner impregnated with an isophthalic neopentyl glycol resin.
    - a) Curing parameters, such as curing speed, inner air pressure, and wattage, per the manufacturer.
    - b) Optimal curing speed or travel speed of energized UV light sources is determined for each length of liner based on liner diameter, liner thickness, and exothermic reaction temperature.
    - c) Invert liner into pipe with standard pressure drum.
    - d) After completion of inversion process introduce light chain in liner and close ends with couplings.
    - e) Remove and discard inner film material after curing to provide optimal quality of final product.
    - f) Control panel operating UV curing unit light chain may be pulled on a trailer attached to UV unit.
    - g) Flushing of UV cured CIPP liner to reduce styrene residual is not required.
- C. Manholes
- 1. CIPP terminating in manhole shall be cut in shape and manner approved by DEN Project Manager.
  - 2. Seal pipe openings and fill in annular space using products specified in Part 2 Products.
    - a. CIPP connections at manhole opening shall be watertight seal.
    - b. Install seal per manufacturer's instructions.
    - c. Recheck seal repair after 48 hours. If seal does not hold, continue to repair until there are no leaks.
  - 3. Channels: When CIPP is installed continuous through manhole, create per DEN Project Manager's instructions. Do not break or shear pipe.
  - 4. Inverts:
    - a. Finish manhole inverts to provide smooth transition between connections.
    - b. Use CIPP liner material, an approved epoxy, or similar material to form smooth transition to eliminate sharp edges of CIPP, within host pipe, and in manholes at concrete bench and channel invert.
    - c. Invert rehabilitation shall be compatible with manhole rehabilitation activities.
- D. Service Reinstatements
- 1. General:
    - a. After liner has been cured in placed, reconnect service connections.
    - b. Using CCTV, field locate existing and determine number of service connections.
    - c. Service interruptions shall not exceed 24 hours.

- d. Do not reconnect services from abandoned or vacant lots, unless directed otherwise by DEN.
  - e. Do not reactivate reconnected services until accepted by DEN Project Manager. This process shall be completed prior to the work described in Paragraph, Liner Cutting, below and before installation of lateral liner.
  - f. Show distance from nearest downstream manhole to reconnected service on record drawings.
2. Liner Cutting:
    - a. Cut liner pipe from interior of pipeline using a robotic cutter.
    - b. Holes cut through liner shall be neat and smooth in order to prevent blockage at service connections.
    - c. Cut-in service connections shall be opened to a minimum of 95 percent of building's sewer flow capacity.
    - d. Recover coupons at downstream manhole and remove.
  3. Make connections to existing lateral using elastomeric boots, full-encirclement clamps, or by other method approved by DEN Project Manager.
  4. External Reconnection: Service lateral connections to new 10-inch CIPP and larger to be made with an Inserta-Tee" (Inserta Fittings Company). Remove appropriate amount of carrier pipe to allow Inserta-Tee to be installed.
- E. Field Quality Control
1. CIPP installation shall be free from visual defects such as foreign inclusions, dry spots, keel, boat hull, pinholes, wrinkles, and other deformities.
    - a. Defects and deformities may, at discretion of DEN Project Manager, be cause for rejection of entire liner.
    - b. Correct failed CIPP and defective CIPP from post-installation television inspection or test reports for structural values or thickness as determined by DEN Project Manager.
    - c. Method of repair, which may require field or workshop demonstration, shall be approved by DEN Project Manager prior to commencement of the Work.
    - d. Remove and replace pipe identified with defects or deformities.
  2. CIPP Properties Testing:
    - a. Sampling and Measuring:
      - 1) Cut one minimum 12-inch long restrained pipe section from cured liner. Samples will be used to satisfy material testing requirements.
      - 2) Prepare samples in accordance with restrained sample method referenced in ASTM F1216 or ASTM F2019.
      - 3) Take restrained samples from excess cured CIPP at manhole connection where installation was started or terminated.
      - 4) Each sample shall be large enough to provide three specimens for tensile testing and five specimens for flexural properties testing.
    - b. Field Thickness Testing:
      - 1) Perform prior to conducting laboratory tests.
      - 2) Take wall thickness measurements in accordance with ASTM D2122.
      - 3) Make a minimum of four (4) measurements, evenly spaced, on each test specimen.
      - 4) Calculate average thickness using measured values.
      - 5) Average thickness shall be equal or greater than required design thickness.



- 6) Failure of thickness test shall be grounds for rejection for CIPP liner.
  - c. Laboratory Testing:
    - 1) Send one sample to independent laboratory and test for modulus of elasticity and flexural strength.
    - 2) Preparation and testing standards shall be performed in accordance with approved submittals.
    - 3) Failure of a test may be grounds for rejection of CIPP liner. Test second sample at direction of DEN Project Manager.
  - d. Resin Sampling:
    - 1) Wet-out facility resin mixing equipment shall have a valve downstream of the mixing function and immediately upstream of application of mixed resin to tube where resin samples may be drawn.
    - 2) Batch mix facilities, if any, shall provide for sampling of mixed batch.
    - 3) Submitted “wet-out” schedule cannot be modified without 24-hour notice to DEN Project Manager.
    - 4) Resin samples shall be drawn at times determined by DEN Project Manager.
  - e. Physical samples removed for testing as requested by DEN Project Manager shall be individually labeled and logged to record the following:
    - 1) DEN Project Manager’s Project number and title.
    - 2) Sample number.
    - 3) Segment number of line as noted on plans.
    - 4) Date and time of sample.
    - 5) Name of Contractor.
    - 6) Location and by whom tested.
    - 7) Results of test.
    - 8) Street name and address.
    - 9) Starting and ending manhole identification number for each length of pipe lined.
    - 10) Label as follows:
      - a) Sample A: Restrain Sample.
      - b) Sample B: Restrain Sample.
3. CIPP Correction:
- a. Correct failed liner or liner deemed unacceptable by DEN Project Manager as a result of CCTV inspection, leakage test results, laboratory testing, or thickness test.

b. Remedy for failed laboratory and thickness test shall be as shown in the following table:

Pipe Correction			
Test	Required Value	Test Result	Remedy
Flexural Strength	4,500 psi	4,300 to 4,490 psi	10% unit price reduction
	4,500 psi	4,100 to 4,290 psi	30% unit price reduction
	4,500 psi	Less than 4,100 psi	Pipe replacement
Flexural Modulus	250,000 psi	238,000 to 249,000 psi	10% unit price reduction
	250,000 psi	225,000 to 237,900 psi	30% unit price reduction
	250,000 psi	Less than 225,000 psi	Pipe replacement
Thickness	Minimum or design, whichever is greater	≥90% to 100%	No unit price reduction
	Minimum or design, Whichever is greater	≥80%, but less than 90%	15% unit price Reduction
	Minimum or design, whichever is greater	<80%	Pipe replacement

4. Where pipe removal and replacement is required, remove and replace entire segment length from manhole to manhole and payment shall be made in full for CIPP.

### 3.6 POINT REPAIR BY EXCAVATION

- A. Excavate and backfill trenches in accordance with Section 31 23 16 - Excavation and 31 23 23 Backfill and Surface Restoration. Point repairs in unimproved areas are to be backfilled with flowfill and native material. Point repairs in paved or concrete areas are to be backfilled with CLSM. Point repairs in airfield require replacement of the entire concrete panel per the details in the Drawings.
- B. Perform work in accordance with OSHA standards.
- C. Install and operate necessary dewatering and surface water control measures as required.
- D. Remove and lawfully dispose of excess excavated material and debris from the work site daily.
- E. Connect the new pipe to sound, unbroken existing pipe using flexible adapters. If joints cannot be made watertight using flexible adapters, place waterstop gaskets on each joint and encase in a reinforced concrete collar. Reconnect affected service connections or stacks using full-bodied fittings. No field fabrication of fittings allowed.
- F. Backfill the excavation and complete site restoration as specified in Section 31 23 23 Backfill and Surface Restoration.

- G. Complete post repair.

3.7 POINT REPAIR BY MECHANICAL REPAIR SLEEVE

- A. Confirm application is acceptable and approved with manufacturer and certified installer.
- B. Obtain measurements of pipe diameter and length of repair for coordination with manufacturer.
- C. Install the mechanical repair sleeve per manufacturer's instructions using certified installation and manufacturer approved equipment and methodology.

3.8 GRAVITY PIPE LEAKAGE TESTING:

- A. Pneumatic Testing for 18-inch and Smaller Diameter Pipe:
  - 1. Equipment:
    - a. Calibrate gauges with standardized test gauge provided by Contractor at start of each testing day. DEN Project Manager will witness calibration.
    - b. Install compressor, air piping manifolds, gauges, and valves at ground surface.
    - c. Provide pressure release device, such as rupture disc or pressure relief valve, to relieve pressure at 6 psi or less.
    - d. Restrain plugs used to close sewer lines to prevent blowoff.
  - 2. Procedure:
    - a. No person shall enter manhole or structure, or occupy area above opening of manhole or structure where pipe is under pressure.
    - b. Determine height of groundwater table at time of test.
    - c. Slowly introduce air into pipe section until internal air pressure reaches 4 psi greater than average backpressure of groundwater submerging pipe.
    - d. Allow 2 minutes minimum for air temperature to stabilize.
    - e. Allowable leakage for sewers constructed of air-permeable materials, such a concrete or clay:
      - 1) When pressure is decreased to 3.5 psig, air pressure test shall begin.
      - 2) Test shall consist of measuring time in seconds for pressure in pipe to drop from 3.5 psig to 2.5 psig.
      - 3) Pipe leakage shall be considered acceptable if time in seconds for pressure drop is equal to or greater than required time as calculated below:

$$K = 0.0111d^2L$$

$$C = 0.000392dL$$

If  $C_t$  is less than or equal to 1.0, then time =  $K_t$

If  $C_t$  is between 1.0 and 1.75, then time =  $K_t/C_t$

If  $C_t$  is greater than or equal to 1.75, then time =  $K_t/1.75$

Where: d = pipe diameter in inches

L = pipe length in feet

K = value for each length of pipe of a specific diameter

C = value for each length of pipe of a specific diameter

$K_t$  = Sum of all K values

$C_t$  = Sum of all C values

3. This method is based upon allowable air loss rate of 0.003 cfm per square foot of internal pipe surface, with total air loss rate not less than 2.0 cfm or greater than 3.5 cfm.
  - a. Hydrostatic Head:
    - 1) At least 6 feet above maximum estimated groundwater level in section being tested, but no less than 6 feet above inside top of highest section of pipe in test section, including service connections.
    - 2) In every case, determine height of water table at time of test by exploratory holes or such other methods approved by DEN Project Manager. DEN Project Manager will make final decision regarding test height for water in pipe section being tested.
    - 3) If hydrostatic head is other than 6 feet, allowable leakage as computed by criteria above shall be adjusted by the square root of actual head divided by square root of 6.
  - b. Length of Pipe Tested: Limit length such that pressure on invert of lower end of section does not exceed 16 feet of water column. In no case shall length be greater than 700 feet or distance between manholes when greater than 700 feet.
  - c. Dispose of test water in a manner that will not damage or interfere with adjacent property and in a manner acceptable with DEN Project Manager and regulatory agencies.

### 3.9 OBSTRUCTION REMOVAL

- A. Remote Device: Remove obstructions identified during video inspection of a sanitary sewer line segment which could cause a non-uniform liner pipe installation or obstruction of the liner during installation. Obtain authorization from the DEN Project Manager for obstruction removal with a remote device before proceeding.
  1. Use a power-driven cutting device (robotic cutter) to remove protruding taps. Cut protruding taps so that protrusions are no greater than 3/4 inch. If a protruding tap cannot be removed by the cutting device, then a point repair may be performed. Obtain authorization from the DEN Project Manager before proceeding.
  2. To remove other obstructions, use a remote device. Pull or drive the device from manhole to manhole up to a continuous length of 500 feet using a solid steel mandrel, porcupine, root saw, bucket, robotic cutter or similar device to remove the obstruction. Select a device that is adequately sized to remove the obstruction.
- B. Excavation: Use excavation as the method of obstruction removal when installation of the liner in the sanitary sewer is in progress. If during the liner insertion operation, a collapsed sewer, off-set joint or other obstruction is encountered which prevents or blocks the passage or insertion of the liner, notify the DEN Project Manager for authorization to excavate. Uncover and remove the obstruction as follows:
  1. Excavate at the point where there is an obstruction. Use a trench safety system as required.
- C. Break out the minimum amount of existing sanitary sewer pipe as needed. Remove only that amount of material which is causing the obstruction.

3.10 CLEANING

- A. After point repair and/or liner has been completed and accepted by DEN Project Manager, clean entire Project area and restore Site to original condition.

**PART 4 MEASUREMENT AND PAYMENT**

4.1 Measurement and payment are as follows:

- A-C. Point repairs are to be measured on a lump sum basis per repair and includes furnishing all equipment, labor, and materials necessary for repair of the manhole or pipeline as shown on the Drawings including but not limited to CCTV, flushing the line as needed, cured-in-place piping lining, mechanical repair sleeve installation, excavation, removing and hauling the existing segment of pipe, installing a new section of pipe, fittings, backfilling, importing or hauling backfill material, and surface restoration. Pay item includes all other work necessary to complete the installation per the Drawings and as specified.

<b>Pay Item</b>	<b>Pay Unit</b>
330131.A SAG05501-SAG04049 Point Repair	Lump Sum
330131.B SAG05509-SAG05508 Point Repair	Lump Sum
330131.C SAG05621-SAG04043 Point Repair	Lump Sum

**END OF SECTION**

**SECTION 33 01 30.80  
MANHOLE REHABILITATION**

**PART 1 GENERAL**

1.1 REFERENCES

- A. The following is a list of standards that may be referenced in this section:
1. ASTM International (ASTM):
    - a. D638, Test Method for Tensile Properties of Plastics.
    - b. D790, Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials.
    - c. D3753 Standard Specification for Glass Fiber Reinforced Polyester Manholes.
    - d. C150/C150M, Standard Specification for Portland Cement.
    - e. C293/C293M, Standard Test Method for Flexural Strength of Concrete (Using Simple Beam With Center-Point Loading).
    - f. C307, Standard Test Method for Tensile Strength of Chemical-Resistant Mortar, Grouts, and Monolithic Surfacing.
    - g. C348, Standard Test Method for Flexural Strength of Hydraulic-Cement Mortars.
    - h. C413, Standard Test Method for Absorption of Chemical-Resistant Mortars, Grouts, Monolithic Surfacing, and Polymer Concretes.
    - i. C478, Standard Specification for Precast Reinforced Concrete Manhole Sections.
    - j. C496/C496M, Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens.
    - k. C497, Standard Test Methods for Concrete Pipe, Manhole Sections, or Tile.
    - l. C580, Standard Test Method for Flexural Strength and Modulus of Elasticity of Chemical-Resistant Mortars, Grouts, Monolithic Surfacing and Polymer Concretes.
    - m. C596, Standard Test Method for Drying Shrinkage of Mortar Containing Hydraulic Cement.
    - n. C631, Standard Specification for Bonding Compounds for Interior Gypsum Plastering.
    - o. C666/C666M, Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing.
    - p. C882 Standard Test Method for Bond Strength of Epoxy Systems Used with Concrete by Slant Shear.
    - q. C924, Standard Practice for Testing Concrete Pipe Sewer Lines by Low-Pressure Air Test Method.
    - r. C952, Standard Test Method for Bond Strength of Mortar to Masonry Units.
    - s. C1202, Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration.
    - t. C267, Standard Test Method for Determining the Chemical Resistance of Grouts.
    - u. D695 Standard Test Method for Compressive Properties of Rigid Plastics.
    - v. D638 Standard Test Method for Tensile Properties of Plastics.
    - w. D790 Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials.
    - x. D882, Standard Test Method for Tensile Properties of Thin Plastic Sheeting.

- y. D1042, Standard Test Method for Linear Dimensional Changes of Plastics under Accelerated Service Conditions.
- z. D2834, Standard Test Method for Nonvolatile Matter (Total Solids) in Water-Emulsion Floor Polishes, Solvent-Based Floor Polishes, and Polymer-Emulsion Floor Polishes.
- aa. D3574, Standard Test Methods for Flexible Cellular Materials—Slab, Bonded, and Molded Urethane Foams.
- bb. D4414, Standard Practice for Measurement of Wet Film Thickness by Notch Gages.
- cc. D4541, Standard Method for Pull-Off Strength of Coatings Using Portable Adhesion Tester.
- dd. NACE International, (NACE): SPO 188, Discontinuity (Holiday) Testing of New Protective Coatings on Conductive Substrates. SSPC-SP 13 Surface Preparation of Concrete Grouting.
- ee. The Society for Protective Coatings (SSPC): SP 10, Near-White Metal Blast Cleaning.

## 1.2 SUBMITTALS

### A. Action Submittals:

1. Site layout plan detailing placement of equipment and materials for completion of work. Construction phasing plans and coordination in the airfield approved by den Project Manager and DEN Airport Operations.
2. Rehabilitation system product data to include:
  - a. Material handling and storage.
  - b. Material properties.
  - c. Mixing and proportioning requirements.
  - d. Maximum pot life.
  - e. Film/coating thickness.
  - f. Curing.
  - g. Test results.
  - h. Certification of all rehabilitation materials.
  - i. Calculations.
3. Shop Drawings:
  - a. Corbel (Cone): details of construction.
  - b. Manholes over existing piping: plans for preventing materials from entering. flow and downstream infrastructure.

### B. Informational Submittals:

1. Construction photographs.
2. Confined space entry plan and program.
3. Confined space entry permit.
4. DEN Risk Management and DFD permits.
5. Plan for capturing extraneous debris during rehabilitation processes and debris disposal. Contractor shall properly dispose of all debris resulting from preparation and rehabilitation activities at no additional cost to DEN. Disposal shall be in accordance with all local, state, and federal laws and shall not involve disposal within sewer system.
6. Applicator's Qualifications.
7. Manufacturer (or Manufacturer's Representative) Certificates and Reports.
8. Post-CCTV inspection DVDs as specified in Section 33 01 30.16, Television Inspection of Sewer Pipelines.
9. Description, layout, and application sequencing plan.

10. Manufacturer's Certificate of Compliance, Product Data and Samples, for specified materials.
11. Product manufacturers' certification that each proposed rehabilitation product is compatible with the other product(s) to be used.
12. Material Safety Data Sheets (MSDS) for all products used.
13. Epoxy Lining Resin:
  - a. Type test performed information.
  - b. Method of installation/work plan. Prior to commencing with any phase of the work covered by this section, provide manufacturer's recommended resurfacing material, including: generic description, surface preparation, mixing instruction, application procedures, minimum and maximum thickness, ACI 308 curing procedures (including method(s) and duration), subsequent preparation necessary to receive epoxy lining materials, and minimum and maximum curing/recoating times, all must be submitted in writing and shall be followed in detail by the Contractor.
  - c. Submit written flow management plan per Section 01 57 28 Temporary Flow Control to DEN Project Manager for approval prior to beginning of flow management operations. Flow-through plugs, if utilized, will require a written flow management plan submittal prior to insertion. If no flow management is anticipated, Contractor shall provide written verification that coating/lining product installation and performance of the work can be accomplished according to manufacturer recommendations without the use of flow management. Contractor shall use means necessary, without pumping, to keep the concrete surfaces that are being rehabilitated dry at all times throughout the coating/lining installation process.
14. Precast manhole sections: manufacturer's results of tests performed on representative sections to be furnished.

### 1.3 QUALITY ASSURANCE

- A. Applicator's Qualifications:
  1. Minimum 5 years' experience in application of products to be used.
  2. Manufacturer's Certifications:
    - a. Applicator has been trained and approved in the handling, mixing and application of the products to be used.
    - b. Equipment to be used for applying the product has been approved and the applicator personnel have been trained and certified for proper use of the equipment.
  3. Five (5) recent references of applicator (projects of similar size and scope) indicating successful application within the past 10 years.

### 1.4 DELIVERY, STORAGE, AND HANDLING

- A. Deliver lining products to Site in unopened containers that plainly show, at time of use, product name, date of manufacture, batch number, and name of manufacturer.
- B. Store lining products in protected area with heating or cooling as required to maintain temperatures within range recommended by product manufacturer.
- C. Handle and store materials in accordance with manufacturer's recommendations and MSDS. Materials exceeding storage life recommended by the manufacturer shall be removed from the Site.



- D. Storage of materials within the airfield should be coordinated with DEN Airport Operations via DEN Project Manager.

## 1.5 WARRANTY

- A. The applicator shall provide a written warranty of all work against defects in materials and workmanship for a period of five (5) years, unless otherwise noted from the date of final acceptance of the project.
- B. Should a defect be observed within a lined manhole during this warranty period or as part of the warranty inspection, applicator shall within a reasonable time after receipt of written notice of the defect complete repair(s) to the liner to the satisfaction of the DEN Project Manager and DEN Asset Manager. Contractor is responsible for all repairs to the manhole that resulted from the liner defect. No compensation shall be afforded for the repair of defects within the warranty period.

## PART 2 PRODUCTS

### 2.1 GENERAL

- A. Environmental Requirements:
  - 1. Provide sanitary sewer flow control as detailed in Specification Section 01 57 28, Temporary Flow Control.
  - 2. Provide traffic control as detailed in Specification Section 015525 Traffic Control.
  - 3. Control the environment within the facility that is to be lined. This includes maintaining the required application temperature and humidity for the linings being applied.
  - 4. Provide illumination for surface preparation and application and curing of all underlayment and lining materials.
  - 5. Provide equipment to ventilate the facilities during the application and cure of the lining materials.
  - 6. The products shall be capable of protecting the manhole at typical hydrogen sulfide (H<sub>2</sub>S) of 25 mg/l and intermittent H<sub>2</sub>S of 100 mg/L.
  - 7. Product shall not be affected by typical wastewater constituents to include acid/bases and oils and grease.
- B. Manufacturers:
  - 1. All materials shall be approved by the DEN Project Manager and shall have a documented, proven performance record in similar facilities and exposure conditions.
  - 2. Manufacturers shall be regularly engaged in the production of such materials for identical service conditions and have a minimum of 5 years of verifiable experience in manufacture of these products.
  - 3. Products shall meet federal, state, and local requirements limiting the emission of volatile organic compounds.
  - 4. Materials, including underlayment and lining shall be produced by the same manufacturer. Mixing of systems is not allowed.

2.2 EPOXY LINING SYSTEM

- A. Characteristics:
1. 100 percent solids, plural component epoxy, capable of spray or roller application.
  2. System capable of application to damp concrete surfaces in high relative humidity environment.
  3. Resistant to attack from hydrogen sulfide and sulfuric acids generated from microbiological sources.
  4. System shall meet requirements of ASTM C722 and ASTM D1763, and be 100 percent solids epoxy resin. A minimum finish thickness of 125 mils is required.
- B. Properties:
1. Bond Strength, ASTM C478: Concrete failure.
  2. Tensile Strength, ASTM C307: 2,500 psi, minimum.
  3. Flexural Strength, ASTM C580: 4,800 psi.
  4. Moisture Absorption, ASTM C413: 0.1 percent.
  5. Shrinkage, ASTM C631: 0.11 percent, maximum.
- C. Manufacturers and Products: No alternatives to the listed manufacturer's and products will be accepted.

Manufacturers	Products
1. Environmental Coatings, Inc.	Sewer-Shield 100 (Trowel) Sewer-Shield 101S (Spray) Sewer-Shield 101A Sewer-Shield 150
2. Sauereisen, Inc.	SewerGard 210X Epoxy
3. Warren Environmental, Inc.	S-301 Epoxy

- D. Underlayment mortar or build-back material:
1. No alternatives to the listed manufacturer's and products will be accepted.
  2. System shall be compatible with 100% solids high-build epoxy product, from same manufacturer. Mortar or build-back material shall be used as required by manufacturer or if concrete deterioration exceeds ¼-inch. Mortar or build-back material shall be compatible with the lining materials.

Manufacturers	Products
1. Environmental Coatings	Sewer-Shield C-120 Acid Resistant Underlayment
2. Sauereisen, Inc.	RestoKrete 208 Epoxy-modified resurfacer
3. Warren Environmental	S-301 Epoxy Mortar/Mastic or 301-14XT as recommended by manufacturer

## 2.3 INFLOW AND INFILTRATION

- A. General
  - 1. Active inflow or infiltration into manholes shall be eliminated using either a hydraulic cement or chemical pressure grout system.
  
- B. Products:
  - 1. Hydraulic Cement:
    - a. Rapid-setting, high-early strength, cementitious product specifically formulated for leak control.
    - b. Manufacturers and Products:
      - 1) IPA; Ipanex-R or Octocrete.
      - 2) Strong Systems, Inc.; Strong-Seal QSR or Rapid Set.
  - 2. Pressure Grouting Systems:
    - a. Urethane gel or polyurethane resin installed by pressurized injection.
    - b. While being injected, the chemical sealant shall react/perform in the presence of infiltrating water. Flooding around the manhole may be required in the event the groundwater level has dropped when the work is to be performed.
    - c. The cured sealant must be capable of withstanding submergence in water without degradation.
    - d. The cured sealant must prevent the passage of water through the manhole defect.
    - e. The cured sealant must be flexible.
    - f. In place, the cured sealant shall be able to withstand freeze/thaw and wet/dry cycles without adversely affecting the seal.
    - g. The cured sealant must not be biodegradable. Additives may be used to meet this requirement, without affecting long-term strength.
    - h. The cured sealant shall be chemically stable and resistant to concentrations of acids, alkalis, and organics found in normal sewage.
    - i. Residual sealing materials must be easily removable from the bench of manhole to prevent reduction or blockage of the sewer flow.
    - j. Manufacturers and Products:
      - 1) Prime Resins; Prime-Flex 900 XLV or 920.
      - 2) Avanti International; AV-350 multi-grout or AV-254.
      - 3) Approved Equal.
  - 3. Frame to Structure/Manhole Seal:
    - a. External seal for manholes with new concrete collars: trowable bitumastic applied per the Drawings with 6 MIL plastic wrap.
    - b. External seal for manholes without concrete collars and interior joint seals for manholes without complete rehabilitation: Joint Wraps shall be made of materials that have been proven to be resistant to the following exposures and requirements:
      - 1) In accordance with ASTM C923.
      - 2) Designed for application and have demonstrated history of accommodating differential expansion between frame and concrete.
      - 3) Expansive type wraps shall be fabricated of high quality rubber or urethane.
      - 4) Thickness: Minimum 3/16 inch or as recommended by manufacturer for installation climate.
      - 5) Width: Minimum 8 inches.
      - 6) Bands: If required, constructed of minimum 16-gauge sheet if channeled, or 5/16-inch diameter if round.

- 7) Wrap shall not restrict access to manhole.
- 8) Manufacturers and Products:
  - a) External Seal:
    - (1) Sealing Systems, Inc., Loretto, MN; Infi-Shield.
    - (2) Trelleborg Engineered Systems, Milford, NH; NPC Flexrib Frame-Chimney Seals.
    - (3) Cretex Specialty Products, Waukesha, WI; X-85 Seal.
  - b) Internal Seal:
    - (1) Sealing Systems, Inc., Loretto, MN; Flex-Seal Utility Sealant.
    - (2) Trelleborg Engineered Systems, Milford, NH; NPC Flexrib Frame-Chimney Seals.
    - (3) Cretex Specialty Products, Waukesha, WI; Internal Manhole Chimney Seal.
- c. Butyl Joint Sealant:
  - 1) In accordance with ASTM C1311 or ASTM C990.
  - 2) Trowelable or cartridge applied.
  - 3) Manufacturers and Products:
    - a) Tremco Commercial Sealants and Waterproofing, Beachwood, OH; Tremco Butyl Sealant.
    - b) Bostik, Middleton, MA; Chem-Calk 300.
    - c) Press-Seal Gasket Company, Fort Wayne, IN; EZ-Stik #3.

#### 2.4 PATCHING REPAIRS

- A. Cementitious Mortar:
  1. Consisting of one part portland cement and two parts clean sharp sand.
  2. Cement: Type 1 conforming to ASTM C150/C150M.
  3. Sand: Conforming to ASTM C144.
- B. Patching Material: Quick setting fiber reinforced cementitious material.
- C. Hydraulic Cement:
  1. Rapid-setting, high-early strength, cementitious product specifically formulated for leak control.
  2. Manufacturers and Products:
    - a. IPA; Ipanex-R or Octocrete.
    - b. Strong Systems, Inc.; Strong-Seal QSR or Rapid Set.
- D. Bonding Agent:
  1. Chemical bonding agent that bonds new concrete to a clean structurally sound surface.
  2. Manufacturer and Product: Larsen Products Company; Weld-Crete.

#### 2.5 PRECAST MANHOLES

- A. Riser Sections:
  1. 24 or 27-inches in diameter as indicated in the inspection forms.
  2. Fabricate in accordance with ASTM C478.
  3. Minimum Wall Thickness: 4 inches or 1/12 times inside diameter, whichever is greater.
  4. Top and bottom shall be parallel.

5. Joints: Confined O-ring with rubber gaskets meeting ASTM C443.
- B. Corbel (Cone) Sections:
1. Same wall thickness and reinforcement as riser section.
  2. Top and bottom shall be parallel.
  3. Corbel sections are to be eccentric and match the thickness and height of the existing manhole wall.

## 2.6 MANHOLE EXTENSIONS

- A. Concrete grade rings; maximum 6-inches high, maximum total grade extension: 24-inches.
- B. Fabricate in accordance with ASTM C478.

## 2.7 PREFORMED PLASTIC GASKETS

- A. Hamilton Kent of Nevada, Sparks, NV; Kent-Seal No. 2.
- B. Henry Company, Houston, TX; Ram-Nek.

## 2.8 SOURCE QUALITY CONTROL

- A. All test specimens shall be mat tested and meet permeability test requirements of ASTM C14.
- B. Conduct tests at point of manufacture prior to delivery of any section.
- C. Sections to be tested will be selected at random from stockpiled material to be supplied for the Project.

## 2.9 MANHOLE FRAMES AND COVER

- A. Castings:
  1. Tough, close-grained gray iron, sound, smooth, clean, free from blisters, blowholes, shrinkage, cold shuts, and defects.
  2. Cast Iron: ASTM A48 Class 30B.
  3. Ductile Iron: ASTM A536, Grade 60-40-12.
  4. Plane or grind bearing surfaces to ensure flat, true surfaces.
- B. Cover: To conform with City and County of Denver standard covers.
- C. Capscrews for Watertight Covers: High temper phosphor bronze with 60,000 psi minimum tensile strength meeting ASTM B139.
- D. All manhole covers replaced in the airfield as identified on the Mapbook, shall be rated for 100,000 lbs and be aircraft rated per FAA requirements.
  1. Manufacturers:
    - 1) Neenah.
    - 2) Or approved equal.

## 2.10 MANHOLE FRAME TO STRUCTURE SEALS

- A. Gasket:
1. Extrude or mold from a high-grade rubber compound.
  2. Comply with material test requirements of ASTM C923.
  3. Minimum Thickness: 3/16 inch.
  4. Minimum Unstretched Length: Sufficient to extend from the manhole frame, across a maximum of 12 inches of extension rings, to the manhole cone section.
  5. Fabricate bands for compressing sleeve against manhole from Type 304 stainless steel:
    - a. Channeled Sheet: Minimum 16-gauge, ASTM A167.
    - b. Round: 5/16-inch diameter, ASTM A240.
- B. Screws, Bolts, or Nuts: Stainless Steel conforming to ASTM F593 and ASTM 594, Type 304.
- C. Gasket shall be made only of materials that have been proven to be resistant to the following exposures and conditions:
1. Sanitary sewage.
  2. Corrosion or rotting under wet or dry conditions.
  3. Gaseous environment in sanitary sewers and at road surfaces including common levels of ozone, carbon monoxide, and other trace gases at the sites of installation.
  4. Biological environment in soils and sanitary sewers.
  5. Chemical attack by road salts, road oil, and common street spillages or solvents used in street construction or maintenance.
  6. Temperature ranges, variations, and gradients in the area of construction.
  7. Variations in moisture conditions and humidity.
  8. Fatigue failure caused by a minimum of 30 freeze-thaw cycles per year.
  9. Vibrations due to traffic loading.
  10. Fatigue failure due to repeated variations of tensile, compressive and shear stresses, and repeated elongation and compression.
  11. Any combination of the above.
- D. Materials used shall be compatible with each other and with manhole materials.
- E. Design gasket to meet the following requirements:
1. Continuously prevent leakage of water from outside the manhole into the manhole at the joints between the manhole frame and the cone section.
  2. Seal shall remain flexible, allowing repeated vertical movements of frame from 0-up to 2-inches or repeated horizontal movements of frame with respect to top of extension or cone from 0-up to 1/2-inch due to pavement movements or other causes, or both types of movement occurring simultaneously at rates not exceeding 1/10-inch per minute.

## 2.11 TEST EQUIPMENT

- A. Contractor shall obtain and be knowledgeable in the use of the following equipment:
1. U.S. Weather Bureau Psychrometric Tables for determining dew point from wet and dry bulb temperatures, as available from KTA-Tator, Inc., Pittsburgh, PA.
  2. A portable, self-contained, hand-held sling psychrometer with thermometers ranging from 20 degrees F to 120 degrees F and built-in slide rule for determination of relative humidity as manufactured by Bacharach instrument Co., Pittsburgh, PA; or Taylor Co. A digital psychrometer is also acceptable.

3. A hand-held digital thermometer, range minus 20 degrees F to 200 degrees F, and interchangeable surface temperature and air temperature probes as manufactured by Atkins.
  4. A high voltage holiday detector for thick film coatings as manufactured by Tinker and Razor, Model AP/W, San Gabriel, CA or equivalent.
  5. Ten (10) hand-held pH pencils suitable for measuring pH of concrete surfaces as manufactured by Burrel Scientific, Model Insta-Check Surface pH pencil, No. P-13N, Pittsburgh, PA.
- B. This test equipment shall be used for monitoring and testing requirements.
- C. The test equipment shall be stored at the Project Site for the Contractor's daily use and shall be maintained in accurate, working conditions at all times. The test equipment shall be available to the DEN Project Manager or designated representative for testing purposes.

### **PART 3 EXECUTION**

#### **3.1 GENERAL**

- A. Notify DEN Project manager three (3) days, minimum, prior to start of surface preparation work or coating application work.
- B. Contractor shall conform and comply with all local state and federal regulations in the performance of the work including those set forth by OSHA, RCRA, and EPA and other authorities.
- C. Control environment within manhole; this includes maintaining temperature and humidity for linings being applied in accordance with the requirements of the system manufacturer. Provide illumination for surface preparation, application, and inspection and curing of underlayment and lining materials.
- D. Remove or protect flow meters and any other gates or equipment installed within the manhole during completion of work. Reinstall flow meters, gates and equipment if removed in accordance with the manufacturer's recommendations and requirements of the DEN Project Manager.
- E. Prevent construction materials from entering sewer pipelines. Any materials that do enter the system shall be the responsibility of the Contractor to locate and remove at their expense.
- F. Provide traffic control as required and specified.
- G. Provide temporary flow control as required and specified.

#### **3.2 EXCAVATION AND BACKFILL**

- A. Excavation: As specified in Section 31 23 16, Excavation.
- B. Backfill: As specified in Section 31 23 23.15, Trench Backfill.

#### **3.3 COVERAGE**

- A. System shall be applied/cover all walls, underside of top slab, chimney, corbel, intermediate platforms (top and bottom), bench, and invert of the manhole.

- B. Surface Preparation:
1. Perform surface preparation in presence of DEN Project Manager or designated representative, unless DEN Project Manager agrees Work may be performed in DEN Project Manager's or designated representative's absence.
  2. Prepare surface in accordance with recommendations of manufacturer and the following:
    - a. High pressure water spray shall be a minimum of 3,500 psi.
    - b. Remove all previously applied coating systems. If after all reasonable efforts to remove the coating system, including 5,000 psi pressure wash, if the result is clean surfaces with no loose or detached materials in a condition suitable for coatings and linings as specified then the existing coating that is adhered after the preparation is complete can be coated over top with the specified materials. The coating shall be roughened to promote adhesion.
    - c. Remove all loose and protruding concrete or brick and mortar.
    - d. Remove all manhole steps and plug holes with quick setting high early strength hydraulic cement.
    - e. Mark and protect embedded anchors prior to blasting.
    - f. Manholes that were noted to have existing cone (corbel) lining (epoxy or PVC) are identified on the manhole summary sheets and the detailed inspection forms. The existing PVC lining shall be removed when the lining is in poor condition, the concrete behind the lining is in poor condition, and/or the seal of the lining is in poor condition. The option to remove and replace the cone section is at the Contractor's discretion and is no additional cost to DEN.
  3. Notify DEN Project Manager if any reinforcing steel is exposed by cleaning for review and determination if additional rehabilitation beyond that detailed is required.
  4. Surface pH:
    - a. Regularly, approximately every 100 square feet, measure surface pH using pH test pencils to verify compliance with Specification.
    - b. Surfaces not meeting requirements shall be marked and reblasted.
    - c. Concrete Surface: 10 pH, minimum.
- C. Inflow and Infiltration:
1. Mark all locations of inflow and infiltration into the manhole. In general the criteria for the systems shall be:
    - a. Hydraulic Cements shall be used to eliminate minor weeps and seeps from small cracks, joints and other manhole defects.
    - b. Chemical pressure grout systems shall be used to stop active flow.
  2. Hydraulic cement and chemical pressure grout system shall be installed in accordance with the manufacturer's recommendations.
- D. Bench Construction and Invert Repair:
1. Bench: Construct using quick-setting grout or repair mortar per manufacturer's recommendations.
  2. Invert Repair:
    - a. Perform on inverts with visible damage or where infiltration is present.
    - b. After blocking flow through manhole and cleaning invert, apply quick-setting patch material.
    - c. Finished invert surface shall have a smooth surface and form a continuous monolithic conduit with sewer pipe entering and leaving manhole.
  3. Form watertight seal with manhole walls, base, and pipe seal.
  4. Prevent wastewater contact with new bench and invert as required by the manufacturer to ensure a durable final product.



### 3.4 SYSTEM APPLICATION/INSTALLATION

- A. General:
1. DEN Project Manager or designated representative will inspect all cleaned and repaired manholes before application of lining system; provide 24-hour notification.
  2. Manufacturer/manufacturer's representative will inspect 10% of cleaned and repaired manholes before application of lining system.
  3. Apply or install system in accordance with the manufacturer's recommendations. Rehabilitation sequence to start with pressure grouting, followed by surface preparation, bench/invert/wall repairs, and lining.
  4. Upon completion of work, DEN Project Manager or designated representative will inspect all rehabilitated manholes and be present for testing.
  5. Manufacturer/manufacturer's representative shall inspect all rehabilitated manholes.
- B. Frame-To-Structure Seal:
1. Install in accordance with details of manufacturer's recommendations.
  2. Seal shall extend from side of manhole frame down to cone or corbel of manhole.

### 3.5 EXTERIOR MANHOLE REHABILITATION

- A. Frame and Cover Replacement:
1. Existing manhole frames and covers shall be reused except where indicated in the Mapbook.
  2. Set frames in three (3) equally spaced beads of butyl sealant that run full circumference of frame.
  3. Install exterior manhole frame to structure seals in accordance with manufacturer's instructions. Seal shall cover grade rings.
- B. Chimney/Corbel Rehabilitation:
1. Chimney/corbel replacement shall be in accordance with manufacturer's instructions.
  2. Excavate around existing manhole and remove all existing chimney/corbel components and materials.
  3. Clean remaining surfaces and install pre-cast gaskets in accordance with manufacturer's instructions.
  4. Place and true up replacement chimney/corbel and add grade risers to adjust top of frame to grade.

### 3.6 SURFACE PREPARATION

- A. Prepare surface in accordance with manufacturer's recommendations using high pressure water blasting (3,500 psi minimum at the nozzle), hydroblasting (10,000 psi minimum at the nozzle), dry abrasive blasting (100 psi minimum at the nozzle) along with other additional methods in accordance with the following industry standards:
1. SSPC SP 13/NACE No. 6.
  2. ASTM D4258.
  3. ASTM D4259.
  4. Applicable NACE/SSPC standard for metal surface.
- B. Notify DEN Project Manager for review of any reinforcing steel exposed by cleaning and direction regarding any additional rehabilitation to be added to the scope of Work.

- C. Surface pH:
1. Regularly, approximately every 100 square feet, measure surface pH using pH test pencils to verify compliance with specification.
  2. Mark and re-blast surfaces not meeting requirements.
  3. Concrete Surface: 10 pH, minimum.

### 3.7 MANHOLE CHEMICAL PRESSURE GROUTING

- A. General: Pressure grouting shall be done in accordance with the Drawings and on any sections that have evidence of rain-derived inflow and infiltration (I/I). Any structurally unsound manholes observed by Contractor shall be replaced as directed by DEN Project Manager.
1. The existing manhole structure designated for pressure grouting for pipe seals, locations of I/I, or for precast joints shall be thoroughly cleaned prior to grouting. Contractor shall dispose of all debris and prevent any debris from entering the existing sewer lines.
  2. Pressure grouting may be performed between barrel sections, including base, prior to completing other work in the manhole with the exception of the shallowest barrel section and the cone (corbel). All other grade adjustments, frame and cover replacements, chimney repairs, frame seals, step removal, and other repairs shall be completed prior to pressure grouting. Pressure grouting shall be done prior to manhole lining. All roots exposed in the manhole shall be removed.
  3. Pressure chemical grouting of the manhole may include precast wall joints, voids in concrete manholes, pipe seals, or bench and invert.
- B. Grouted and Coated Pipe Sealing:
1. Injection holes shall be drilled with a minimum of three holes around the pipe/manhole wall connection. After removal of the grouting probe, activated oakum rope shall be used to fill the injection holes. Pipe seal pressure grouting will include the entire lower 18 inches of the manhole. Injection holes shall be patched with waterproof, quick-setting mortar and covered with a moisture resistant two-part epoxy adhesive coating. Any pipe damaged by Contractor while drilling the injection holes shall be replaced at no expense to DEN.
  2. Contractor shall, at no additional cost to DEN, replace any portion of the existing manhole or pipe that is damaged during pipe sealing.
  3. The deteriorated area of the pipe seal shall be removed to sound material. Care shall be taken to avoid damaging other parts of the manhole structure. Loose and concrete or debris, and pipe shall be removed from the manhole.
  4. A bonding agent shall be applied to existing surfaces to provide a firm adhesion between original and new cementitious materials in accordance with manufacturer's recommendation.
  5. Contractor shall place rapid-set grout, to the area. Rapid-set grout shall be placed in such a manner that it is consolidated, fills existing voids, and creates a smooth, dense surface in accordance with the Drawings.
  6. Wastewater flow shall be maintained by methods that prevent contact with new pipe seal for 6 to 8 hours after rapid-set grout placement.
  7. The pipe seal shall form a water tight seal with the manhole wall, bench, trough, and pipe. The manhole and pipes shall be cleaned of all debris and foreign matter.
  8. All manholes scheduled for rehabilitation shall have all pipe seals (including drops, services and other pipe connections) and the lower 18 inches of the manhole drilled and grouted. The lower 18 inches is measured from the lowest invert elevation up 18 inches. Drilling and grouting the lower 18 inches shall include at least two rows of

- drill and grout holes. Grouting the pipe seals and the lower 18 inches is subsidiary to the manhole rehabilitation and will not be paid for separately.
9. Contractor is responsible to stop all active inflow and infiltration leaks in the manhole prior to placing the interior coating. Work and materials required to stop leaks in the manhole are considered subsidiary to manhole rehabilitation and will not be paid for separately.
  10. Manholes with drop line service connections shall have the pipe seals of all grade lines and drop lines grouted in addition to the bottom 18 inches of the manhole. All incoming and outgoing pipe seals shall be grouted, regardless of the height above the flowline of the manhole.
- C. Manhole Wall Sealing:
1. General: Prior to pressure grouting of manholes specified in the Drawings, all unsealed step holes, missing pipe seals, leaking cracks, and unsealed lift holes shall be repaired. A quick-setting cement shall be used to fill these defects.
  2. Grout Material Utilization:
    - a. Frame, Wall, Pipe Seal, Bench, and Invert: Urethane grout or other approved chemical pressure grout shall be utilized for the entire manhole.
    - b. No grouting operations shall be performed at temperatures below manufacturer's recommendations or where the temperature of the groundwater is below manufacturer's recommendations.
  3. Wall Grouting:
    - a. Surface Preparation: Prior to pressure grouting of manhole cone, entire surface area shall be coated with a layer of dry polymer mortar in accordance with the manufacturer's recommendations. Dry polymer mortar shall not be applied to the wall portion of the manhole unless grout migration back into the manhole is observed during the grouting operation. No drilling or pressure grouting shall be done until the dry polymer mortar has been allowed to dry for a period of 24 hours. The dry polymer mortar shall extend to a point 12 inches below the joint between the cone and wall.
    - b. Wall Drilling: Where there is evidence of leaking, a minimum of four injection holes shall be drilled at 90 degree angles from each other at the same plane of elevation. Additional rows shall be separated by a distance of 24 inches, and the holes shall be staggered with the holes in the rows above and below. After removal of the grouting probe, activated oakum rope or an equal approved by the Owner and Engineer shall be used to fill the injection holes. Injection holes shall be patched with a waterproof quick-setting mortar.
- D. Precast Joint Sealing: A minimum of four (4) injection holes shall be drilled at 90 degree angles from each other at the same plane of elevation approximately 6 inches above the precast section joint. An additional row of holes shall be drilled 6 inches below the joint staggered by 45 degree as shown in the Drawings. After removal of the grouting probe, activated oakum rope shall be used to fill the injection holes. Injection holes shall be patched with a waterproof, quick-setting hydraulic cement.

### 3.8 TESTING

- A. General:
1. Perform testing, document, and submit results to the DEN Project Manager. The Contractor may not proceed with rehabilitation product application until surface preparation work is approved by DEN Project Manager.

2. Provide DEN Project Manager 24 hours notice of start of testing.
  3. Manufacturer/manufacturer's representative shall be present for testing as required for preparation of proper installation documentation.
- B. Air, Concrete Substrate, and Lining Materials:
1. Temperatures:
    - a. Measure and record twice daily air, concrete substrate, and lining surface temperatures within structure during mixing, application, and curing of materials; verify compliance with manufacturer's temperature ranges.
    - b. Take measurements in morning and afternoon in presence of DEN Project Manager or authorized representative.
    - c. If outside acceptable range, make adjustments to return to and maintain manufacturer's required temperatures prior to continuing lining application.
  2. Humidity:
    - a. Measure and record twice daily relative humidity within structure during mixing, application, and curing of materials; verify compliance with manufacturer's requirements.
    - b. Take measurements in morning and afternoon in presence of DEN Project Manager or authorized representative.
    - c. If outside acceptable range, make adjustments to return to and maintain manufacturer's required relative humidity prior to continuing lining application.
- C. Cementitious Lining System: Take a minimum of two 2-inch by 2-inch cubes of coating material from each day's work with date, location, and job recorded on each. Cylinders shall be sent to a certified testing laboratory for testing. Compression test shall be conducted per ASTM C780, and results shall be furnished to DEN Project Manager.
- D. Epoxy Lining and Polyurethane/Polymer Lining System:
1. Wet Film Thickness Gauge: During application, use wet film thickness gauge; meet ASTM D4414 to ensure monolithic coating and uniform thickness.
  2. Holiday Detection:
    - a. In accordance with NACE SPO 188.
    - b. After 24 hours minimum and 72 hours maximum, spark test lining system to ensure pinhole-free lining.
    - c. Mark defects and repaired per manufacturer's instructions.
    - d. Voltage to be set at 100 volts per mil of epoxy thickness.
    - e. After identification of pinholes, thin areas, and other imperfections, re-apply epoxy material and retest.
  3. Adhesion Test:
    - a. Test 10 percent minimum of manholes for adhesion/bond of coating to substrate. DEN Project Manager or designated representative will select manholes to be tested.
    - b. Conduct in accordance with ASTM D4542 as modified herein.
      - 1) Prepare coating and dollies to receive adhesive.
      - 2) Complete within 24 hours minimum and 72 hours maximum of curing.
      - 3) Attach three 20-millimeter dollies minimum. Adhesive used to attach dollies to coating shall be rapid setting with tensile strength in excess of coating product and permitted to cure in accordance with manufacturer's recommendations.
      - 4) Failure of dolly adhesive shall be deemed a nontest and require retesting.

- 5) Prior to performing pull test, score coating to within 30 mils of substrate by mechanical means without disturbing dolly or bond within test area.
- 6) Two (2) of the three (3) adhesion pulls shall exceed 200 psi or concrete failure with more than 80 percent of subsurface adhered to coating.
- 7) Should a structure fail to achieve two successful pulls as described above, perform additional testing at discretion of DEN Project Manager.
- 8) Areas detected to have inadequate bond strength shall be evaluated by DEN Project Manager or designated representative.
- 9) Further bond tests may be performed in area to determine extent of potentially deficient bonded area.
- 10) Repair deficient areas.

### 3.9 MANHOLE LINING MANUFACTURER'S FIELD SERVICES

- A. Provide manufacturer's representative at Site for construction activities indicated below for observation of product application, verification of quality assurance, and to determine compliance with manufacturer's instructions.
- B. Manufacturer's Representative: Present at Site for minimum person-days listed below, travel time excluded:
  1. 1 person-day for start of surface preparation/surface preparation inspection.
  2. 1 person-day for start of underlayment application.
  3. 1 person-day for start of system installation.
  4. 1 person-day for final inspection.

### 3.10 INSTALLATION OF PRECAST MANHOLES

- A. Sections:
  1. Carefully inspect precast manhole sections to be joined.
  2. Thoroughly clean ends of sections to be joined.
  3. Do not use sections with chips or cracks in the tongue.
- B. Preformed Plastic Gaskets:
  1. Use only pipe primer furnished by gasket manufacturer.
  2. Install gasket material in accordance with manufacturer's instructions.
  3. Completed manholes shall be rigid and watertight.
- C. Rubber Gasketed Joints: Install in accordance with manufacturer's instructions.

### 3.11 MANHOLE INVERT

- A. Construct with smooth transitions to ensure an unobstructed flow through manhole. Remove sharp edges or rough sections that tend to obstruct flow.
- B. Where full section of pipe is laid through manhole, break out top section as shown and cover exposed edge of pipe completely with mortar. Trowel mortar surfaces smooth.

### 3.12 MANHOLE FRAME AND COVERS

- A. Set frames in bed of mortar with mortar carried over flange as shown.

- B. Set tops of covers flush with surface of adjoining pavement or ground surface, unless otherwise shown or directed.
- C. Install exterior manhole frame to structure seals in accordance with manufacturer's instructions.
- D. Frame and cover shall be visually level and may be accomplished using shims, bitumastic sealant, or Quadex Aluminaliner as required to accommodate field conditions.

### 3.13 WATERTIGHT MANHOLES

- A. Install frame fasteners at locations shown.

### 3.14 MANHOLES OVER EXISTING PIPING

- A. Maintain flow through existing pipelines at all times.
- B. Concrete Pipe: Apply a bonding agent on all surfaces to be in contact with concrete.
- C. Construct base under existing piping.
- D. Construct manhole as specified.
- E. Sawcut and break out existing pipe within new manhole, cover edges with mortar, and trowel smooth.
- F. Protect new concrete and mortar work for 7 days after placing concrete.

## PART 4 MEASUREMENT AND PAYMENT

### 4.1 Measurement and payment are as follows:

- A. Cover – Not Rated for 100,000 lbs
  - 1. Cover replacement will be measured by the actual number of covers that need to be replaced. The actual number of covers replaced shall include all equipment labor, and materials necessary for installation of the covers as shown on the Drawings.
- B. Cover - Rated for 100,000 lbs
  - 1. Cover replacement will be measured by the actual number of covers that need to be replaced that meet the FAA requirements on the airfield. The actual number of covers replaced shall include all equipment labor, and materials necessary for installation of the covers as shown on the Drawings.
- C. Frame
  - 1. Frame replacement shall be measured per the actual number of frames to be replaced. Bid item includes all equipment, labor, excavation, and materials necessary for installation of the frames as shown on the Drawings including all other work necessary to complete the installation per the Drawings and as specified. Bid item also includes all materials and labor required for removal and replacement of the existing frame and cover. Surface restoration shall also be included. Existing chimney shall be protected-in-place.

- D. Frame Seal - Excavation
1. Frame seal replacement with excavation shall be measured per the actual number of frame seals to be replaced. Bid item includes all equipment, labor, excavation, backfill, and materials necessary for installation of the frame seals as shown on the Drawings including all other work necessary to complete the installation per the Drawings and as specified. Bid item also includes all materials and labor required for removal and replacement of the existing frame and cover. Surface restoration shall also be included. Existing frame, cover, and chimney shall be protected-in-place.
- E. Raise Frame and Cover – Grade Rings
1. Raise frame and cover with grade rings shall be measured per the vertical feet of grade rings that need to be added to raise the frame and cover to two (2) feet minimum above ground. Bid item includes all equipment, labor, excavation, backfill, and materials necessary for installation of the grade rings as shown on the Drawings including all other work necessary to complete the installation per the Drawings and as specified. Bid item also includes all materials and labor required for removal and replacement of the existing frame and cover as well as survey of the new elevation at the top of the manhole cover.
- F. Raise Frame and Cover – Manhole Wall
1. Raise frame and cover with the addition of a manhole wall section shall be measured per the vertical feet of manhole that needs to be added to raise the frame and cover to two (2) foot minimum above ground. Bid item includes all equipment, labor, excavation, backfill, and materials necessary for installation of the manhole wall as shown on the Drawings including all other work necessary to complete the installation per the Drawings and as specified. Bid item also includes all materials and labor required for removal and replacement of the existing frame and cover as well as survey of the new elevation at the top of the manhole cover.
- G. Corbel
1. Corbel replacement shall be measured per the actual number of corbels to be replaced. Bid item includes all equipment, labor, excavation, backfill, and materials necessary for installation of the corbel as shown on the Drawings including all other work necessary to complete the installation per the Drawings and as specified. Bid item also includes all materials and labor required for removal and replacement of the existing frame, cover, and chimney.
- H. Chimney
1. Chimney replacement shall be measured per the vertical feet of chimney that shall be replaced. Bid item includes all equipment, labor, excavation, and materials necessary for installation of the chimney as shown on the Drawings including all other work necessary to complete the installation per the Drawings and as specified. Bid item also includes all materials and labor required for removal and replacement of the existing frame and cover and removal of the existing chimney.
- I. Frame Seal – No Excavation 24” and 27”
1. Frame seal replacement without excavation shall be measured per the actual number of frame seals to be replaced. Bid item includes all equipment, labor, and materials necessary for installation of the frame seals as shown on the Drawings including all other work necessary to complete the installation per the Drawings and as specified.

- J. Complete Manhole Rehabilitation
1. Complete manhole rehabilitation will be measured by the square feet of manhole that needs coating and includes rehabilitation of the chimney, corbel, wall, bench, and invert. Complete manhole rehabilitation also includes drilling, grouting, and sealing of the joints between the backfill ground material and the outer surface of the concrete manhole. Bid item includes furnishing all equipment, labor, and materials necessary for manhole rehabilitation including pressure spraying existing surfaces for preparation of the new material. A system must be put in place to capture all materials that could enter into the sewer system. Bid item includes removal and disposal of this material. Bid item also includes all other work necessary to complete the installation per the Drawings and as specified.
- K. Pipe Seals – Various Sizes
1. Pipe seals will be measured by the actual number of pipe seals to be replaced. See the supplemental bid form for pipe seal sizes and quantities. The actual number of pipe seals replaced shall include all equipment labor, and materials necessary for installation of the pipe seals as shown on the Drawings including removal and disposal of the existing pipe seals where present. Pipes and surrounding concrete manhole shall be protected in place for removal and installation of the pipe seals.

<b>Pay Item</b>		<b>Pay Unit</b>
330130.80.A	Cover Replacement	Each
330130.80.B	Cover Replacement – Rated for 100,000 lbs	Each
330130.80.C	Frame Replacement	Each
330130.80.D	Frame Seal Replacement - Excavation	Each
330130.80.E	Raise Frame and Cover – Grade Rings	Vertical Feet
330130.80.F	Raise Frame and Cover – Manhole Wall	Vertical Feet
330130.80.G	Corbel Replacement	Each
330130.80.H	Chimney Replacement	Vertical Feet
330130.80.I	Frame Seal Replacement 24”& 27”– No Excavation	Each
330130.80.J	Complete Manhole Rehabilitation	Square Feet
330130.80.K	Pipe Seal – Various Sizes	Each

**END OF SECTION**



## ITEM P-150 DEMOLITION

### DESCRIPTION

**150-1.1** This item shall consist of removal of existing items outlined within the project limits. The Owner reserves the right to keep all items to be removed/demolished. Prior to demolition, the Contractor shall coordinate with the Owner to determine the salvage requirements. The Contractor shall dispose of material not salvaged at a licensed disposal site or as directed by the DEN Project Manager. Material salvaged and not turned over to the Owner shall become the property of the Contractor. The Contractor shall refer to the Demolition Plans for specific project demolition requirements.

The Contractor shall protect personnel from possible airborne contaminants such as dried fecal matter (bird droppings), concrete dust, and metal dust. The Contractor is responsible for determining compliance with OSHA safety requirements. Do not begin demolition or deconstruction until authorization is received from the DEN Project Manager. Remove rubbish and debris from the project site; do not allow accumulations on airfield pavements or infield areas. Remove rubbish and debris from airport property at a minimum of weekly, or as otherwise directed by the DEN Project Manager. In the interest of occupational safety and health, all work shall be performed in accordance with the DEN ROCIP provisions, The DEN General Requirements, the Construction Safety and Phasing provisions, and all pertinent OSHA safety requirements.

Prevent the spread of dust and debris on airfield pavements and avoid the creation of a nuisance and/or hazard in the surrounding area. Sweep and/or vacuum remove dust and debris from pavements as often as necessary to control the spread of debris that may result in foreign object damage potential to aircraft.

The Contractor shall notify all utility, oil, and gas facility owners and the DEN Project Manager in writing 30 days in advance of requiring work in areas currently occupied by oil and gas wells and buried pipelines.

The Contractor shall refer to and also consider as integral contractual requirements for demolition, the DEN Division 02 “Existing Conditions” demolition specifications.

**150-1.2 BURIED PIPELINES.** Contractor is responsible to contact the Owner as to the status of the pipeline. If pipelines have been abandoned in-place by the pipeline owners, the pipelines may not have been purged or cleaned and may contain petroleum products. The Contractor shall exercise extreme care in removing these facilities and is responsible for removing the pipe including any remaining contents, irrespective of the current pipe conditions. The Contractor should also expect to find other pipelines, etc. which have been abandoned by unknown owners during the 15 to 20-year life of the oil and gas fields. Contract documents indicate the general location of known pipelines and developed utilities. All pipelines shown on the drawings shall be located by the Contractor by potholing to verify location, depth, and usage. The Contractor shall remove all utility pipes and lines included in the project area, in accordance with these specifications. All buried pipelines, utilities, buried tanks, and any other structures within the construction area of all runways, taxiways and aprons extending to 10 feet (3 m) outside the limits of construction and not less than 15 feet

(4.6 m) below the finished grade level shall be removed. The Contractor shall notify oil and gas facility owners and the DEN Project Manager in writing 30 days in advance of requiring work in areas currently occupied by oil and gas wells and buried pipelines.

Piping a minimum of 15 feet (4.6 m) below finished grade elevations, or plan excavation, may be left in place or removed and salvaged at the discretion of the Contractor. The ends of any pipelines left in place shall have the ends capped prior to burial, according to applicable Federal Department of Transportation Regulations. Any piping which is left in place shall be surveyed and the coordinates of the ends of the abandoned pipe (or other items left in place) shall be provided to the DEN Project Manager and included on the "as-built" drawings.

**150-1.3 ELECTRICAL.** The Contractor shall remove all abandoned cable, cable identified to be removed, ductwork, base cans including concrete encasement and all light fixtures, signs, and duct markers within the construction limits of pavements to be removed, widened or constructed, or as shown on the Drawings. Protect existing airfield lighting fixtures and base plates from damage and deliver them to the Airport for storage, as directed by the DEN Project Manager. Discard all base cans, conduit, transformers and cable off-site. The Electrical Contractor shall provide written documentation to the DEN Project Manager that electrical cable has been removed prior to slab saw-cutting and demolition.

**150-1.4 FOUNDATIONS AND SLABS ON GRADE.** All structures at or above grade and to a depth of not less than 15 feet (4.6 m) below the final finished grade line and within 10 feet horizontally of the construction limits shall be removed, as indicated on the plans.

**150-1.5 WATER WELLS.** There is a possibility that water wells are located in work areas. The wells are permitted by the State of Colorado and shall be abandoned in accordance with current Revised and Amended Rules and Regulations of the Board of Examiners of Water Well Construction and Pump Installation Contractors.

**150-1.6 REMOVAL OF PAVEMENT MARKINGS AND CURING COMPOUND.** All paint and concrete curing compound to be removed, as shown on the plans, shall be removed from the surface of the existing pavement. Equipment, tools and machines used in the performance of the removal operations shall be safe and in satisfactory working condition at all times. The Contractor shall provide satisfactory evidence that the Contractor's equipment has been used in the performance of similar work. Method for removal shall be approved by the DEN Project Manager, prior to commencing with removal operations. On asphalt pavements, water blasting will be allowed only if it can be demonstrated that no major damage to the asphalt pavement occurs, otherwise, grinding will be required. Sandblasting will not be permitted. Major damage is defined as changing the properties of the pavement or removing pavement over 1/8 inch (3 mm) deep. On concrete pavements, water blasting shall be used for all removals. Sandblasting will not be permitted.

The water blasting equipment shall be truck mounted and shall be capable of water pressures of 2,000 to 40,000 psi (14 to 276 MPa). The equipment shall be capable of adjusting the pressure to accomplish paint or cure removal without damaging the paving surface. The equipment shall be capable of following a straight line and be maneuverable to accommodate various pavement markings. The spray width needs to be able to accommodate lines 6” and wider. If water blasting is used to remove lines on active airfield pavements, a vacuum system will be provided to allow for timely repainting and the prevention of any debris being ingested into propellers or turbine engines, once the water blasting equipment has exited the active pavements.

If required on asphalt pavement, the grinding equipment shall be capable of adjusting the height to accomplish paint removal with only lightly scaring, but not damaging the paving surface. The equipment shall be capable of following a straight line and be maneuverable to accommodate various pavement markings. A vacuum truck shall be used to immediately clean up all debris created by the removal process.

No material shall be deposited on the airfield pavement. All wastes shall be disposed of in areas indicated in the contract documents.

**150-1.7 EXISTING ROADWAYS.** Roadway demolition shall consist of all portions of asphalt and concrete roadway within the project limits, including all existing haul roads and any alternate access road.

**150-1.8 EXISTING CONCRETE PAVEMENT REMOVAL AND REPAIR.** All operations shall be carefully controlled to prevent damage to the adjacent concrete pavement and to the underlying base materials to remain in place. All saw cuts shall be made perpendicular to the slab surface.

**a. Removal of Existing Pavement Slab.** When it is necessary to remove existing concrete pavement and leave adjacent concrete in place, the joint between the removal area and adjoining pavement to stay in place shall first be cut full-depth with a standard diamond-type concrete saw. Next, a full-depth sawcut shall be made parallel to the joint, at least 24 inches (610 mm) from the joint and at least 12 inches (305 mm) from the end of any dowels. All pavements between this last saw cut and the joint line shall be carefully broken up and removed using hand-held jackhammers, 30 lb. (14 kg) or less, or the approved light-duty equipment which will not cause stress to propagate across the joint saw cut and cause distress in the pavement which is to remain in place. The joint face shall be sawed or otherwise trimmed so that there is no abrupt offset in any direction greater than 1/2-inch (13 mm) and no gradual offset greater than 1 inch (25 mm) when tested in a horizontal direction with a 12 foot (3.7 m) straightedge. Saw-cutting depth may vary nominally, and no extra payment will be allotted for varying depths. Saw-cutting shall be considered incidental to the associated work.

The Contractor shall remove the remaining portion of concrete pavement slab by lifting and placing directly into haul trucks. The Contractor will not be allowed to use hydraulic rams on excavators that may damage the cement-treated base below the pavement to be removed.

An alternative removal method may be accepted by the DEN Project Manager, if the Contractor can demonstrate to the DEN Project Manager successful removal without damage to adjacent concrete or base material below. If, during subsequent removals it is found the method is causing damage to the adjacent panels or base material below, the Contractor's method shall be rejected by the DEN Project Manager and the DEN Project Manager shall direct the Contractor to begin using the method above.

The Contractor's removal operation shall not cause damage to cables, utility ducts, pipelines, or drainage structures under the pavement. Concrete slabs that are damaged by under breaking shall be removed or repaired, as directed by the DEN Project Manager. Any damage shall be repaired at the Contractor's expense.

**b. Edge Repair.** The edge of existing concrete pavement against which new pavement abuts shall be protected from damage at all times. Areas which are damaged during construction shall be repaired at no cost to the Owner. Repair of previously existing damage areas will be paid for as listed in the bid schedule.

(1) **Spall Repair.** Spalls shall be repaired where indicated and where directed by the DEN Project Manager. Repair materials and procedures shall be completed, as outlined in specification P-501.

(2) **Under-break Repair.** Any under-breaking of slabs that are to remain in-place shall result in the entire slab removal and replacement at the Contractor's expense to the next joint. If approved by the DEN Project Manager, the under-break may be repaired, as indicated in the plans.

(3) **Underlying Material.** The underlying material adjacent to the edge of, and under the existing pavement which is to remain in place, shall be protected from damage or disturbance during removal operations and until placement of new concrete, and shall be shaped as shown on the drawings or as directed. Sufficient material shall be kept in place outside the joint line to prevent disturbance (or sloughing) of material under the pavement which is to remain in place. Any material under the portion of the concrete pavement to remain in place which is disturbed or loses its compaction, shall be carefully removed and replaced with material as indicated in the plans. The underlying material outside the joint line shall be thoroughly compacted and moist when new concrete is placed. If the disturbed material causes under-breaking of concrete panels that are to remain in-place, it shall result in the entire slab removal and replacement at the Contractor's expense to the next joint. If approved by the DEN Project Manager, the under-break may be repaired, as indicated in the plans.

**150-1.9 EXISTING ASPHALT CONCRETE PAVEMENT REMOVAL AND REPAIR BY MILLING.** This item shall consist of milling existing bituminous concrete pavement to allow for placement of sufficient thickness of bituminous concrete overlay for pavement repairs or construction on the airfield pavements. The vertical edges of the milled surface shall be sawcut to expose a clean, true, vertical edge to pave against. All operations shall be carefully controlled to prevent damage to the asphalt pavement and to the underlying material to remain in place. Stair-step milling is required for the runway and taxiway shoulder widening interface. This item shall consist of multiple passes as required to establish the "stair-step", as shown on the plans.

**150-1.10 EXISTING FULL-DEPTH ASPHALT CONCRETE PAVEMENT**

**REMOVAL.** This item shall consist of saw-cutting and removal of existing bituminous concrete pavement (including base materials). Asphalt pavement to be removed shall be cut to the full depth of the bituminous material around the perimeter of the area to be removed. The pavement shall be removed so the joint for each layer of pavement replacement is offset 1 foot from the joint in the preceding layer. This does not apply if the removed pavement is to be replaced with concrete or soil. Asphalt pavement to be removed in conjunction with full-depth asphalt pavement removal shall be completed by milling operations, or other method, as directed by the DEN Project Manager. Contractor shall coordinate with the DEN Project Manager for asphalt millings salvage, stockpile, and/or placement requirements.

Removal operations shall be carefully controlled to prevent damage to the adjacent pavement and to underlying materials to remain in place. Areas which are damaged during construction shall be repaired at no cost to the Owner.

**150-1.11 REMOVAL OF SIGNS AND DELINEATORS.** Sign demolition shall consist of the removal and disposal of the all existing signs and delineators, including their foundations and posts, within the project limits along all existing haul roads and any alternate access road.

**150-1.12 WASTE DISPOSAL.** All waste material generated as a result of demolition operations shall be disposed of as indicated in the plans; contract documents, including Section 017419 *Construction Waste Management and Disposal*; and the local laws and regulations pertaining to disposal of these materials.

**MATERIALS**

**150-2.1 BURIED PIPELINE.** Materials used to cap off pipelines remaining in the ground shall be of the size and type normally used for this operation.

**150-2.2 EQUIPMENT.** Excavation and Hauling Equipment: Provide equipment as necessary to remove and dispose of items outlined in the plans for demolition and to restore the area.

**CONSTRUCTION METHODS**

**150-3.1 GENERAL.** Blasting will not be allowed on this project.

**150-3.2 REMOVAL ITEMS.** Remove items where shown on the plans. Care shall be taken not to damage any items to be salvaged and returned to the Owner or existing items which are to remain in operation.

**150-3.3 PROTECTION.** Before beginning any deconstruction or demolition, record existing conditions in the presence of the DEN Project Manager showing the condition of structures and other facilities adjacent to areas of alteration or removal. Record of existing conditions shall be obtained by way of photographic or video log, as required by the DEN Project Manager. Include in record the elevation of the top of inlets, elevation of inlet barrel segments, manhole/inlet floor slabs, possible conflicting plumbing lines, the location and extent of existing cracks and other damages.

Take necessary precautions to avoid damage to existing items and/or portions of existing items that will remain in place, to be reused. Repair or replace damaged items, as approved by the DEN Project Manager. Coordinate the work of this section with all other work indicated.

**150-3.4 BURIED PIPELINE AND STORM SEWERS.**

**a. Trenching.** The removal of cover on top of and surrounding the abandoned pipelines shall be performed without damaging the pipeline. All trench sidewalls shall be properly sloped or benched and/or braced, shored or sheeted to afford safe working conditions, to protect adjacent pipelines, and to prevent caving.

**b. Testing.** The Contractor shall test the exposed trench excavation and the pipeline for dangerous or explosive gases and to positively determine that the line has been emptied, cleaned, and/or purged, prior to performing any further operations.

**c. Cutting of Pipeline and Storm Sewers.** Extreme care shall be exercised whenever the pipeline or storm sewer to be removed is cut into, especially the first cut on the abandoned pipeline. The Contractor shall use a method to cut the pipeline into sections for removal which provides safety for workers and equipment. The initial cut shall not be made with a cutting torch.

**(1) Backfilling.** If required, select embankment (1" maximum size), per Item P-152 (or placement of CLSM per Item P-153) to 12 inches (305 mm) over the top of the pipe shall be completed before backfilling operations are started.

The Contractor shall take all necessary precautions to protect the pipe from any damage, movement or shifting. In general, backfilling shall be performed by pushing the material from the end of the trench into, along and directly over the pipe so that the material will be applied in the form of a rolling slope rather than by side filling which may damage the pipe. Backfilling from the sides of the trench will be permitted after sufficient material has first been carefully placed over the pipe to such a depth as to protect the pipe.

Compaction equipment used above the pipe zone shall be of a type that does not damage the pipe. Provide for the proper maintenance of traffic flow and accessibility as may be necessary. Make adequate provisions for the safety of property and persons. Temporary cribbing, sheeting, or other timbering shall be removed unless specifically authorized in writing. Dewatering per Section 312319 shall be continued until the trench is completely backfilled. Brush, stumps, logs, planking, disconnected drains, boulders, etc. shall be removed from the material to be used for backfilling the trench.

(2) **General Compaction Requirements.** Requirements of this section shall apply unless more stringent requirements are established by the local agency involved. Trench backfill shall be compacted to the requirements of Item P-152.

(3) **Mechanical Compaction.** Method of compaction shall be at Contractor's option, as approved by the DEN Project Manager.

The Contractor shall be responsible to provide the proper size and type of compaction equipment and select the proper method of utilizing said equipment to attain the required compaction density. In-place compaction tests shall be made. Contractor shall remove and re-compact material that does not meet specified requirements.

d. **Removal of Water and Residual Petroleum Products from Pipelines.** Any pipeline containing water or residual petroleum products, after abandonment by the pipeline owner, shall have the water or the residual products removed from the pipeline, by the Contractor, using a nitrogen purge, steam, or other approved means. The material removed from the pipeline shall be hauled away and disposed of properly. The Contractor shall assume that all pipelines to be removed contain significant amounts of residual products that must be disposed of offsite.

**150-3.5 BURIED UTILITY LINES.** The Contractor shall remove all abandoned electrical, telephone, and other utility lines whether shown on the contract drawings or not. All known lines are shown, but there may be other unknown abandoned lines in the area. It shall be the Contractor's responsibility to check the status of all abandoned lines. Care shall be taken to assure that all abandoned electric lines are not live and cannot be activated accidentally.

**150-3.6 GROUND SURFACE REPAIR.** The Contractor shall rough grade and compact areas affected by demolition to maintain site grades and contours. All holes remaining after demolition operations shall have sides broken down to flatten out the slopes, and shall be filled with acceptable material, moistened and properly compacted in layers to the density required in Item P-152. The ground surface area repaired shall properly drain and that water will not pond.

**150-3.7 WATER WELLS.** The Contractor shall employ a licensed water well contractor to demolish and abandon existing water wells and provide necessary documentation to the State of Colorado Agencies and Boards, as required.

**150-3.8 INSPECTION POINTS.** Upon completion of demolition work, and prior to backfilling operations, the DEN Project Manager shall inspect the Contractor's work. After backfilling and grading operations, the Contractor's Quality Control Inspector shall perform inspection and final acceptance, per Division 1 General Requirements Section 014510 – *Contractor Quality Control* and Section 014520 *Contractor Quality Control Program - FAA*.

**150-3.9 MILLING.** The construction operation shall be scheduled and proceed in a manner that produces a uniformly finished milled surface with a neat uniform right angle cut at the end of the milled section. The depth of the asphalt pavement removal shall be as called for on the plans and/or full depth of the joining lift. The entire area designated on the plans shall be milled until the pavement surfaces result in pavement that conforms to the typical section and cross section requirements specified. The milling process shall produce a pavement surface that is true to grade with a uniform texture. The transverse slope of the pavement shall be uniform to a degree that no depressions or mis-alignment of slope greater than 1/2-inch in 16 feet are present when tested with a straightedge.

Milling shall be performed with a power-operated milling machine or grinder, capable of producing a finished surface that provides a good bond to the new overlay. The milling machine or grinder shall operate without tearing or gouging the under laying surface. The milling machine or grinder shall be equipped with automatic grade and slope controls. All millings shall be removed and disposed of in a DEN approved waste site. If the Contractor mills or grinds deeper or wider than the plans specify, the Contractor shall replace the material that was removed with new material at no additional cost to the Owner.

The Contractor shall establish positive means for removal of milled residue. Solid residue shall be removed from pavement surfaces before it is blown by traffic action or wind. Residue shall not be permitted to flow into drainage facilities. The milled residue shall be disposed of legally off airport property. The millings generated shall be disposed of off-site, or as indicated in the plans, or as dictated by the DEN Project Manager.

**150-3.10 FULL-DEPTH ASPHALT SAWCUT.** A smooth, straight, vertical edge along existing pavements to remain shall be established by saw-cutting to the full depth of the asphalt section. The sawcut edge of pavement shall be cleaned and bituminous tack coat applied, per Item P-603, prior to paving against the sawcut edge.

### **BASIS OF PAYMENT**

No measurement for payment is associated with this specification section. Payment will be made under specification section 31 23 23 Backfill and Surface Restoration.

### **END OF ITEM P-150**



## ITEM P-152 EXCAVATION, SUBGRADE, AND EMBANKMENT

### DESCRIPTION

**152-1.1** This item covers excavation, disposal, placement, and compaction of all materials within the limits of the work required to construct safety areas, runways, taxiways, aprons, and intermediate areas as well as other areas for drainage, building construction, parking, or other purposes in accordance with these specifications and in conformity to the dimensions and typical sections shown on the plans.

**152-1.2 CLASSIFICATION.** All material excavated shall be classified as defined below:

**a. Unclassified Excavation.** Unclassified excavation shall consist of the excavation and placement of all material, regardless of its nature, which is not otherwise classified and paid for under one of the following items. Unclassified excavation material shall consist of material cut within the project construction limits and placed within the construction limits as embankment or structural fill.

**b. Borrow Excavation.** Borrow excavation shall consist of approved material required for the construction of embankments or for other portions of the work in excess of the quantity of usable material available from required excavations. Borrow material shall be obtained from areas designated by the DEN Project Manager within the limits of the airport property but outside the normal limits of necessary grading, or from areas outside the airport.

**c. Waste Embankment.** Waste embankment shall consist of material excavated under “Unclassified Excavation” operations, which is in excess of materials required for placement within the construction limits as embankment or structural fill. Waste embankment materials shall be placed, graded, and compacted on Airport Property, as designated by the Engineer.

**152-1.3 UNSUITABLE EXCAVATION.** Any material containing vegetable or organic matter, such as muck, peat, organic silt, or sod shall be considered unsuitable for use in embankment construction. Material, suitable for topsoil may be used on the embankment slope when approved by the DEN Project Manager.

**152-1.4 SELECT EMBANKMENT.** Select Embankment shall consist of material as described below.

There are 2 zones of Select Embankment Material:

- Lower Select Embankment: the lower 4.5 feet (1.4 m)
- Upper Select Embankment: the upper 1.5 feet (.5 m).
- The upper 8 inches (200 mm) to 1 foot (300 mm) of the Upper Select Embankment will be cement treated.

Lower Select Embankment material shall consist of existing in-place select fill, including moisture conditioning of the existing on-site select fill. Moisture conditioning of the existing select fill shall be performed to a depth of 12 inches below planned finished grades or to 3 feet (1 m) below existing site grades, whichever is greater. This will require over-excavation of existing soils using a maximum 8 inch (200 mm) lift thickness, and tested for classification (including gradation and Atterberg limits), swell-consolidation, and water soluble sulfates will not be required for Lower Select Embankment material consisting of in-place and moisture conditioned existing on-site select fill.

If required, imported Lower Select Embankment materials be free of unsuitable materials, including claystone, contain 100% passing the 3 inch (75 mm) sieve, less than 90% passing the No. 200 sieve, have a maximum Liquid Limit of 40, a maximum Plasticity Index of 30, and less than 3% swell potential. The swell sample shall be remolded to 95% of the maximum dry density at optimum moisture as determined by ASTM D 698 for initial acceptance of the proposed imported Lower Select Embankment Material. During placement of the imported Lower Select Embankment Material, the swell sample shall be obtained from the compacted in-place imported Lower Select Embankment Material.

The lower and upper select embankment materials should be properly moisture conditioned and compacted in accordance with the specifications.

Upper Select embankment material shall be obtained from the borrow area indicated in the plans and shall meet the requirements of the specification.

**a. Cement Treated Upper Select Embankment.** The Upper Select Embankment material, of which the upper 12 inches (300 mm) will be cement-treated, shall be an imported material free of unsuitable materials, with 100% passing the 1-inch sieve, no more than 45% retained on a No. 4 sieve, less than 50% passing the No. 200 sieve, a maximum Plasticity Index of 15, a maximum water soluble sulfates content of 0.5%, and less than 3% swell potential. The swell sample shall be remolded to 95% of the maximum dry density at optimum moisture as determined by ASTM D 698 for initial acceptance of the proposed Upper Select Embankment material. During placement of the Upper Select Embankment material, the swell sample shall be obtained from the compacted in-place Upper Select Embankment material.

**152-1.5 MATERIAL CLASSIFICATION.** Non-cohesive soils, for the purposes of determining compaction control, are those with a plasticity index of less than 3 when tested in accordance with ASTM D 4318. Any other material shall be considered cohesive.

## CONSTRUCTION METHODS

**152-2.1 GENERAL.** Before beginning excavation, grading, and embankment operations in any area, the area shall be completely cleared and grubbed in accordance with Item P-151, as applicable. This work shall be measured and paid for as incidental to the associated work items.

The suitability of material to be placed in embankments shall be subject to approval by the DEN Project Manager. All unsuitable material shall be disposed of in waste areas shown on the plans. All waste areas shall be graded to allow positive drainage of the area and of adjacent areas. The surface elevation of waste areas shall not extend above the surface elevation of adjacent usable areas of the airport, unless specified on the plans or approved by the DEN Project Manager.

When the Contractor's excavating operations encounter artifacts of historical or archaeological significance, the operations shall be temporarily discontinued and the DEN Project Manager notified. At the direction of the DEN Project Manager, the Contractor shall excavate the site in such a manner as to preserve the artifacts encountered and allow for their removal. Such excavation will be paid for as extra work.

Those areas outside of the limits of the pavement areas where the top layer of soil material has become compacted by hauling or other Contractor activities shall be scarified and disked to a depth of 4 inches (100 mm), to loosen and pulverize the soil.

If it is necessary to interrupt existing surface drainage, sewers or under-drainage, conduits, utilities, or similar underground structures, the Contractor shall be responsible for and shall take all necessary precautions to preserve them or provide temporary services. When such facilities are encountered, the Contractor shall notify the DEN Project Manager, who shall arrange for their removal if necessary. The Contractor, at his or her expense, shall satisfactorily repair or pay the cost of all damage to such facilities or structures that may result from any of the Contractor's operations during the period of the contract.

**152-2.2 EXCAVATION.** No excavation shall be started until the work has been staked out by the Contractor and the DEN Project Manager has obtained from the Contractor, the survey notes of the elevations and measurements of the ground surface. All areas to be excavated shall be stripped of vegetation and topsoil. Topsoil shall be stockpiled for future use in areas designated on the plans or by the DEN Project Manager. All suitable excavated material shall be used in the formation of embankment, subgrade, or other purposes shown on the plans. All unsuitable material shall be disposed of as shown on the plans.

When the volume of the excavation exceeds that required to construct the embankments to the grades indicated, the excess shall be used to grade the areas of ultimate development or disposed as directed by the DEN Project Manager. When the volume of excavation is not sufficient for constructing the embankments to the grades indicated, the deficiency shall be obtained from borrow areas.

The grade shall be maintained so that the surface is well drained at all times. When necessary, temporary drains and drainage ditches shall be installed to intercept or divert surface water that may affect the work.

**a. Selective Grading.** When selective grading is indicated on the plans, the more suitable material designated by the DEN Project Manager shall be used in constructing the embankment or in capping the pavement subgrade. If, at the time of excavation, it is not possible to place this material in its final location, it shall be stockpiled in approved areas so that it can be measured for payment as specified in paragraph 152-3.3.

**b. Undercutting.** Rock, shale, hardpan, loose rock, boulders, or other material unsatisfactory for safety areas, subgrades, roads, shoulders, or any areas intended for turf shall be excavated to a minimum depth of 12 inches (300 mm) below the subgrade, or to the depth specified by the DEN Project Manager. Muck, peat, matted roots, or other yielding material, unsatisfactory for subgrade foundation, shall be removed to the depth specified. Unsuitable materials shall be disposed of off the airport. The cost is incidental to this item]. This excavated material shall be paid for at the contract unit price per cubic yard (per cubic meter) for “Unclassified Excavation.” The excavated area shall be backfilled with suitable material obtained from the grading operations or borrow areas and compacted to specified densities. The necessary backfill will constitute a part of the embankment. Where rock cuts are made, backfill with select material. Any pockets created in the rock surface shall be drained in accordance with the details shown on the plans.

**c. Overbreak.** Overbreak, including slides, is that portion of any material displaced or loosened beyond the finished work as planned or authorized by the DEN Project Manager. All overbreak shall be graded or removed by the Contractor and disposed of as directed by the DEN Project Manager. The DEN Project Manager shall determine if the displacement of such material was unavoidable and his or her decision shall be final. Payment will not be made for the removal and disposal of overbreak that the DEN Project Manager determines as avoidable. Unavoidable overbreak will be classified as “Unclassified Excavation.”

**d. Hazardous Materials.** Some material (equipment, debris, soil, wastes, etc.) may be affected by hazardous constituents, chemicals or compounds used during oil and gas production, residential development, public improvement construction or agricultural use. Material contaminated or potentially contaminated with hazardous constituents, chemicals or compounds shall be assessed by the contractor regarding the hazardous characteristic(s) of each material. The assessment will be made in accordance with requirements specified by the Colorado Department of Public Health and Environment (CDPHE) and the Colorado Department of Natural Resources - Oil and Gas Conservation Commission (OGCC). The Contractor shall notify the Engineer in writing immediately upon discovery or suspicion of the existence of such hazardous material.

**e. Removal of Utilities.** The removal of existing structures and utilities required to permit the orderly progress of work will be accomplished by someone other than the Contractor; for example, the utility unless otherwise shown on the plans. All existing foundations shall be excavated at least 2 feet (60 cm) below the top of subgrade or as indicated on the plans, and the material disposed of as directed by the DEN Project Manager. All foundations thus excavated shall be backfilled with suitable material and compacted as specified.

**f. Compaction Requirements.** The subgrade under areas to be paved shall be compacted to a depth of 8 inches and to a density of not less than 95 percent of the maximum density as determined by ASTM D 698. The material to be compacted shall be within +0% to -2% of optimum moisture content before being rolled to obtain the prescribed compaction (except for expansive soils).

The in-place field density shall be determined in accordance with ASTM D 1556 or ASTM D 2167. ASTM D6938 shall be used to determine the moisture content of the material. The machine shall be calibrated in accordance with ASTM D 6938. Stones or rock fragments larger than 4 inches (100 mm) in their greatest dimension will not be permitted in the top 6 inches (150 mm) of the subgrade. The finished grading operations, conforming to the typical cross-section, shall be completed and maintained at least 1,000 feet (300 m) ahead of the paving operations or as directed by the DEN Project Manager.

All testing shall be done by a laboratory hired by the Contractor. The results shall be furnished daily to the Engineer for determination of acceptance.

In areas of excavation, a minimum of two density and moisture content tests shall be taken per day or a minimum of one test per 1,000 square yards, whichever results in a greater number of tests. Density and moisture content tests are only required on the final surface. If field-tested density or moisture content of the final surface is found to be outside of a specified range, the area represented by the test shall be re-worked and re-tested. Pavement materials shall not be placed on the completed surface until testing results have been furnished to, and approved in writing by the Engineer.

All loose or protruding rocks on the back slopes of cuts shall be pried loose or otherwise removed to the slope finished grade line. All cut-and-fill slopes shall be uniformly dressed to the slope, cross-section, and alignment shown on the plans or as directed by the DEN Project Manager.

**Blasting shall not be allowed.**

**152-2.3 BORROW EXCAVATION.** Borrow areas within the airport property are indicated on the plans. Borrow excavation shall be made only at these designated locations and within the horizontal and vertical limits as staked or as directed.

The contractor shall distinguish borrow sources to distinguish materials to be used as common embankment and select embankment. The Contractor shall prepare a Select Embankment Material Plan for select material excavation and select material placement based on the plan information and the Contractor's further exploration of upper select embankment material availability. The Select Embankment Material Plan shall contain the results of the following investigation:

- a. Select Borrow investigation for designated areas.
- b. Test hole or pit explorations in runway/taxiway and select borrow areas at approximately 300' on centers.
- c. Sample testing at each exploration for depth of topsoil, depth of select material, elevation of surface, and laboratory tests for Plasticity Index, sieve analysis, percent passing 200 sieve, classification, soluble sulfates, and swell consolidation.
- d. Detailed log of each test hole or pit.
- e. Estimate of select material available in each area.

When borrow sources are outside the boundaries of the airport property, it shall be the Contractor's responsibility to locate and obtain the borrow source, subject to the approval of the DEN Project Manager. The Contractor shall notify the DEN Project Manager at least 15 days prior to beginning the excavation so necessary measurements and tests can be made. All borrow pits shall be opened up to expose the various strata of acceptable material to allow obtaining a uniform product. All unsuitable material shall be disposed of by the Contractor. Borrow pits shall be excavated to regular lines to permit accurate measurements, and they shall be drained and left in a neat, presentable condition with all slopes dressed uniformly.

**152-2.4 PREPARATION OF EMBANKMENT AREA.** Where an embankment is to be constructed to a height of 4 feet (1.2 m) or less, all sod and vegetative matter shall be removed from the surface upon which the embankment is to be placed. The cleared surface shall be broken up by plowing or scarifying to a minimum depth of 6 inches (150 mm) and shall then be compacted as indicated in paragraph 152-2.6. When the height of fill is greater than 4 feet (1.2 m), sod not required to be removed shall be thoroughly disked and recompacted to the density of the surrounding ground before construction of embankment.

Sloped surfaces steeper than one (1) vertical to four (4) horizontal shall be plowed, stepped, benched, or broken up so that the fill material will bond with the existing material. When the subgrade is part fill and part excavation or natural ground, the excavated or natural ground portion shall be scarified to a depth of 12 inches (300 mm) and compacted as specified for the adjacent fill.

No direct payment shall be made for the work performed under this section. The necessary clearing and grubbing and the quantity of excavation removed will be paid for under the respective items of work.

**152-2.5 FORMATION OF EMBANKMENTS.** Embankments shall be formed in successive horizontal layers of not more than 8 inches (200 mm) in loose depth for the full width of the cross-section, unless otherwise approved by the DEN Project Manager.

The layers shall be placed, to produce a soil structure as shown on the typical cross-section or as directed by the DEN Project Manager. Materials such as brush, hedge, roots, stumps, grass and other organic matter, shall not be incorporated or buried in the embankment.

Earthwork operations shall be suspended at any time when satisfactory results cannot be obtained because of rain, freezing, or other unsatisfactory weather conditions in the field. Frozen material shall not be placed in the embankment nor shall embankment be placed upon frozen material. Material shall not be placed on surfaces that are muddy, frozen, or contain frost. The Contractor shall drag, blade, or slope the embankment to provide surface drainage at all times.

The material in each layer shall be within +0% to -2% of optimum moisture content before rolling to obtain the prescribed compaction. To achieve a uniform moisture content throughout the layer, the material shall be moistened or aerated as necessary. Samples of all embankment materials for testing, both before and after placement and compaction, will be taken for each 1,000 square yards. Based on these tests, the Contractor shall make the necessary corrections and adjustments in methods, materials or moisture content to achieve the specified embankment density.

Rolling operations shall be continued until the embankment is compacted to not less than 95% of maximum density for non-cohesive soils, and 90% of maximum density for cohesive soils as determined by ASTM D 698. Under all areas to be paved, the embankments shall be compacted to a depth of 8 inches and to a density of not less than 95% percent of the maximum density as determined by ASTM D 698.

On all areas outside of the pavement areas, no compaction will be required on the top 4 in (100 mm).

The in-place field density shall be determined in accordance with ASTM D 1556 or ASTM D 2167. ASTM D 6938 using Procedure A, the direct transmission method, and ASTM D 6938 shall be used to determine the moisture content of the material. The machine shall be calibrated in accordance with ASTM D 6938. The Contractor's laboratory shall perform all density tests in the DEN Project Manager's presence and provide the test results upon completion to the DEN Project Manager for acceptance.

In embankment areas, a minimum of two density and moisture content tests shall be taken per lift per day or a minimum of one test per 1,000 cubic yards of material placed, whichever results in a greater number of tests. If field-tested density or moisture content of a completed lift is found to be outside of a specified range, the area represented by the test shall be re-worked and re-tested. Additional embankment or pavement materials shall not be placed on the completed lift or area until testing results have been furnished to, and approved in writing by the DEN Project Manager.

Compaction areas shall be kept separate, and no layer shall be covered by another layer until the proper density is obtained.

During construction of the embankment, the Contractor shall route all construction equipment evenly over the entire width of the embankment as each layer is placed. Layer placement shall begin in the deepest portion of the embankment fill. As placement progresses, the layers shall be constructed approximately parallel to the finished pavement grade line.

When rock and other embankment material are excavated at approximately the same time, the rock shall be incorporated into the outer portion of the embankment and the other material shall be incorporated under the future paved areas. Stones or fragmentary rock larger than 4 inches (100 mm) in their greatest dimensions will not be allowed in the top 6 inches (150 mm) of the subgrade. Rockfill shall be brought up in layers as specified or as directed by the DEN Project Manager and the finer material shall be used to fill the voids with forming a dense, compact mass. Rock or boulders shall not be disposed of outside the excavation or embankment areas, except at places and in the manner designated on the plans or by the DEN Project Manager.

When the excavated material consists predominantly of rock fragments of such size that the material cannot be placed in layers of the prescribed thickness without crushing, pulverizing or further breaking down the pieces, such material may be placed in the embankment as directed in layers not exceeding 2 feet (60 cm) in thickness. Each layer shall be leveled and smoothed with suitable equipment by distribution of spalls and finer fragments of rock. The layer shall not be constructed above an elevation 4 feet (1.2 m) below the finished subgrade.

Payment for compacted embankment will be made under “Waste Embankment.”

**152-2.6 FINISHING AND PROTECTION OF SUBGRADE.** After the subgrade is substantially complete, the Contractor shall remove any soft or other unstable material over the full width of the subgrade that will not compact properly. All low areas, holes or depressions in the subgrade shall be brought to grade with suitable select material. Scarifying, blading, rolling and other methods shall be performed to provide a thoroughly compacted subgrade shaped to the lines and grades shown on the plans.



Grading of the subgrade shall be performed so that it will drain readily. The Contractor shall protect the subgrade from damage and limit hauling over the finished subgrade to only traffic essential for construction purposes. All ruts or rough places that develop in the completed subgrade shall be graded and recompacted.

No subbase, base, or surface course shall be placed on the subgrade until the subgrade has been approved by the DEN Project Manager.

**152-2.7 HAUL.** All hauling will be considered a necessary and incidental part of the work. The Contractor shall include the cost in the contract unit price for the pay of items of work involved. No payment will be made separately or directly for hauling on any part of the work.

**152-2.8 TOLERANCES.** In those areas upon which a subbase or base course is to be placed, the top of the subgrade shall be of such smoothness that, when tested with a 12-foot (3.7-m) straightedge applied parallel and at right angles to the centerline, it shall not show any deviation in excess of 1/2 inch (12 mm), and shall not be more than 0.05 feet (15 mm) from true grade as established by grade hubs. The smoothness measurements shall be made by the Contractor on a 50-foot grid parallel and perpendicular to the centerline in the presence of the DEN Project Manager. The grade shall be determined at spot elevations shown on the Plans for the surface course, on a grid not to exceed 50 feet. Any deviation in excess of these amounts shall be corrected by loosening, adding, or removing materials; reshaping; and re-compacting.

On safety areas, intermediate and other designated areas, the surface shall be of such smoothness that it will not vary more than 0.10 feet (3 mm) from true grade as shown on the typical sections and/or contours shown on the plans and meeting FAA grading criteria. Any deviation in excess of this amount shall be corrected by loosening, adding or removing materials, and reshaping.

**152-2.9 TOPSOIL.** When topsoil is specified or required as shown on the plans or under Item T-905, it shall be salvaged from stripping or other grading operations. The topsoil shall meet the requirements of Item T-905. If, at the time of excavation or stripping, the topsoil cannot be placed in its final section of finished construction, the material shall be stockpiled at approved locations. If, in the judgment of the DEN Project Manager, it is practical to place the salvaged topsoil at the time of excavation or stripping, the material shall be placed in its final position without stockpiling or further re-handling.

Upon completion of grading operations, stockpiled topsoil shall be handled and placed as directed, or as required in Item T-905.

**152-2.10 RESTORING BORROW AREAS.** The Contractor shall, upon completion of his borrow excavation activities, prepare the borrow sites for planting by performing the following work:

- a. Remove and bury all rock over 6" in dimension in accordance with rock disposal methods as noted under Section 2.2 Excavation.
- b. Grade all sites to drain as indicated in these specifications and drawings.
- c. Remove all trash and other foreign objects so that the areas can be reused for farming purposes.
- d. Rip the borrow area site in a manner as approved by the DEN Project Manager. After the area is ripped to the 18 inch ( 450 mm) depth, the area ripped shall be treated on the surface to reduce excessive surface roughness or cloddiness and produce an area suitable for future seeding. Treatment may include discing, harrowing, cultipacking or other means as approved by the Engineer. In areas where rock is the predominant surface remaining, the Contractor may spread 18 inches (450 mm) of acceptable material over the rock areas as approved by the Engineer at no additional cost to the City.

All work required to prepare the borrow area for planting as designated under this section shall be considered as incidental work.

#### **BASIS OF PAYMENT**

No measurement for payment is associated with this specification section. Measurement for payment is under specification 31 23 23 Excavation and Surface Restoration.

### TESTING REQUIREMENTS

ASTM D698	Test for Moisture-Density Relations of Soils and Soil-Aggregate Mixtures, Using 5.5-pound (2.49 kg) Rammer and 12 in (305 mm) Drop
ASTM D1556	Test for Density of Soil In Place by the Sand-Cone Method
ASTM D1557	Test for Laboratory Compaction Characteristics of Soil Using Modified Effort
ASTM D2167	Test for Density and Unit Weight of Soil In Place by the Rubber Balloon Method.
ASTM D6938	In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods

**END OF ITEM P-152**

## ITEM P-153 CONTROLLED LOW-STRENGTH MATERIAL (CLSM)

### DESCRIPTION

**153-1.1** This item shall consist of furnishing, transporting, and placing a controlled low-strength material (CLSM) as flowable backfill in trenches or at other locations shown on the plans or as directed by the DEN Project Manager.

### MATERIALS

#### 153-2.1 MATERIALS

**a. Portland Cement.** Portland cement shall conform to the requirements of ASTM C150 Type I or II. If for any reason, cement becomes partially set or contains lumps of caked cement, it shall be rejected. Cement salvaged from discarded or used bags shall not be used.

**b. Fly Ash.** Flyash shall conform to ASTM C618, Class C or F.

**c. Fine Aggregate (Sand).** Fine aggregate shall conform to the requirements of ASTM C33 except for aggregate gradation. Any aggregate gradation which produces performance characteristics of the CLSM specified here will be accepted, except as follows.

Sieve Size	Percent Passing by weight
3/4 inch (19 mm)	100
No. 200 (0.075 mm)	0 - 12

**d. Water.** Water used in mixing shall be potable and free of oil, salt, acid, alkali, sugar, vegetable matter, or other substances injurious to the finished product.

**e.** The CLSM used in the construction of Item L-110, Duct Bank, shall have Red Color added.

## MIX DESIGN

**153-3.1 PROPORTIONS.** The Contractor shall submit, to the DEN Project Manager, a mix design including the proportions and source of aggregate, fly ash, cement, water, and approved admixtures. No CLSM mixture shall be produced for payment until the DEN Project Manager has given written approval of the proportions. The proportions shall be prepared by a laboratory and shall remain in effect for the duration of the project. Laboratory costs are incidental to this item. The proportions shall establish a single percentage or weight for aggregate, fly ash, cement, water, and any admixtures proposed.

**a. Compressive Strength.** CLSM shall be designed to achieve a 28-day compressive strength of 100 to 300 psi when tested in accordance with ASTM D4832. There should be no significant strength gain after 28 days.

**b. Consistency.** CLSM should be designed to achieve a consistency that will produce an approximate 8-inch diameter circular-type spread without segregation when tested by: (1) filling a 3-inch inside diameter by 6-inch length flow cylinder (non-absorbent pipe) (2) strike off of the flow cylinder and start of lift within five seconds of filling and (3) by steady upward pull, lift the cylinder in a time period of between two and four seconds. Adjustments of the material proportions should be made to achieve proper solid suspension and flowable characteristics, however the theoretical yield shall be maintained at one cubic yard (cubic meter) for the given batch weights.

## CONSTRUCTION METHODS

### 153-4.1 PLACEMENT.

**a. Placement.** CLSM may be placed by any reasonable means from a mixing unit into the space to be filled. Agitation is required during transportation and waiting time. Placement shall be performed so structures or pipes are not displaced from their final position and intrusion of CLSM into unwanted areas is avoided. The material shall be brought up uniformly to the fill line shown on the plans or as directed by the DEN Project Manager. Each placement of CLSM shall be as continuous an operation as possible. If CLSM is placed in more than one layer, the base layer shall be free of surface water and loose foreign material prior to placement of the next layer.

**b. Limitations of Placement.** CLSM shall not be placed on frozen ground. Mixing and placing may begin when the air or ground temperature is at least 35°F and rising. At the time of placement, CLSM shall have a temperature of at least 40°F. Mixing and placement shall stop when the air temperature is 40°F and falling or when the anticipated air or ground temperature will be 35°F or less in the 24 hour period following proposed placement.

## 153-4.2 CURING AND PROTECTION

**a. Curing.** The air in contact with the CLSM shall be maintained at temperatures above freezing for a minimum of 72 hours. If the CLSM is subjected to temperatures below 32°F, the material may be rejected by the DEN Project Manager if damage to the material is observed.

**b. Protection.** The CLSM shall not be subject to loads and shall remain undisturbed by construction activities for a period of 48 hours or until a compressive strength of 15 psi is obtained. The Contractor shall be responsible for providing evidence to the DEN Project Manager that the material has reached the desired strength. Acceptable evidence shall be based upon compressive tests made in accordance with paragraph 153-3.1a.

**153-4.3 Acceptance.** Acceptance of CLSM delivered and placed as shown on the plans or as directed by the DEN Project Manager shall be based upon mix design approval and batch tickets provided by the Contractor to confirm that the delivered material conforms to the mix design. The Contractor shall verify by additional testing, each 1,000 cubic yards of material used. Verification shall include confirmation of material proportions and tests of compressive strength to confirm that the material meets the original mix design and the requirements of CLSM as defined in this specification. Adjustments shall be made as necessary to the proportions and materials prior to further production.

## BASIS OF PAYMENT

No measurement for payment is associated with this specification section. Payment will be made under specification section 31 23 23 Backfill and Surface Restoration.

## TESTING REQUIREMENTS

ASTM D4832      Standard Test Method for Preparation and Testing of Controlled Low-Strength Material (CLSM) Test Cylinders

### **MATERIAL REQUIREMENTS**

ASTM C33	Standard Specification for Concrete Aggregates
ASTM C150	Standard Specification for Portland Cement
ASTM C618	Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
ASTM C595	Standard Specification for Blended Hydraulic Cements

**END OF ITEM P-153**

## ITEM P-161 GEOTEXTILE

### DESCRIPTION

**161-1.1** This item shall consist of the work necessary to furnish and install geotextile fabrics (bondbreaker fabric) on base course and asphalt pavement, complete.

**161-1.2 QUALITY ASSURANCE CERTIFICATION.** Contractors shall furnish geotextile fabric materials and shall submit to the DEN Project Manager a mill certificate or affidavit signed by a legally authorized official from the company manufacturing the fabric. The mill certificate or affidavit shall attest that the fabric meets chemical, physical, and manufacturing requirements stated in this Specification. Contractors shall also submit to the DEN Project Manager, not later than 45 days prior to commencing work in this section, documented evidence of proven technical competence, past record of satisfactory performance on similar projects, and sufficient capacity to do the volume of work specified herein.

**161-1.3 SUBMITTALS.** All contractors shall furnish to the DEN Project Manager, no later than 45 days prior to delivery of materials to the project, the following data:

- a. Complete material specifications, descriptive drawings, and literature.
- b. Listing of all exceptions to the requirements specified herein.
- c. Factory test results of materials certified by fabric manufacturer being similar shall be submitted showing conformance with the requirements of these Specifications and which by actual usage has been demonstrated to be satisfactory for the intended application.

Before commencing the work specified under this section, the Contractor shall submit to the DEN Project Manager for approval all installation drawings, procedures, and a schedule for carrying out the work.

Contractors shall submit certification from manufacturer that the product delivered to the project site will have property values equal to or greater than those specified. Certified property values shall be equal to the average value less 2 standard deviations.

A sample of 1 square foot of the geotextile fabric shall be furnished to the DEN Project Manager from each shipment for verification and testing. The lot number of the roll and the location of the sample obtained must be documented.

Samples of fabric sewn seams and/or securing pins shall also be furnished if required on the project.



**161-1.4 MANUFACTURER’S SERVICES.** A fabric manufacturer's representative shall inspect the site for acceptability and provide technical supervision and assistance at all times during installation of the fabric, and as may be required by the DEN Project Manager.

**MATERIALS**

**161-2.1 NON-WOVEN GEOTEXTILE FABRIC.** The non-woven geotextile fabric shall be used for areas beneath the shoulder section of Item P-404 and placed as a bond breaker over Item P-304 and P-306 for PCC pavement sections. For filter fabric installed as a component part of the underdrain system, refer to the requirements in Item D-705. Fabric material shall be a pervious sheet of polyester, polypropylene, polyethylene, or polyamide fibers oriented into a stable network so that the fibers retain their relative position with respect to each other. The fabric shall be composed of continuous or discontinuous (staple) fibers held together through spun bonding, melt bonding, resin bonding, or needle punching. The edges of the fabric shall be salvaged or otherwise finished to prevent the other material from pulling away from the fabric. The fabric shall be woven into a width greater than 6 feet. The fabric shall conform to the physical requirements in Table No. 1.

<b>Table 1</b>		
<b>PHYSICAL REQUIREMENTS (for Nonwoven Fabric)</b>		
<b>Physical</b>	<b>Physical Requirements</b>	<b>Test Method</b>
Thickness, MU., min	70	ASTM D 5199
Mass (Weight), oz./sq.yd., min.	6.0	ASTM D 5261
Water Permittivity sec, min.	1.5	ASTM D 4491 (Falling Head)
Apparent Opening Six (AOS), U.S. Standard Sieve Size	50	ASTM D 4751
Grab Tensile Strength, lbs., min	180	ASTM D 4632
Grab Elongation, % min.	50	ASTM D 4632
Mullen Burst Strength, psi, min.	290	ASTM D 3786
Puncture Strength, lbs., min.	806	ASTM D 4833
Trapezoid Tear Strength, lbs., min.	75	ASTM D 4533
Seam Efficiency, %	70-90	ASTM D 4632
Hydrocarbon Resistance, % Change	<20	USEPA 9090 (Modified)
Ultraviolet Radiation Resistance, % Strength Retention, min. at 150 hours	70	ASTM D 4355

**161-2.2 SECURING PINS.** Securing pins for geotextile fabric shall be secured with 9 inch steel staples having a 3/16 inch diameter with pointed ends. Geotextile fabric over Cement Treated Base (CTB) shall be secured with concrete nails with 1.5 inch diameter washers long enough to hold the fabric in place while the next pavement section is placed.

**161-2.3 SEAMS.** Seams shall be required in applications where stress transfer from one geotextile to another is necessary. Seaming may replace overlapping at the Contractor's option.

Seam types shall be a flat or player seam, a "J" type seam, or a butterfly scam. A "J" type seam is preferred. Stitch counts (stitches per inch) shall range from 3 to 7. The standard stitch type shall be a chainstitch.

Sewing machinery shall make a double thread chainstitch, Type 401, and be capable of penetrating four layers of the geotextile. Machines may be hand held or table/equipment mounted, depending on fabric specified.

Sewing thread shall consist of nylon, polypropylene, polyester, or Kevlar thread.

A minimum 2 inches of fabric shall extend beyond the seam threads or a length sufficient to develop the required seam strength.

Seam strength shall be measured using grab-tensile procedures in accordance with ASTM D 4632. Seam efficiency is defined as the ratio of tensile strength across the seam to the strength of the intact fabric.

Factory sewing shall be utilized wherever possible to eliminate or reduce field seams.

**161-2.4 DELIVERY, STORAGE, AND HANDLING OF MATERIAL.** Geotextile materials delivered to site shall be inspected for damage, unloaded, and stored with the minimum of handling. Materials shall not be stored directly on the ground. During shipment and storage, filter cloth shall be furnished with a suitable wrapping for protection against moisture and extended ultraviolet exposure prior to placement. Rolls shall be stored in a manner which protects them from the elements. If stored outdoors, they shall be elevated and protected with a waterproof cover. Materials shall be handled in such a manner as to ensure delivery to the site in sound, undamaged condition.

Contractor shall furnish certified test reports with each shipment of material attesting that the fabric meets tile requirements of this Specification. Each roll shall be labeled or tagged to provide product identification sufficient for inventory and quality control purposes.

## CONSTRUCTION METHODS

**161-3.1 GENERAL.** The geotextile fabric shall be placed in the manner and at the locations shown in the Drawings or as directed by the DEN Project Manager.

At the time of installation, fabric shall be rejected if it has defects, ribs, holes, flaws, deterioration, or damage incurred during manufacture, transportation, storage, or placement. Visual review of the fabric shall be performed once the fabric has been placed and prior to placement of any overlying materials.

The fabric shall be placed with the machine direction (long dimension) down slope or normal to the natural slope, unless otherwise directed by the DEN Project Manager, and shall be laid smooth and free of tension, stress, folds, wrinkles, or creases. The strips shall be laid smooth to provide a minimum width of 12 inches, or greater if specified, of overlap for each joint. Overlap Joints and seams shall be measured as a single layer of cloth.

Securing pins with washers shall be inserted through both strips of overlapped cloth at not greater than the following intervals along a line through the midpoint of the overlap. Securing pins are not necessarily required during installation for underdrains:

Pin Spacing	Slope
2 feet	Steeper than 3:1
3 feet	3:1 to 4:1
5 feet	Flatter than 4:1

Additional pins regardless of location shall be installed as necessary to prevent any slippage of the filter fabric. Each securing pin shall be pushed through the fabric until the washer bears against the fabric and secures it firmly to the foundation. Bags of soil or other methods approved by the DEN Project Manager shall be used to secure the geotextile during installation.

The fabric shall be protected at all times during construction from contamination by surface runoff and any fabric so contaminated shall be removed and replaced with uncontaminated fabric.

Should the fabric be damaged during any of the installation, the torn or punctured section shall be repaired by placing a piece of fabric which extends at least 18 inches in all directions beyond the damaged area. The fabric shall be sewn, secured with pins and washers as described above, or other methods as approved by the DEN Project Manager.

**161-3.2 PAVEMENT APPLICATIONS.** Geotextiles shall be overlapped a minimum of 12 inches in the direction of flow.

Subbase shall be cleared of all sharp objects. Unroll geotextile fabric on prepared subbase. Provide minimum 18 inch overlap of material. Provide minimum 12 inch overlap of material with geotextile lining of underdrain trench.

Place overlying asphalt treated permeable base material in same direction as the geotextile overlap to avoid separation. Construction equipment other than hauling and paving equipment necessary for placement of the asphalt treated permeable base shall not be allowed on the geotextile. Operate hauling and paving equipment in a manner to prevent damage or displacement of the geotextile. Equipment shall avoid sudden acceleration, hard braking, and sharp turns while on the geotextile, and the paver shall not turn while on the geotextile. Large fabric wrinkles which may develop during the spreading operations shall be folded and flattened in the direction of the spreading. Special care shall be given to maintaining proper overlap and fabric continuity.

After placement of the asphalt treated permeable base, wrap geotextile around edge to completely surround exposed asphalt treated permeable base. The exposed fabric shall then be covered with the subsequent course.

Any damage to the fabric, such as tears, puncture, or excessive displacement, shall be repaired. The asphalt treated permeable base shall be removed from the top of from the fabric and the damaged area repaired as previously described Section 3.1.

### **BASIS OF PAYMENT**

No measurement for payment is associated with this specification section. Payment will be made under specification section 31 23 23 Backfill and Surface Restoration.

### **MATERIAL REQUIREMENTS**

ASTM D 5199	Method for Measuring Thickness of Textile Materials
ASTM D 5261	Test Method for Mass per Unit Area (Weight) of Woven Fabric
ASTM D 3786	Test Method for Hydraulic Bursting Strength of Knitted Goods and Nonwoven Fabrics: Diaphragm Bursting Strength Tester Method.
ASTM D 4355	Test Method for Deterioration of Geotextiles from Exposure to ultraviolet Light and Water (Xenon-Arc Type Apparatus)
ASTM D 4491	Test Methods for Water Permeability of Geotextiles by Permittivity
ASTM D 4533	Test Method for Trapezoid-Tearing Strength of Geotextiles
ASTM D 4632	Test Method for Breaking Load and Elongation of Geotextiles (Grab Method)
ASTM D 4751	Test Method for Determining the Apparent Opening Size of a Geotextile
ASTM D 4833	Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products.
USEPA 9090	Compatibility Test for Wastes and Membrane Liners

**END OF ITEM P-161**

## ITEM P-301 SOIL-CEMENT BASE COURSE

### DESCRIPTION

**301-1.1** This item shall consist of constructing a base course by uniformly mixing soil, Portland cement, and water. The mixed material shall be spread, shaped, and compacted in accordance with these specifications and in conformity to the dimensions and typical cross-section shown on the plans. Tests shall be required for each approved soil included within the treated layer.

Runway, taxiway, or apron pavements shall be built in a series of parallel lanes using a plan that reduces the number of longitudinal and transverse joints to a minimum.

### MATERIALS

**301-2.1 PORTLAND CEMENT.** Portland cement shall conform to the requirements of ASTM C150, Type V.

**301-2.2 WATER.** Water used for mixing or curing shall be potable, reasonably clean and free of oil, salt, acid, alkali, sugar, vegetable, or other substances injurious to the finished product.

**301-2.3 SOIL.** The soil shall consist of the upper most 18 inches of select embankment as placed and paid for by Specifications Item P-152, Upper Select Embankment.

**301-2.4 BITUMINOUS MATERIAL.** The types, grades, controlling specifications, and application temperatures for the bituminous materials used for curing the soil-cement shall be emulsified asphalt (RS-1, SS-1, or CRS-1).

### MIX DESIGN

**301-3.1 PROPORTIONS.** Before the start of base course construction, tests shall be made on the soil or soil-aggregate material to be stabilized to determine the quantity of cement required for the mix design to provide a minimum 200 psi unconfined compressive strength at 5 days. Tests are required for each approved soil which will be included in the treated layer.

Test specimens containing various amounts of cement shall be compacted per ASTM D558, and the optimum moisture determined for each approved soil which will be in the treated layer. The specimens shall be tested for compressive strength in accordance with ASTM D1633. Samples at the optimum moisture shall be subjected to the wet-dry and the freeze-

thaw test in accordance with American Association of State Highway and Transportation Officials (AASHTO) T135 and AASHTO T136, respectively.

The specified cement content for construction shall be the cement content of the test specimen which has a weight loss of 14% or less for granular soils, 10% for the more plastic granular and silty soils, and 7% for clay soils after 12 cycles of the durability test.

The compressive strength of soaked specimens should increase with both age and increase in cement content.

**301-3.2 TESTING LABORATORY.** The Contractor shall employ a testing laboratory to design the soil-cement base course mixture. The laboratory shall meet the requirements of ASTM D3740 including accreditation. Accreditation shall include all test procedures required to develop the mix design. A certification signed by the manager of the laboratory stating it meets these requirements shall be submitted to the DEN Project Manager. The certification shall contain as a minimum:

- a. Qualifications of personnel; including the laboratory manager, supervising technician, and testing technicians involved in developing the soil-cement base course mixture.
- b. Evidence of current accreditation by a nationally recognized laboratory accreditation organization for all test methods used in developing the soil-cement base course mixture.

**301-3.3 MIX DESIGN SUBMITTAL** The contractor shall submit the laboratory soil-cement base course mix design to the Project manager at least thirty (30) days prior to use. The submittal shall include the following:

- a. Source of soil
- b. Gradation of soil
- c. Atterberg limits of soil
- d. Water soluble sulfate content of soil
- e. Swell potential of soil
- f. Certificate of Compliance current within one (1) year verifying that the cement meets the specification requirements and support of this statement with test results
- g. Moisture-density relationships for each cement content
- h. Compressive strength results for each cement content
- i. Recommended cement content
- j. Testing laboratory qualifications

## CONSTRUCTION METHODS

**301-4.1 WEATHER LIMITATIONS.** The soil-cement base shall not be mixed or placed while the atmospheric temperature is below 40°F (4°C) or when conditions indicate that the temperature may fall below 40°F (4°C) within 24 hours, or when the weather is foggy or rainy, or to soils that are frozen or contain frost, or when the underlying material is frozen.

**301-4.2 EQUIPMENT.** The soil-cement may be constructed with any equipment that will meet the requirements for soil pulverization, cement application, mixing, water application, incorporation of materials, compaction, finishing, and curing specified here.

**301-4.3 PREPARATION.** The area to be stabilized shall be graded and shaped to conform to the lines, grades and cross-section shown on the plans. Any soft or yielding areas in the subgrade shall be removed and replaced with acceptable soil and compacted to the specified density.

**301-4.4 PULVERIZATION.** After completion of moist-mixing, the soil for the base course shall be pulverized so that 100% by dry weight passes a 1-inch (25 mm) sieve and a minimum of 80% passes a No. 4 (4.75 mm) sieve.

**301-4.5 CEMENT APPLICATION, MIXING, AND SPREADING.** Mixing of the soil, cement, and water shall be accomplished by the central-plant-mixed method or the mixed in place method.

**a. Central Plant Mixed Method.** The soil, cement, and water shall be mixed in either a batch or continuous-flow type pugmill. The plant shall be equipped with feeding and metering devices that will add the soil, cement, and water into the mixer in the specified quantities. Soil and cement shall be mixed sufficiently to prevent cement balls from forming when water is added. Mixing shall continue until a uniform mixture of soil, cement, and water is obtained.

The mixture shall be hauled to the project in trucks equipped with protective covers. The mixture shall be placed on the moistened subgrade in a uniform layer by an approved spreader. Not more than 30 minutes shall elapse between the placement of soil-cement in adjacent lane.

The layer of soil-cement shall be uniform in thickness and surface contour and of sufficient quantity that the completed base conforms to the required line, grade and cross-section. Dumping of the mixture in piles or windrows on the subgrade shall not be permitted.

Not more than 60 minutes shall elapse between the start of moist mixing and the start of compaction of soil-cement.



**b. Mixed-in-Place Method.** Approximately shape pulverized material to the cross-section indicated. Cement shall be applied so that when uniformly mixed with the soil, the specified cement content is obtained, and a sufficient quantity of cement-treated soil is produced to construct a compacted cement-treated course conforming to the lines, grades, and cross-section indicated. Immediately after the cement has been distributed, it shall be mixed with the soil. The cement shall not be mixed below the required depth. Continue mixing until the cement has been sufficiently blended with the soil to prevent the formation of cement balls when water is applied. Determine moisture content of the mixture immediately after completion of mixing of the soil and cement. Provide water supply and pressure distributing equipment that will permit the application within three (3) hours of all mixing water on the section being processed. Incorporate water in the mix so that concentration of water near the surface does not occur. After all mixing water has been applied, continue mixing until the water is uniformly distributed throughout the full depth of the mixture. Do not apply cement if the soil moisture content exceeds the optimum moisture content specified for the cement-treated mixture. After mixing is complete, the proportions of the mixture shall be in accordance with the approved mix design.

**301-4.6 COMPACTION.** Immediately after spreading, the mixture shall be thoroughly compacted. The number, type, and weight of rollers shall be sufficient to compact the mixture to the required density.

The field density of the compacted mixture shall be at least 98% of the maximum density of laboratory prepared specimens compacted and tested in accordance with ASTM D558. Two tests shall be conducted each for the first 2 days of placement, then 1 test each day thereafter. Additional tests shall be performed as variations in the soil-cement base course occur and when in-place density tests do not correlate with previous test results. The in-place field density shall be determined in accordance with ASTM D1556, ASTM D2167, or ASTM D6938 using Procedure A, the direct transmission method, and ASTM D6938 shall be used to determine the moisture content of the material. The machine shall be calibrated in accordance with ASTM D6938. One test shall be conducted for each 300 square yards of material placed per lift, per day, or fraction thereof. No portion of the mixture shall remain undisturbed during mixing and before compaction for more than 30 minutes. The moisture content of the mixture at the start of compaction shall be within  $\pm 2$  percentage points of the optimum moisture content. The optimum moisture content shall be determined in accordance with ASTM D558. All testing shall be done by the Contractor's laboratory in the presence of the DEN Project Manager and density test results shall be furnished upon completion to the DEN Project Manager for acceptance determination.

The compressive strength of the material shall be a minimum 200 psi. Test specimens containing various amounts of cement shall be compacted per ASTM D558, and specimens shall be tested for compressive strength in accordance with ASTM D1633. One set of four cylinders shall be made per 1,000 square yards, with a minimum of 2 sets per day. Two of the cylinders per set shall be cured for 5 days and accelerated, and two of the cylinders per set shall be seated and cured at 28 days at ambient temperature. The strength shall not be corrected for diameter.

**301-4.7 FINISHING.** Finishing operations shall be completed during daylight hours. The completed base course shall conform to the required lines, grades, and cross-section. If necessary, the surface shall be lightly scarified to eliminate any imprints made by the compacting or shaping equipment. The surface shall then be recompact to the required density. The finishing operations shall be complete within two (2) hours after completion of mixing operations.

**301-4.8 CONSTRUCTION JOINTS.** At the end of each day's construction, a straight transverse construction joint shall be formed by a header or by cutting back into the compacted material to form a true vertical face free of loose material.

The protection provided for construction joints shall permit the placing, spreading, and compacting of base material without injury to the previous work. Where it is necessary to operate or turn any equipment on the completed base course, sufficient protection and cover shall be provided to prevent damage to the finished surface. A supply of mats or wooden planks shall be maintained and used as approved and directed by the DEN Project Manager.

Care shall be exercised to ensure thorough compaction of the base material immediately adjacent to all construction joints. When spreading or compacting base material adjacent to a previously constructed lane, care shall be taken to avoid damaging the previous work.

**301-4.9 PROTECTION AND CURING.** After the base course has been finished to grade and compacted as specified, it shall be protected against drying for a period of seven (7) days by the application of bituminous material or other acceptable methods. The curing method shall begin as soon as possible, but no later than 24 hours after the completion of finishing operations. The finished base course shall be kept moist continuously until the curing material is placed.

The bituminous material specified shall be uniformly applied to the surface of the completed base course at the rate of approximately 0.2 gallons per square yard (0.91 l/m<sup>2</sup>) with approved heating and distributing equipment. The exact rate and temperature of application to give complete coverage without excessive runoff shall be as specified.

At the time the bituminous material is applied, the surface shall be dense, free of all loose and extraneous material, and shall contain sufficient moisture to prevent penetration of the bituminous material. Water shall be applied in sufficient quantity to fill the surface voids immediately before the bituminous curing material is applied.

The curing material shall be maintained and applied as needed by the Contractor during the 7-day protection period.

Completed portions of the cement-treated soil area may be opened to light traffic, if approved by the DEN Project Manager, and provided the curing is not impaired. Sufficient protection from freezing shall be provided to the soil-cement for seven (7) days after its construction and until it has hardened.

**301-4.10 CONSTRUCTION LIMITATIONS.** When any of the operations after the application of cement are interrupted for more than 30 minutes or when the uncompacted soil-cement mixture is wetted by rain so that the moisture content is exceeded by a small amount, the decision to reconstruct the portion affected shall rest with the DEN Project Manager. If the uncompacted, rain-wetted mixture exceeds the specified moisture content tolerance, the Contractor shall reconstruct the affected portion at the Contractor's expense the portion affected. All material along the longitudinal or transverse construction joints not properly compacted shall be removed and replaced, at the Contractor's expense, with properly moistened and mixed soil-cement compacted to specified density.

**301-4.11 SURFACE TESTS.** The finished surface shall not vary more than 3/8 inch (9 mm) when tested with a 12-foot (3.7-m) straightedge applied parallel with, or at right angles to, the longitudinal axis of the pavement. Any variations in excess of this tolerance shall be corrected by the Contractor, at the Contractor's expense, in a manner satisfactory to the DEN Project Manager.

**301-4.12 THICKNESS.** The completed thickness of the stabilized course shall be within 1/2 inch (12 mm) of the thickness indicated. Where the measured thickness is more than 1/2 inch (12 mm) deficient, such areas shall be corrected by scarifying, adding mixture of proper gradation, reblading, and recompacting as directed. Where the measured thickness is more than 1/2 inch (12 mm) thicker than indicated, the course shall be considered as conforming to the specified thickness requirements. Average job thickness shall be the average of all thickness measurements taken for the job, but shall be within 1/4 inch (6 mm) of the thickness indicated. The thickness of the stabilized course shall be measured at intervals which ensure one measurement for each 300 square yards (250 m<sup>2</sup>) of stabilized course. Measurements shall be made in 3-inch (75 mm) diameter test holes penetrating the stabilized course. Where the average thickness shown by the measurements made in one day's construction is not within the tolerance given, the DEN Project Manager shall evaluate the area and determine if, in the DEN Project Manager's opinion, it shall be reconstructed at the Contractor's expense or the deficiency deducted from the total material in place.

**301-4.13 MAINTENANCE.** The Contractor shall be required to maintain, at the Contractor's expense, the entire base course within the limits of the contract in a condition satisfactory to the DEN Project Manager until all the work has been completed. Maintenance shall include immediate repairs of any defects that may occur either before or after the cement is applied. The work shall be repeated as often as necessary to keep the area intact at all times. Repairs shall be made to ensure restoration of a uniform surface and the durability of the area repaired. Faulty work shall be replaced for the full depth of treatment. Adding a thin layer of soil-cement to the completed work to remedy low areas shall not be permitted.

**301-4.14 QUALITY CONTROL/QUALITY ASSURANCE TESTING SUMMARY.** Unless stated otherwise, all testing is conducted by the Contractor. All necessary field and laboratory testing shall be considered incidental to the work and no additional payment will be made.

The following table summarizes the testing required in this specification. The information included in this table does not waive any requirements listed previously in the specification.

All test results shall be provided to the DEN Project Manager within 48 hours of completion of the tests.

<b>Table 6 P-301 TESTING SUMMARY</b>				
<b>Specification Reference</b>	<b>Test Type</b>	<b>Test Standard</b>	<b>Minimum Testing Frequency</b>	<b>Responsible Party</b>
4.6	Moisture-Density Relationship	ASTM D558	Two each for the first 2 days of placement, then 1 test each day thereafter.	Contractor
4.6	In-Place Density and Moisture Content	ASTM D1556 ASTM D2167 ASTM D6938	One test for each 300 square yards of material placed per lift, per day, or fraction thereof	Contractor
4.6	Compressive Strength		One set of 4 cylinders per 1,000 square yards	Contractor
4.11	Smoothness	±3/8 inch	As directed by the DEN Project Manager	Contractor
4.12	Thickness	±1/2 inch	1 test per 300 square yard	Contractor

### **BASIS OF PAYMENT**

No measurement for payment is associated with this specification section. Payment will be made under specification section 31 23 23 Backfill and Surface Restoration.

### **TEST REQUIREMENTS**

ASTM C136	Standard Test Method for Sieve or Screen Analysis of Fine and Coarse Aggregates
ASTM D558	Standard Test Methods for Moisture-Density (Unit Weight) Relations of Soil-Cement Mixtures
ASTM D1556	Standard Test Method for Density and Unit Weight of Soil In-Place by the Sand Cone Method

AASHTO T135 Standard Method of Test for Wetting-and-Drying Test of Compacted Soil-Cement Mixtures

AASHTO T136 Standard Method of Test for Freezing-and-Thawing Tests of Compacted Soil-Cement Mixtures

### **MATERIAL REQUIREMENTS**

ASTM C150 Standard Specification for Portland Cement

ASTM D977 Standard Specification for Emulsified Asphalt

ASTM D2027 Standard Specification for Cutback Asphalt (Medium-Curing Type)

ASTM D2028 Standard Specification for Cutback Asphalt (Rapid-Curing Type)

ASTM D2397 Standard Specification for Cationic Emulsified Asphalt

**END OF ITEM P-301**

## ITEM P-403 HOT MIX ASPHALT (HMA) PAVEMENTS (BASE, LEVELING OR SURFACE COURSE)

### DESCRIPTION

**403-1.1** This item shall consist of a base course composed of mineral aggregate and asphalt cement binder (asphalt binder) mixed in a central mixing plant and placed on a prepared course in accordance with these specifications and shall conform to the lines, grades, thicknesses, and typical cross-sections shown on the plans. Each course shall be constructed to the depth, typical section, and elevation required by the plans and shall be rolled, finished, and approved before the placement of the next course.

The work set forth in this section consists of the Contractor's preparation and submittal of an appropriate mix design, including the contractor's options with respect thereto, discussion of appropriate equipment for use by the Contractor and the placement of pavement composed of mineral aggregate and asphalt cement binder (asphalt binder) mixed in a central mixing plant and placed on a prepared course in accordance with these specifications and shall conform to the lines, grades, thicknesses, and typical cross-sections shown on the plans. Each course shall be constructed to the depth, typical section, and elevation required by the plans and shall be rolled, finished, and approved before the placement of the next course.

Section headings used in this Section P-403 or any other part of this Contract are for convenience only and shall not be used in the interpretation of this Section P-403 or any other section or subsection of this Contract so as to indicate that phrases or clauses describing standards, tests, equipment, workmanship, material descriptions, characteristics or results to be achieved are confined to the Section heading under which they appear. Any requirement appearing in one location shall be as binding as if appearing in all. It is the intention of this contract that the work will result in an end hot mix asphalt pavement product which is dense, homogeneous, without segregation.

### MATERIALS

**403-2.1 AGGREGATE.** Aggregates shall consist of crushed stone, crushed gravel crushed slag, screenings, natural sand and mineral filler, as required. The aggregates should be free of ferrous sulfides, such as pyrite, that would cause "rust" staining that can bleed through pavement markings. The portion retained on the No. 4 (4.75 mm) sieve is coarse aggregate. The portion passing the No. 4 (4.75 mm) sieve and retained on the No. 200 (0.075 mm) sieve is fine aggregate, and the portion passing the No. 200 (0.075 mm) sieve is mineral filler.

**a. Coarse Aggregate.** Coarse aggregate shall consist of sound, tough, durable particles, free from films of matter that would prevent thorough coating and bonding with the bituminous material and free from organic matter and other deleterious substances. The percentage of wear shall not be greater than 40 percent when tested in accordance with ASTM C131. The sodium sulfate soundness loss shall not exceed 12%, or the magnesium sulfate soundness loss shall not exceed 18%, after five cycles, when tested in accordance with ASTM C88. Clay Lumps and friable particles shall not exceed 1.0% when tested in accordance with ASTM C142.

Aggregate shall contain at least 75 percent by weight of individual pieces having two or more fractured faces and 85 percent by weight having at least one fractured face. The area of each face shall be equal to at least 75% of the smallest mid-sectional area of the piece. When two fractured faces are contiguous, the angle between the planes of fractures shall be at least 30 degrees to count as two fractured faces. Fractured faces shall be achieved by crushing.

The aggregate shall not contain more than a total of 20% by weight of flat particles, elongated particles, and flat and elongated particles when tested in accordance with ASTM D4791 with a value of 3:1.

Slag shall be air-cooled, blast furnace slag, and shall have a compacted weight of not less than 70 pounds per cubic foot when tested in accordance with ASTM C29.

**b. Fine Aggregate.** Fine aggregate shall consist of clean, sound, tough, durable, angular shaped particles produced by crushing stone, slag, or gravel that meets the requirements for wear and soundness specified for coarse aggregate. The aggregate particles shall be free from coatings of clay, silt, or other objectionable matter.

The fine aggregate, including any blended material for the fine aggregate, shall have a plasticity index of not more than six (6) and a liquid limit of not more than 25 when tested in accordance with ASTM D4318.

The soundness loss shall not exceed 10% when sodium sulfate is used or 15% when magnesium sulfate is used, after five cycles, when tested per ASTM C88.

Clay lumps and friable particles shall not exceed 1.0 percent, by weight, when tested in accordance with ASTM C142.

Natural (non-manufactured) sand may be used to obtain the gradation of the aggregate blend or to improve the workability of the mix. The amount of sand to be added will be adjusted to produce mixtures conforming to requirements of this specification. The fine aggregate shall not contain more than 15% natural sand by weight of total aggregates. If used, the natural sand shall meet the requirements of ASTM D1073 and shall have a plasticity index of not more than six (6) and a liquid limit of not more than 25 when tested in accordance with ASTM D4318.

The aggregate shall have sand equivalent values of 40 or greater when tested in accordance with ASTM D2419.

c. **Sampling.** ASTM D75 shall be used in sampling coarse and fine aggregate, and ASTM C183 shall be used in sampling mineral filler.

**403-2.2 MINERAL FILLER.** If filler, in addition to that naturally present in the aggregate, is necessary, it shall meet the requirements of ASTM D242.

**403-2.3 ASPHALT CEMENT BINDER.** Asphalt cement binder shall conform to ASTM D6373 Performance Grade (PG) 64-22. A certificate of compliance from the manufacturer shall be included with the mix design submittal.

The supplier's certified test report with test data indicating grade certification for the asphalt binder shall be provided to the DEN Project Manager for each load at the time of delivery to the mix plant. A certified test report with test data indicating grade certification for the asphalt binder shall also be provided to the DEN Project Manager for any modification of the asphalt binder after delivery to the mix plant and before use in the HMA.

**403-2.4 PRELIMINARY MATERIAL ACCEPTANCE.** Prior to delivery of materials to the job site, the Contractor shall submit certified test reports to the DEN Project Manager for the following materials:

- a. **Coarse Aggregate.**
  - (1) Percent of wear
  - (2) Soundness
  - (3) Clay lumps and friable particles
  - (4) Percent fractured faces
  - (5) Flat and elongated particles
  - (6) [Unit weight of slag]
- b. **Fine Aggregate:**
  - (1) Liquid limit and Plasticity index
  - (2) Soundness
  - (3) Clay lumps and friable particles
  - (4) Percent natural sand
  - (5) Sand equivalent
- c. **Mineral Filler.**
- d. **Asphalt Binder.** Test results for asphalt binder shall include temperature/viscosity charts for mixing and compaction temperatures.



The certifications shall show the appropriate ASTM tests for each material, the test results, and a statement that the material meets the specification requirement.

The DEN Project Manager may request samples for testing, prior to and during production, to verify the quality of the materials and to ensure conformance with the applicable specifications.

**403-2.5 ANTI-STRIPPING AGENT.** Any anti-stripping agent or additive if required shall be heat stable, shall not change the asphalt cement viscosity beyond specifications, shall contain no harmful ingredients, shall be added in recommended proportion by approved method, and shall be a material approved by the Department of Transportation of the State in which the project is located.

## COMPOSITION

**403-3.1 COMPOSITION OF MIXTURE.** The HMA plant mix shall be composed of a mixture of well-graded aggregate, filler and anti-strip agent if required, and asphalt binder. The several aggregate fractions shall be sized, handled in separate size groups, and combined in such proportions that the resulting mixture meets the grading requirements of the job mix formula (JMF).

**403-3.2 JOB MIX FORMULA.** No hot-mixed asphalt (HMA) for payment shall be produced until a JMF has been approved in writing by the DEN Project Manager. The asphalt mix design and JMF shall be prepared by an accredited laboratory that meets the requirements of paragraph 403-3.4. The HMA shall be designed using procedures contained in Asphalt Institute MS-2 Mix Design Manual, 7th Edition. ASTM D6926 shall be used for preparation of specimens using the manually held and operated hammer for the mix design procedure. ASTM D6927 shall be used for testing for Marshall stability and flow.

If material variability exceeds the standard deviations indicated, the JMF and subsequent production targets shall be based on a stability greater than shown in Table 1 and the flow shall be targeted close to the mid-range of the criteria in order to meet the acceptance requirements.

Tensile Strength Ratio (TSR) of the composite mixture, as determined by ASTM D4867, shall not be less than 75 when tested at a saturation of 70-80% or an anti-stripping agent shall be added to the HMA, as necessary, to produce a TSR of not less than 75 when tested at a saturation of 70-80%. If an anti-strip agent is required, it shall be provided by the Contractor at no additional cost to the Owner.

The JMF shall be submitted in writing by the Contractor at least 30 days prior to the start of paving operations. The JMF shall be developed within the same construction season using aggregates currently being produced.

The submitted JMF shall be stamped or sealed by the responsible professional Engineer of the laboratory and shall include the following items as a minimum:

- a. Percent passing each sieve size for total combined gradation, individual gradation of all aggregate stockpiles and percent by weight of each stockpile used in the JMF.
- b. Percent of asphalt cement.
- c. Asphalt performance, grade, and type of modifier if used.
- d. Number of blows per side of molded specimen.
- e. Laboratory mixing temperature.
- f. Laboratory compaction temperature.
- g. Temperature-viscosity relationship of the PG asphalt cement binder showing acceptable range of mixing and compaction temperatures and for modified binders include supplier recommended mixing and compaction temperatures.
- h. Plot of the combined gradation on the 0.45 power gradation curve.
- i. Graphical plots of stability, flow, air voids, voids in the mineral aggregate, and unit weight versus asphalt content.
- j. Specific gravity and absorption of each aggregate.
- k. Percent natural sand.
- l. Percent fractured faces.
- m. Percent by weight of flat particles, elongated particles, and flat and elongated particles (and criteria).
- n. Tensile Strength Ratio (TSR).
- o. Anti-strip agent (if required).
- p. Date the JMF was developed. Mix designs that are not dated or which are from a prior construction season shall not be accepted.

The Contractor shall submit to the DEN Project Manager the results of verification testing of three (3) asphalt samples prepared at the optimum asphalt content. The average of the results of this testing shall indicate conformance with the JMF requirements specified in Tables 1 and 3.

When the project requires asphalt mixtures of differing aggregate gradations, a separate JMF and the results of JMF verification testing shall be submitted for each mix.

The JMF for each mixture shall be in effect until a modification is approved in writing by the DEN Project Manager. Should a change in sources of materials be made, a new JMF must be submitted within 15 days and approved by the DEN Project Manager in writing before the new material is used. After the initial production JMF has been approved by the DEN Project Manager and a new or modified JMF is required for whatever reason, the subsequent cost of the DEN Project Manager's approval of the new or modified JMF will be borne by the Contractor. There will be no time extension given or considerations for extra costs associated

with the stoppage of production paving or restart of production paving due to the time needed for the DEN Project Manager to approve the initial, new or modified JMF.

The Marshall Design Criteria applicable to the project shall be as specified in Table 1.

**Table 1. Marshall Design Criteria**

Test Property	Value
Number of blows	75
Stability, pounds minimum	1800
Flow, 0.01 inch (0.25 mm)	8-16
Air voids (percent)	3.5
Percent voids in mineral aggregate, minimum	See Table 2.

**Table 2. Minimum Percent Voids In Mineral Aggregate (VMA)**

Aggregate (See Table 3)	Minimum VMA
Gradation 1	14

The mineral aggregate shall be of such size that the percentage composition by weight, as determined by laboratory sieves, will conform to the gradation or gradations specified in Table 3 when tested in accordance with ASTM C136 and ASTM C117.

The gradations in Table 3 represent the limits that shall determine the suitability of aggregate for use from the sources of supply, be well graded from coarse to fine and shall not vary from the low limit on one sieve to the high limit on the adjacent sieve, or vice versa.

**Table 3. Aggregate - HMA Pavements**

Sieve Size	Percentage by Weight Passing Sieve
1 inch (25 mm)	100
3/4 inch (19 mm)	76-98
1/2 inch (12 mm)	66-86
3/8 inch (9 mm)	57-77
No. 4 (4.75 mm)	40-60
No. 8 (2.36 mm)	26-46
No. 16 (1.18 mm)	17-37
No. 30 (0.60 mm)	11-27
No. 50 (0.30 mm)	7-19

Sieve Size	Percentage by Weight Passing Sieve
No. 100 (0.15 mm)	6-16
No. 200 (0.075 mm)	3-6
Asphalt Percent:	
Stone or gravel	4.5-7.0
Slag	5.0-7.5

The aggregate gradations shown are based on aggregates of uniform specific gravity. The percentages passing the various sieves shall be corrected when aggregates of varying specific gravities are used, as indicated in the Asphalt Institute MS-2 Mix Design Manual, 7th Edition.

**403-3.3 RECLAIMED ASPHALT CONCRETE.** RAP shall not be used.

**403-3.4 JOB MIX FORMULA (JMF) LABORATORY.** The Contractor's laboratory used to develop the JMF shall be accredited in accordance with ASTM D3666. The laboratory accreditation must be current and listed on the accrediting authority's website. All test methods required for developing the JMF must be listed on the lab accreditation. A copy of the laboratory's current accreditation and accredited test methods shall be submitted to the DEN Project Manager prior to start of construction.

**403-3.5 TEST SECTION.** Prior to full production, the Contractor shall prepare and place a quantity of HMA according to the JMF. The amount of HMA shall be sufficient to construct a test section 300 long and 24 wide, placed in two lanes, with a longitudinal cold joint, and shall be of the same depth specified for the construction of the course which it represents. A cold joint for this test section is an exposed construction joint at least four (4) hours old or whose mat has cooled to less than 160°F. The cold joint must be cut back using the same procedure that will be used during production in accordance with 403-4.12. The underlying grade or pavement structure upon which the test section is to be constructed shall be the same as the remainder of the course represented by the test section. The equipment used in construction of the test section shall be the same type and weight to be used on the remainder of the course represented by the test section.

The test section shall be evaluated for acceptance as a single lot in accordance with the acceptance criteria in paragraph 403-5.1 and 403-5.2. The test section shall be divided into equal sublots. As a minimum the test section shall consist of three (3) sublots.

The test section shall be considered acceptable if the average mat density of the test section cores is greater than or equal to 96% and the average joint density of the test section cores is greater than or equal to 94%.

The test results shall be acceptable for the work to continue. If all of the test results meet the specified requirements, the test section shall remain as part of the project pavement. If test

section is not considered acceptable, the test section shall be removed and replaced at no cost to the Owner and another test section shall be constructed.

If the initial test section should prove to be unacceptable, the necessary adjustments to the job mix formula, plant operation, placing procedures, and/or rolling procedures shall be made. Additional test sections, as required, shall be constructed and evaluated for conformance to the specifications. Full production shall not begin until an acceptable test section has been constructed and accepted in writing by the DEN Project Manager. Once an acceptable test section has been placed, payment for the test section that meets specification requirements shall be made in accordance with paragraph 403-8.1.

Job mix control testing shall be performed by the Contractor at the start of plant production and in conjunction with the calibration of the plant for the JMF. If the aggregates produced by the plant do not satisfy the gradation requirements or produce a mix that meets the JMF, it will be necessary to reevaluate and redesign the mix using plant-produced aggregates. Specimens shall be prepared and the optimum asphalt content determined in the same manner as for the original JMF tests.

Contractor will not be allowed to place the test section until the Contractor Quality Control Program, showing conformance with the requirements of paragraph 403-6.1, has been approved, in writing, by the DEN Project Manager.

## CONSTRUCTION METHODS

**403-4.1 WEATHER LIMITATIONS.** The HMA shall not be placed upon a wet surface or when the surface temperature of the underlying course is less than specified in Table 4. The temperature requirements may be waived by the DEN Project Manager, if requested; however, all other requirements including compaction shall be met.

**Table 4. Surface Temperature Limitations of Underlying Course**

Mat Thickness	Base Temperature (Minimum)
	Degrees F
3 inches or greater	40
Greater than 2 inches but less than 3 inches	45

**403-4.2 HMA PLANT.** Plants used for the preparation of HMA shall conform to the requirements of American Association of State Highway and Transportation Officials (AASHTO) M156 with the following changes:

a. Requirements for all plants include:

(1) **Truck scales.** The HMA shall be weighed on approved scales furnished by the Contractor, or on certified public scales at the Contractor's expense. Scales shall be inspected and sealed as often as the DEN Project Manager deems necessary to assure their accuracy. Scales shall conform to the requirements of the General Provisions, subsection 90-01.

In lieu of scales, and as approved by the DEN Project Manager, HMA weights may be determined by the use of an electronic weighing system equipped with an automatic printer that weighs the total HMA production and as often thereafter as requested by the DEN Project Manager.

(2) **Testing facilities.** The Contractor shall ensure laboratory facilities are provided at the plant for the Contractor's quality control testing and use of the DEN Project Manager. The lab shall have sufficient space so that both testing representatives (DEN Project Manager's and Contractor's) can operate efficiently. The lab shall meet the requirements of ASTM D3666 including all necessary equipment, materials, and current reference standards to comply with the specifications and masonry saw with diamond blade for trimming pavement cores and samples. The laboratory shall be weather tight, sufficiently heated in cold weather, air-conditioned in hot weather to maintain temperatures for testing purposes of 70°F ±5°F. The plant testing laboratory shall be located on the plant site to provide an unobstructed view, from one of its windows, of the trucks being loaded with the plant mix materials.

Failure to provide the specified facilities shall be sufficient cause for disapproving HMA plant operations.

Laboratory facilities shall be kept clean, and all equipment shall be maintained in proper working condition. The DEN Project Manager shall be permitted unrestricted access to inspect the Contractor's laboratory facility and witness quality control activities. The DEN Project Manager will advise the Contractor in writing of any noted deficiencies concerning the laboratory facility, equipment, supplies, or testing personnel and procedures. When the deficiencies are serious enough to be adversely affecting the test results, the incorporation of the materials into the work shall be suspended immediately and will not be permitted to resume until the deficiencies are satisfactorily corrected.

(3) **Inspection of plant.** The DEN Project Manager, or DEN Project Manager's authorized representative, shall have access, at all times, to all areas of the plant for checking adequacy of equipment; inspecting operation of the plant: verifying weights, proportions, and material properties; and checking the temperatures maintained in the preparation of the mixtures.

(4) **Storage bins and surge bins.** The HMA stored in storage and surge bins shall meet the same requirements as HMA loaded directly into trucks and may be permitted under the following conditions:

(a) Stored in non-insulated bins for a period of time not to exceed three (3) hours.

(b) Stored in insulated storage bins for a period of time not to exceed eight (8) hours.

If the DEN Project Manager determines that there is an excessive amount of heat loss, segregation or oxidation of the HMA due to temporary storage, no temporary storage will be allowed.

**403-4.3 HAULING EQUIPMENT.** Trucks used for hauling HMA shall have tight, clean, and smooth metal beds. To prevent the HMA from sticking to the truck beds, the truck beds shall be lightly coated with a minimum amount of paraffin oil, lime solution, or other material approved by the DEN Project Manager. Petroleum products shall not be used for coating truck beds. Each truck shall have a suitable cover to protect the mixture from adverse weather. When necessary, to ensure that the mixture will be delivered to the site at the specified temperature, truck beds shall be insulated or heated and covers shall be securely fastened.

a. **Material Transfer Vehicle (MTV).** A material transfer vehicle is not required.

**403-4.4 HMA PAVERS.** HMA pavers shall be self-propelled with an activated heated screed, capable of spreading and finishing courses of HMA that will meet the specified thickness, smoothness, and grade. The paver shall have sufficient power to propel itself and the hauling equipment without adversely affecting the finished surface.

The paver shall have a receiving hopper of sufficient capacity to permit a uniform spreading operation. The hopper shall be equipped with a distribution system to place the HMA uniformly in front of the screed without segregation. The screed shall effectively produce a finished surface of the required evenness and texture without tearing, showing, or gouging the mixture.

If, during construction, it is found that the spreading and finishing equipment in use leaves tracks or indented areas, or produces other blemishes in the pavement that are not satisfactorily corrected by the scheduled operations, the use of such equipment shall be discontinued and satisfactory equipment shall be provided by the Contractor.

a. **Automatic grade control.** The HMA paver shall be equipped with a control system capable of automatically maintaining the specified screed elevation. The control system shall be automatically actuated from either a reference line and/or through a system of mechanical sensors or sensor-directed mechanisms or devices that will maintain the paver

screed at a predetermined transverse slope and at the proper elevation to obtain the required surface. The transverse slope controller shall be capable of maintaining the screed at the desired slope within  $\pm 0.1\%$ .

The controls shall be capable of working in conjunction with any of the following attachments:

- (1) Ski-type device of not less than 30 feet (9 m) in length
- (2) Taut stringline (wire) set to grade
- (3) Short ski or shoe
- (4) Laser control

**403-4.5 ROLLERS.** Rollers of the vibratory, steel wheel, and pneumatic-tired type shall be used. They shall be in good condition, capable of operating at slow speeds to avoid displacement of the HMA. The number, type, and weight of rollers shall be sufficient to compact the HMA to the required density while it is still in a workable condition.

All rollers shall be specifically designed and suitable for compacting hot mix bituminous concrete and shall be properly used. Rollers that impair the stability of any layer of a pavement structure or underlying soils shall not be used. Depressions in pavement surfaces caused by rollers shall be repaired by the Contractor at their own expense.

The use of equipment that causes crushing of the aggregate will not be permitted.

**a. Density Device.** The Contractor shall have on site a density gauge during all paving operations in order to assist in the determination of the optimum rolling pattern, type of roller and frequencies, as well as to monitor the effect of the rolling operations during production paving. The Contractor shall also supply a qualified technician during all paving operations to calibrate the density gauge and obtain accurate density readings for all new HMA. These densities shall be supplied to the DEN Project Manager upon request at any time during construction. No separate payment will be made for supplying the density gauge and technician.

**403-4.6 PREPARATION OF ASPHALT BINDER.** The asphalt binder shall be heated in a manner that will avoid local overheating and provide a continuous supply of the bituminous material to the mixer at a uniform temperature. The temperature of the unmodified asphalt binder delivered to the mixer shall be sufficient to provide a suitable viscosity for adequate coating of the aggregate particles, but shall not exceed 325°F when added to the aggregate. The temperature of modified asphalt binder shall be no more than 350°F when added to the aggregate.

**403-4.7 PREPARATION OF MINERAL AGGREGATE.** The aggregate for the HMA shall be heated and dried. The maximum temperature and rate of heating shall be such that no damage occurs to the aggregates. The temperature of the aggregate and mineral filler



shall not exceed 350°F when the asphalt binder is added. Particular care shall be taken that aggregates high in calcium or magnesium content are not damaged by overheating. The temperature shall not be lower than is required to obtain complete coating and uniform distribution on the aggregate particles and to provide a mixture of satisfactory workability.

**403-4.8 PREPARATION OF HMA.** The aggregates and the asphalt binder shall be weighed or metered and introduced into the mixer in the amount specified by the JMF.

The combined materials shall be mixed until the aggregate obtains a uniform coating of asphalt binder and is thoroughly distributed throughout the mixture. Wet mixing time shall be the shortest time that will produce a satisfactory mixture, but not less than 25 seconds for batch plants. The wet mixing time for all plants shall be established by the Contractor, based on the procedure for determining the percentage of coated particles described in ASTM D2489, for each individual plant and for each type of aggregate used. The wet mixing time will be set to achieve 95% of coated particles. For continuous mix plants, the minimum mixing time shall be determined by dividing the weight of its contents at operating level by the weight of the mixture delivered per second by the mixer. The moisture content of all HMA upon discharge shall not exceed 0.5%.

**403-4.9 PREPARATION OF THE UNDERLYING SURFACE.** Immediately before placing the HMA, the underlying course shall be cleaned of all dust and debris. A tack coat is required: between the existing pavement surface and the new hot mix asphalt, including milled surfaces; between layers of each lift of hot mix asphalt; and at any vertical surfaces that the new hot mix asphalt will be placed against including cold joints. Tack coat must be applied in accordance with Item P-603.

**403-4.10 LAYDOWN PLAN, TRANSPORTING, PLACING, AND FINISHING.** Prior to the placement of the HMA, the Contractor shall prepare a laydown plan for approval by the DEN Project Manager. This is to minimize the number of cold joints in the pavement. The laydown plan shall include the sequence of paving laydown by stations, width of lanes, temporary ramp locations, and laydown temperature. The laydown plan shall also include estimated time of completion for each portion of the work (that is, milling, paving, rolling, cooling, etc.). Modifications to the laydown plan shall be approved by the DEN Project Manager.

The HMA shall be transported from the mixing plant to the site in vehicles conforming to the requirements of paragraph 403-4.3. Deliveries shall be scheduled so that placing and compacting of HMA is uniform with minimum stopping and starting of the paver. Hauling over freshly placed material shall not be permitted until the material has been compacted, as specified, and allowed to cool to atmospheric temperature.

The alignment and elevation of the paver shall be regulated from outside reference lines established for this purpose for the first lift of all runway and taxiway pavements. Successive lifts of HMA surface course may be placed using a ski, or laser control per paragraph 403-4.4.1, provided grades of the first lift of bituminous surface course meet the tolerances of paragraphs 403-5.2b(5) as verified by a survey. Contractor shall survey each lift of HMA

surface course and certify to DEN Project Manager that every lot of each lift meets the grade tolerances of paragraph 403-5.2b(5) before the next lift can be placed.

The initial placement and compaction of the HMA shall occur at a temperature suitable for obtaining density, surface smoothness, and other specified requirements but not less than 250°F (121°C), unless otherwise indicated in the approved mix design.

Edges of existing HMA pavement abutting the new work shall be saw cut and carefully removed as shown on the drawings and coated with asphalt tack coat before new material is placed against it.

Upon arrival, the mixture shall be placed to the full width by a bituminous paver. It shall be struck off in a uniform layer of such depth that, when the work is completed, it shall have the required thickness and conform to the grade and contour indicated. The speed of the paver shall be regulated to eliminate pulling and tearing of the HMA mat. Unless otherwise permitted, placement of the HMA shall begin along the centerline of a crowned section or on the high side of areas with a one-way slope. The HMA shall be placed in consecutive adjacent strips having a minimum width of 10 feet except where edge lanes require less width to complete the area. Additional screed sections shall not be attached to widen paver to meet the minimum lane width requirements specified above unless additional auger sections are added to match. The longitudinal joint in one course shall offset the longitudinal joint in the course immediately below by at least one foot; however, the joint in the surface top course shall be at the centerline of crowned pavements. Transverse joints in one course shall be offset by at least 10 feet from transverse joints in the previous course.

Transverse joints in adjacent lanes shall be offset a minimum of 10 feet.

On areas where irregularities or unavoidable obstacles make the use of mechanical spreading and finishing equipment impractical, the HMA may be spread and luted by hand tools.

Areas of segregation in the course, as determined by the DEN Project Manager, shall be removed and replaced at the Contractor's expense. The area shall be removed by saw cutting and milling a minimum of 2 inches deep. The area to be removed and replaced shall be a minimum width of the paver and a minimum of 10 feet long.

**403-4.11      COMPACTION OF MIXTURE.** After placing, the HMA shall be thoroughly and uniformly compacted by power rollers. The surface shall be compacted as soon as possible when the mixture has attained sufficient stability so that the rolling does not cause undue displacement, cracking or shoving. The sequence of rolling operations and the type of rollers used shall be at the discretion of the Contractor. The speed of the roller shall, at all times, be sufficiently slow to avoid displacement of the hot mixture and be effective in compaction. Any displacement occurring as a result of reversing the direction of the roller, or from any other cause, shall be corrected at once.

Sufficient rollers shall be furnished to handle the output of the plant. Rolling shall continue until the surface is of uniform texture, true to grade and cross-section, and the required field

density is obtained. To prevent adhesion of the mixture to the roller, the wheels shall be equipped with a scraper and kept properly moistened using a water soluble asphalt release agent approved by the DEN Project Manager.

In areas not accessible to the roller, the mixture shall be thoroughly compacted with approved power driven tampers. Tampers shall weigh not less than 275 pounds, have a tamping plate width not less than 15 inches, be rated at not less than 4,200 vibrations per minute, and be suitably equipped with a standard tamping plate wetting device.

Any HMA that becomes loose and broken, mixed with dirt, contains check-cracking, or in any way defective shall be removed and replaced with fresh hot mixture and immediately compacted to conform to the surrounding area. This work shall be done at the Contractor's expense. Skin patching shall not be allowed.

**403-4.12 JOINTS.** The formation of all joints shall be made in such a manner as to ensure a continuous bond between the courses and obtain the required density. All joints shall have the same texture as other sections of the course and meet the requirements for smoothness and grade. The roller shall not pass over the unprotected end of the freshly laid HMA except when necessary to form a transverse joint. When necessary to form a transverse joint, it shall be made by means of placing a bulkhead or by tapering the course. The tapered edge shall be cut back to its full depth and width on a straight line to expose a vertical face prior to placing the adjacent lane. In both methods, all contact surfaces shall be coated with an asphalt tack coat before placing any fresh HMA against the joint.

Longitudinal joints which are have been left exposed for more than four (4) hours; the surface temperature has cooled to less than 175°F; or are irregular, damaged, uncompacted or otherwise defective shall be cut back 3 inches to 6 inches to expose a clean, sound, uniform vertical surface for the full depth of the course. All cutback material shall be removed from the project. A asphalt tack coat or other product approved by the DEN Project Manager shall be applied to the clean, dry joint prior to placing any additional fresh HMA against the joint. Any laitance produced from cutting joints shall be removed by vacuuming and washing. The cost of this work shall be considered incidental to the cost of the HMA.

**403-4.13 DIAMOND GRINDING.** When required, diamond grinding shall be accomplished by sawing with saw blades impregnated with industrial diamond abrasive. The saw blades shall be assembled in a cutting head mounted on a machine designed specifically for diamond grinding that will produce the required texture and smoothness level without damage to the pavement. The saw blades shall be 1/8-inch wide and there shall be a minimum of 55 to 60 blades per 12 inches of cutting head width; the actual number of blades will be determined by the Contractor and depend on the hardness of the aggregate. Each machine shall be capable of cutting a path at least 3 feet wide. Equipment that causes ravel, aggregate fractures, spalls or disturbance to the pavement will not be permitted. The depth of grinding shall not exceed 1/2 inch and all areas in which diamond grinding has been performed will be subject to the final pavement thickness tolerances specified. Grinding will be tapered in all directions to provide smooth transitions to areas not requiring grinding. Areas that have been ground will be sealed with a surface treatment as directed by the DEN

Project Manager. It may be necessary to seal a larger area to avoid surface treatment creating any conflict with runway or taxiway markings.

**403-4.14 NIGHTTIME PAVING REQUIREMENTS.** Paving during nighttime construction shall require the following:

**a.** All paving machines, rollers, distribution trucks and other vehicles required by the Contractor for his operations shall be equipped with artificial illumination sufficient to safely complete the work.

**b.** Minimum illumination level shall be 20 horizontal foot-candles and maintained in the following areas:

**(1)** An area of 30 feet wide by 30 feet long immediately behind the paving machines during the operations of the machines.

**(2)** An area 15 feet wide by 30 feet long immediately in front and back of all rolling equipment, during operation of the equipment.

**(3)** An area 15 feet wide by 15 feet long at any point where an area is being tack coated prior to the placement of pavement.

**c.** As partial fulfillment of the above requirements, the Contractor shall furnish and use, complete artificial lighting units with a minimum capacity of 3,000 watt electric beam lights, affixed to all equipment in such a way to direct illumination on the area under construction.

**d.** A lighting plan must be submitted by the Contractor and approved by the DEN Project Manager prior to the start of any nighttime work.

## MATERIAL ACCEPTANCE

**403-5.1 ACCEPTANCE SAMPLING AND TESTING.** Unless otherwise specified, all acceptance sampling and testing necessary to determine conformance with the requirements specified in this section will be performed by the DEN Project Manager at no cost to the Contractor except that coring as required in this section shall be completed and paid for by the Contractor.

Testing organizations performing these tests shall be accredited in accordance with ASTM D3666. The laboratory accreditation must be current and listed on the accrediting authority's website. All test methods required for acceptance sampling and testing must be listed on the lab accreditation. A copy of the laboratory's current accreditation and accredited test methods shall be submitted to the DEN Project Manager prior to start of construction. All equipment in Contractor furnished laboratories shall be calibrated by an independent testing organization prior to the start of operations.

**a. Hot Mixed Asphalt.** Plant-produced HMA shall be tested for air voids and stability and flow on a lot basis. Sampling shall be from material deposited in place prior to compaction. Samples shall be taken in accordance with ASTM D979.

A standard lot shall be equal to one day's production or 2000 tons whichever is smaller. If the day's production is expected to exceed 2000 tons, but less than 4000 tons, the lot size shall be 1/2 day's production. If the day's production exceeds 4000 tons, the lot size shall be an equal sized fraction of the day's production, but shall not exceed 2000 tons.

Where more than one plant is simultaneously producing HMA for the job, the lot sizes shall apply separately for each plant.

**(1) Sampling.** Each lot will consist of four equal sublots. Sufficient HMA for preparation of test specimens for all testing will be sampled by the DEN Project Manager on a random basis, in accordance with the procedures contained in ASTM D3665. Samples will be taken in accordance with ASTM D979.

The sample of HMA may be put in a covered metal tin and placed in an oven for not less than 30 minutes nor more than 60 minutes to stabilize to compaction temperature. The compaction temperature of the specimens shall be as specified in the JMF.

**(2) Testing.** Sample specimens shall be tested for stability and flow in accordance with ASTM D6971. Air voids will be determined by the DEN Project Manager in accordance with ASTM D3203. One set of laboratory compacted specimens will be prepared for each subplot in accordance with ASTM D6926 at the number of blows required by paragraph 401-3.2, Table 1. Each set of laboratory compacted specimens will consist of three test specimens prepared from the same sample. The manual hammer in ASTM D 6926 should be used, however mechanical hammers may be used if they are approved by the DEN Project Manager and calibrated to the same manual hammer density by varying the number of blows and for each specific mix. When calibrating the mechanical hammer, at least 5 samples should be compacted with the manual hammer (50 or 75 blows as specified) to establish an average density. Five samples should also be compacted at various blow counts with the mechanical hammer and plotted to give a curve that shows density vs blows. Where the average density of the manual hammer intersects the curve developed from the mechanical hammer, the number of blows required for the mechanical hammer is identified. The guide to control the vertical axis of the hammer shall not be used during compaction.

Prior to testing, the bulk specific gravity of each test specimen shall be measured by the DEN Project Manager in accordance with ASTM D2726 or ASTM D6752 using the procedure for laboratory-prepared thoroughly dry specimens for use in computing air voids and pavement density. ASTM D7227 may be used to expedite test results.

For air voids determination, the theoretical maximum specific gravity of the mixture shall be measured one time for each subplot in accordance with ASTM D2041. The value used in the air voids computation for each subplot shall be based on theoretical maximum specific gravity measurement for the subplot.

The stability and flow for each subplot shall be computed by averaging the results of all test specimens representing that subplot.

(3) **Acceptance.** Acceptance of plant produced HMA for stability, flow, and air voids shall be determined by the DEN Project Manager in accordance with the requirements of paragraph 403-5.a.

**b. In-Place HMA.** HMA placed in the field shall be tested for mat and joint density on a lot basis. A standard lot shall be equal to one day's production or 2000 tons whichever is smaller. If the day's production is expected to exceed 2000 tons, but less than 4000 tons, the lot size shall be 1/2 day's production. If the day's production exceeds 4000 tons, the lot size shall be an equal sized fraction of the day's production, but shall not exceed 2000 tons.

(1) **Mat density.** The lot size shall be the same as that indicated in paragraph 403-5.1a. The lot shall be divided into four equal sublots. One core of finished, compacted HMA shall be taken by the Contractor from each subplot. Core locations will be determined by the DEN Project Manager on a random basis in accordance with procedures contained in ASTM D3665. Cores for mat density shall not be taken closer than one foot from a transverse or longitudinal joint.

(2) **Joint density.** The lot size shall be the total length of longitudinal joints constructed by a lot of HMA as defined in paragraph 403-5.1a. The lot shall be divided into four equal sublots. One core of finished, compacted HMA shall be taken by the Contractor from each subplot. Core locations will be determined by the DEN Project Manager on a random basis in accordance with procedures contained in ASTM D3665. All cores for joint density shall be taken centered on the joint. The minimum core diameter for joint density determination shall be 5 inches.

(3) **Sampling.** Samples shall be neatly cut with a diamond core drill bit. Samples will be taken in accordance with ASTM D979. The minimum diameter of the sample shall be 5 inches. Samples that are defective, as a result of sampling, shall be discarded and another sample taken. The Contractor shall furnish all tools, labor, and materials for cutting samples, cleaning, and filling the cored pavement. Cored pavement shall be cleaned and core holes shall be filled in a manner acceptable to the DEN Project Manager and within one day after sampling. Laitance produced by the coring operation shall be removed immediately. The top most lift of bituminous material shall be completely bonded to the underlying layers of bituminous material. If any of the cores reveal that the surface is not bonded to the bituminous layer immediately below the surface then additional cores shall be taken as directed by the DEN Project Manager in accordance with paragraph 403-5.1b to determine the extent of any delamination. All delaminated areas shall be completely removed by milling to the limits and depth and replaced as directed by the DEN Project Manager at no additional cost.

(4) **Testing.** The bulk specific gravity of each cored sample will be measured by the DEN Project Manager in accordance with ASTM D2726 or ASTM D6752.

Samples will be taken in accordance with ASTM D979. The percent compaction (density) of each sample will be determined by dividing the bulk specific gravity of each subplot sample by the average bulk specific gravity of all laboratory prepared specimens for the lot, as determined in paragraph 403-5.1a(2). The bulk specific gravity used to determine the joint density at joints formed between different lots shall be the lowest of the bulk specific gravity values from the two different lots.

(5) **Acceptance.** Acceptance of field placed HMA for mat density will be determined by the DEN Project Manager in accordance with the requirements of paragraph 403-5.2b(1). Acceptance for joint density will be determined by the DEN Project Manager in accordance with the requirements of paragraph 403-5.2b(2).

c. **Partial Lots HMA.** When operational conditions cause a lot to be terminated before the specified number of tests have been made for the lot, or when the Contractor and DEN Project Manager agree in writing to allow overages or other minor tonnage placements to be considered as partial lots, the following procedure will be used to adjust the lot size and the number of tests for the lot.

The last batch produced where production is halted will be sampled, and its properties shall be considered as representative of the particular subplot from which it was taken. In addition, an agreed to minor placement will be sampled, and its properties shall be considered as representative of the particular subplot from which it was taken. Where three sublots are produced, they shall constitute a lot. Where one or two sublots are produced, they shall be incorporated into the next lot, and the total number of sublots shall be used in the acceptance plan calculation, that is,  $n = 5$  or  $n = 6$ , for example. Partial lots at the end of asphalt production on the project shall be included with the previous lot. The lot size for field placed material shall correspond to that of the plant material, except that, in no cases, shall less than three (3) cored samples be obtained, that is,  $n = 3$ .

#### 403-5.2 ACCEPTANCE CRITERIA.

a. **General.** Acceptance will be based on the following characteristics of the HMA and completed pavement and test results:

- (1) Air Voids
- (2) Mat density
- (3) Joint density
- (4) Thickness
- (5) Grade
- (6) Stability
- (7) Flow

Mat density will be evaluated for acceptance in accordance with paragraph 403-5.2b(1). Stability and flow will be evaluated for acceptance in accordance with paragraph 403-5.1. Joint density will be evaluated for acceptance in accordance with paragraph 403-5.2b(2).

Thickness will be evaluated by the DEN Project Manager for compliance in accordance with paragraph 403-5.2b(3). Acceptance for smoothness will be based on the criteria contained in paragraph 403-5.2b(4). Acceptance for grade will be based on the criteria contained in paragraph 403-5.2b(5).

The DEN Project Manager may at any time reject and require the Contractor to dispose of any batch of HMA which is rendered unfit for use due to contamination, segregation, incomplete coating of aggregate, or improper mix temperature. Such rejection may be based on only visual inspection or temperature measurements. In the event of such rejection, the Contractor may take a representative sample of the rejected material in the presence of the DEN Project Manager, and if it can be demonstrated in the laboratory, in the presence of the DEN Project Manager, that such material was erroneously rejected, payment will be made for the material at the contract unit price. DEN Project Manager shall review and approve laboratory testing plan.

**b. Acceptance Criteria.**

(1) **Mat Density.** Acceptance of each lot of plant produced material for mat density shall be based on the average of all of the densities taken from the sublots. If the average mat density of the lot so established equals or exceeds 96%, the lot shall be acceptable. If the average mat density of the lot is below 96%, the lot shall be removed and replaced at the Contractor's expense.

(2) **Joint Density.** Acceptance of each lot of plant produced HMA for joint density shall be based on the average of all of the joint densities taken from the sublots. If the average joint density of the lot so established equals or exceeds 94%, the lot shall be acceptable. If the average joint density of the lot is less than 94%, the Contractor shall stop production and evaluate the method of compacting joints. Production may resume once the reason for poor compaction has been determined and appropriate measures have been taken to ensure proper compaction.

(3) **Thickness.** Thickness of each course shall be evaluated by the DEN Project Manager for compliance to the requirements shown on the plans. Measurements of thickness shall be made by the DEN Project Manager using the cores extracted for each subplot for density measurement. The maximum allowable deficiency at any point shall not be more than 1/4 inch less than the thickness indicated for the lift. Average thickness of lift, or combined lifts, shall not be less than the indicated thickness. Where thickness deficiency exceeds the specified tolerances, the lot or subplot shall be corrected by the Contractor at his expense by removing the deficient area and replacing with new pavement. The Contractor, at his expense, may take additional cores as approved by the DEN Project Manager to circumscribe the deficient area.



(4) **Grade.** Grade shall be evaluated on the first day of placement and then every 24 hours to allow adjustments to paving operations if measurements do not meet specification requirements. The Contractor must submit the survey data to the DEN Project Manager by the following day after measurements have been taken. The finished surface of the pavement shall not vary from the gradeline elevations and cross-sections shown on the plans by more than 1/2 inch. The finished grade of each lot will be determined by running levels at intervals of 50 feet or less longitudinally and all breaks in grade transversely (not to exceed 50 feet) to determine the elevation of the completed pavement. The Contractor shall pay the cost of surveying of the level runs that shall be performed by a licensed surveyor. The documentation, stamped and signed by a licensed surveyor, shall be provided by the Contractor to the DEN Project Manager. The lot size shall be 2,000 square yards. When more than 15% of all the measurements within a lot are outside the specified tolerance, or if any one shot within the lot deviates 3/4 inch or more from planned grade, the Contractor shall remove the deficient area to the depth of the final course of pavement and replace with new material. Skin patching shall not be permitted. Isolated high points may be ground off providing the course thickness complies with the thickness specified on the plans. High point grinding will be limited to 15 square yard. The surface of the ground pavement shall have a texture consisting of grooves between 0.090 and 0.130 inches wide. The peaks and ridges shall be approximately 1/32 inch higher than the bottom of the grooves. The pavement shall be left in a clean condition. The removal of all of the slurry resulting from the grinding operation shall be continuous. The grinding operation should be controlled so the residue from the operation does not flow across other lanes of pavement. Areas in excess of 15 square yard will require removal and replacement of the pavement in accordance with the limitations noted above. Contractor shall apply a surface treatment as directed by the DEN Project Manager to all areas that have been subject to grinding.

c. **Density Outliers.** If the tests within a lot include a very large or a very small value that appears to be outside the normal limits of variation, check for an outlier in accordance with ASTM E178, at a significance level of 5%, to determine if this value should be discarded.

#### **403-5.3 RESAMPLING PAVEMENT FOR MAT DENSITY.**

a. **General.** Resampling of a lot of pavement will only be allowed for mat density and then, only if the Contractor requests same in writing, within 48 hours after receiving the written test results from the DEN Project Manager. A retest will consist of all the sampling and testing procedures contained in paragraphs 403-5.1. Only one resampling per lot will be permitted.

(1) A redefined mat density shall be calculated for the resampled lot. The number of tests used to calculate the redefined mat density shall include the initial tests made for that lot plus the retests.

(2) The cost for resampling and retesting shall be borne by the Contractor.

**b. Payment for Resampled Lots.** The redefined mat density for a resampled lot shall be used to evaluate the acceptance of that lot in accordance with paragraph 403-5.2.

**c. Outliers.** Check for outliers in accordance with ASTM E178, at a significance level of 5%.

### CONTRACTOR QUALITY CONTROL

**403-6.1 GENERAL.** The Contractor shall perform quality control sampling, testing, and inspection during all phases of the work and shall perform them at a rate sufficient to ensure that the work conforms to the contract requirements, and at minimum test frequencies required by paragraph 403-6.3, including but not limited to:

- a.** Mix Design
- b.** Aggregate Grading
- c.** Quality of Materials
- d.** Stockpile Management
- e.** Proportioning
- f.** Mixing and Transportation
- g.** Placing and Finishing
- h.** Joints
- i.** Compaction
- j.** Personnel
- k.** Laydown plan

The Contractor shall perform quality control sampling, testing, and inspection during all phases of the work and shall perform them at a rate sufficient to ensure that the work conforms to the contract requirements, and at minimum test frequencies required by paragraph 403-6.3. As a part of the process for approving the Contractor's plan, the DEN Project Manager may require the Contractor's technician to perform testing of samples to demonstrate an acceptable level of performance.

No partial payment will be made for materials that are subject to specific quality control requirements without an approved plan.

**403-6.2 CONTRACTOR TESTING LABORATORY.** The lab shall meet the requirements of ASTM D3666 including all necessary equipment, materials, and current reference standards to comply with the specifications.

**403-6.3 QUALITY CONTROL TESTING.** The Contractor shall perform all quality control tests necessary to control the production and construction processes applicable to these specifications and as set forth in the approved Quality Control Program. The testing program shall include, but not necessarily be limited to, tests for the control of asphalt content, aggregate gradation, temperatures, aggregate moisture, field compaction, and surface smoothness. A Quality Control Testing Plan shall be developed as part of the Quality Control Program.

**a. Asphalt Content.** A minimum of two asphalt content tests shall be performed per lot in accordance with ASTM D6307 or ASTM D2172 if the correction factor in ASTM D6307 is greater than 1.0. The asphalt content for the lot will be determined by averaging the test results.

**b. Gradation.** Aggregate gradations shall be determined a minimum of twice per lot from mechanical analysis of extracted aggregate in accordance with ASTM D5444 and ASTM C136, and ASTM C117.

**c. Moisture Content of Aggregate.** The moisture content of aggregate used for production shall be determined a minimum of once per lot in accordance with ASTM C566.

**d. Moisture Content of HMA.** The moisture content of the HMA shall be determined once per lot in accordance with ASTM D1461 or CDOT Procedure CP43.

**e. Temperatures.** Temperatures shall be checked, at least four times per lot, at necessary locations to determine the temperatures of the dryer, the asphalt binder in the storage tank, the HMA at the plant, and the HMA at the job site.

**f. In-Place Density Monitoring.** The Contractor shall conduct any necessary testing to ensure that the specified density is being achieved. A nuclear gauge may be used to monitor the pavement density in accordance with ASTM D2950.

**g. Additional Testing.** Any additional testing that the Contractor deems necessary to control the process may be performed at the Contractor's option.

**h. Monitoring.** The DEN Project Manager reserves the right to monitor any or all of the above testing.

**403-6.4 SAMPLING.** When directed by the DEN Project Manager, the Contractor shall sample and test any material that appears inconsistent with similar material being sampled, unless such material is voluntarily removed and replaced or deficiencies corrected by the Contractor. All sampling shall be in accordance with standard procedures specified.

**403-6.5 CONTROL CHARTS.** The Contractor shall maintain linear control charts both for individual measurements and range (i.e., difference between highest and lowest measurements) for aggregate gradation, asphalt content, and VMA. The VMA for each subplot will be calculated and monitored by the Quality Control laboratory.

Control charts shall be posted in a location satisfactory to the DEN Project Manager and shall be kept current. As a minimum, the control charts shall identify the project number, the contract item number, the test number, each test parameter, the Action and Suspension Limits applicable to each test parameter, and the Contractor’s test results. The Contractor shall use the control charts as part of a process control system for identifying potential problems and assignable causes before they occur. If the Contractor’s projected data during production indicates a problem and the Contractor is not taking satisfactory corrective action, the DEN Project Manager may suspend production or acceptance of the material.

**a. Individual Measurements.** Control charts for individual measurements shall be established to maintain process control within tolerance for aggregate gradation, asphalt content, and VMA. The control charts shall use the JMF target values as indicators of central tendency for the following test parameters with associated Action and Suspension Limits:

<b>Control Chart Limits For Individual Measurements</b>		
<b>Sieve</b>	<b>Action Limit</b>	<b>Suspension Limit</b>
3/4 inch (19 mm)	±6%	±9%
1/2 inch (12 mm)	±6%	±9%
3/8 inch (9 mm)	±6%	±9%
No. 4 (4.75 mm)	±6%	±9%
No. 16 (1.18 mm)	±5%	±7.5%
No. 50 (0.30 mm)	±3%	±4.5%
No. 200 (0.075 mm)	±2%	±3%
Asphalt Content	±0.45%	±0.70%
VMA	-1.00%	-1.5%

**b. Range.** Control charts for range shall be established to control process variability for the test parameters and Suspension Limits listed below. The range shall be computed for each lot as the difference between the two test results for each control parameter. The Suspension Limits specified below are based on a sample size of n = 2. Should the Contractor elect to perform more than two tests per lot, the Suspension Limits shall be adjusted by multiplying the Suspension Limit by 1.18 for n = 3 and by 1.27 for n = 4.

<b>Control Chart Limits Based On Range</b> <b>(Based On n = 2)</b>	
<b>Sieve</b>	<b>Suspension Limit</b>
1/2 inch (12 mm)	11%
3/8 inch (9 mm)	11%
No. 4 (4.75 mm)	11%
No. 16 (1.18 mm)	9%
No. 50 (0.30 mm)	6%
No. 200 (0.075 mm)	3.5%
Asphalt Content	0.8%

c. **Corrective Action.** The Contractor Quality Control Program shall indicate that appropriate action shall be taken when the process is believed to be out of tolerance. The Plan shall contain sets of rules to gauge when a process is out of control and detail what action will be taken to bring the process into control. As a minimum, a process shall be deemed out of control and production stopped and corrective action taken, if:

(1) One point falls outside the Suspension Limit line for individual measurements or range; or

(2) Two points in a row fall outside the Action Limit line for individual measurements.

**403-6.6 QUALITY CONTROL REPORTS.** The Contractor shall maintain records and shall submit reports of quality control activities daily, in accordance with the Contractor Quality Control Program.

**403-6.7 QUALITY CONTROL/QUALITY ASSURANCE TESTING SUMMARY.** Unless stated otherwise, all testing is conducted by the Contractor. All necessary field and laboratory testing shall be considered incidental to the work and no additional payment will be made.

The following table summarizes the testing required in this specification. The information included in this table does not waive any requirements listed previously in the specification. All test results shall be provided to the DEN Project Manager within 48 hours of completion of the tests.

**Table 6  
 P-403 TESTING SUMMARY**

<b>Specification Reference</b>	<b>Test Type</b>	<b>Test Standard</b>	<b>Minimum Testing Frequency</b>	<b>Responsible Party</b>
2.1a & 2.4a	Coarse Aggregate – Material Properties and Quality	ASTM C131, ASTM C88, ASTM C142, Fractured Faces, ASTM D4791, ASTM C29	For each job mix formula approval	Contractor
2.1b & 2.4b	Fine Aggregate – Material Properties and Quality	ASTM D4318, ASTM C88, ASTM C142, ASTM D2419	For each job mix formula approval	Contractor
2.1b & 2.4b	Natural Sand – Material Properties and Quality	ASTM D1073, ASTM D4318	For each job mix formula approval (if applicable)	Contractor
2.2 & 2.4c	Mineral Filler - Material Properties and Quality	ASTM D242	For each job mix formula approval (if applicable)	Contractor
2.3 & 2.4d	Asphalt Cement Binder	ASTM D6373, ASTM D6084	For each job mix formula, and each load delivered to project	Contractor
3.2 & 3.5	Job Mix Formula	Various	For each job mix formula approval	Contractor
3.5	Test Section	Various	Approved section prior to start of full production paving	Contractor
Marshall: 5.1a(2) & 5.2b(2)	Stability and Flow	ASTM D6927	One per subplot	DEN Project Manager

**Table 6**  
**P-403 TESTING SUMMARY**

<b>Specification Reference</b>	<b>Test Type</b>	<b>Test Standard</b>	<b>Minimum Testing Frequency</b>	<b>Responsible Party</b>
5.1a(2) & 5.2b(1)	Air Voids	ASTM D3203	One per subplot	DEN Project Manager
5.1a(2) & 5.1b(4)	Bulk Specific Gravity	ASTM D2726 or ASTM D6752	One per subplot	DEN Project Manager
5.1a(2)	Theoretical Maximum Specific Gravity	ASTM D2041	One per subplot	DEN Project Manager
5.1b(1) & 5.2b(1)	Mat Density	ASTM D2726	One per subplot	DEN Project Manager
5.1b(2) & 5.2b(3)	Joint Density	ASTM D2726	One per subplot	DEN Project Manager
5.2b(3)	Thickness	Not less than ¼ inch deficient from indicated lift thickness, average lift thickness or combined lifts not less than indicated thickness (within grade tolerance)	One per subplot (mat density core)	DEN Project Manager
5.2b(4)	Grade	Less than 0.04 feet	At spot elevations shown on the Paving Plans	Contractor
6.3a	Asphalt Content	ASTM D6307 or ASTM D2172	Two per lot	Contractor
6.3b	Gradation	ASTM D5444, ASTM C136, and ASTM C117	Two per lot	Contractor
6.3c	Moisture Content of Aggregates	ASTM C566	One per lot	Contractor

<b>Table 6 P-403 TESTING SUMMARY</b>				
<b>Specification Reference</b>	<b>Test Type</b>	<b>Test Standard</b>	<b>Minimum Testing Frequency</b>	<b>Responsible Party</b>
6.3d	Moisture Content of HMA	ASTM D1461, CP43	One per lot	Contractor
6.3e	Temperature	6.3e	Four tests per lot	Contractor
6.3f	In-Place Density Monitoring (mat and joint)	ASTM D2950	As needed for QC monitoring	Contractor
6.5	Voids in the Mineral Aggregate (VMA)	-	One per subplot	Contractor

### **BASIS OF PAYMENT**

No measurement for payment is associated with this specification section. Payment will be made under specification section 31 23 23 Backfill and Surface Restoration.

### **TESTING REQUIREMENTS**

AASHTO M156	Standard Specification for Requirements for Mixing Plants for Hot-Mixed, Hot-Laid Bituminous Paving Mixtures
ASTM C29	Standard Test Method for Bulk Density (“Unit Weight”) and Voids in Aggregate
ASTM C88	Standard Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate
ASTM C117	Standard Test Method for Materials Finer than 75- $\mu$ m (No. 200) Sieve in Mineral Aggregates by Washing
ASTM C127	Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate



ASTM C131	Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
ASTM C136	Standard Test Method for Sieve or Screen Analysis of Fine and Coarse Aggregates
ASTM C183	Standard Practice for Sampling and the Amount of Testing of Hydraulic Cement
ASTM C566	Standard Test Method for Total Evaporable Moisture Content of Aggregate by Drying
ASTM D75	Standard Practice for Sampling Aggregates
ASTM D979	Standard Practice for Sampling Bituminous Paving Mixtures
ASTM D1073	Standard Specification for Fine Aggregate for Bituminous Paving Mixtures
ASTM D1074	Standard Test Method for Compressive Strength of Bituminous Mixtures
ASTM D1461	Standard Test Method for Moisture or Volatile Distillates in Bituminous Paving Mixtures
ASTM D2041	Standard Test Method for Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures
ASTM D2172	Standard Test Method for Quantitative Extraction of Bitumen from Bituminous Paving Mixtures
ASTM D2419	Standard Test Method for Sand Equivalent Value of Soils and Fine Aggregate
ASTM D2489	Standard Practice for Estimating Degree of Particle Coating of Bituminous-Aggregate Mixtures
ASTM D2726	Standard Test Method for Bulk Specific Gravity and Density of Non-Absorptive Compacted Bituminous Mixtures
ASTM D2950	Standard Test Method for Density of Bituminous Concrete in Place by Nuclear Methods
ASTM D3203	Standard Test Method for Percent Air Voids in Compacted Dense and Open Bituminous Paving Mixtures
ASTM D3665	Standard Practice for Random Sampling of Construction Materials
ASTM D3666	Standard Specification for Minimum Requirements for Agencies Testing and Inspecting Road and Paving Materials
ASTM D4125	Standard Test Methods for Asphalt Content of Bituminous mixtures by the Nuclear Method

ASTM D4318	Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
ASTM D4791	Standard Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate
ASTM D4867	Standard Test Method for Effect of Moisture on Asphalt Concrete Paving Mixtures
ASTM D5444	Standard Test Method for Mechanical Size Analysis of Extracted Aggregate
ASTM D5581	Standard Test Method for Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus (6 inch-Diameter Specimen)
ASTM D6307	Standard Test Method for Asphalt Content of Hot-Mix Asphalt by Ignition Method
ASTM D6926	Standard Practice for Preparation of Bituminous Specimens Using Marshall Apparatus
ASTM D6927	Standard Test Method for Marshall Stability and Flow of Bituminous Mixtures
ASTM D6752	Standard Test Method for Bulk Specific Gravity and Density of Compacted Bituminous Mixtures Using Automatic Vacuum Sealing Method
ASTM D7227	Standard Practice for Rapid Drying of Compacted Asphalt Specimens Using Vacuum Drying Apparatus
ASTM E11	Standard Specification for Woven Wire Test Sieve Cloth and Test Sieves
ASTM E178	Standard Practice for Dealing with Outlying Observations
AASHTO T030	Standard Method of Test for Mechanical Analysis of Extracted Aggregate
AASHTO T110	Standard Method of Test for Moisture or Volatile Distillates in Hot Mix Asphalt (HMA)
AASHTO T275	Standard Method of Test for Bulk Specific Gravity (Gmb) of Compacted Hot Mix Asphalt (HMA) Using Paraffin-Coated Specimens).
Asphalt Institute Handbook MS-26	Asphalt Binder
Asphalt Institute MS-2 Mix Design Manual, 7th Edition	
CDOT CP43	Colorado Department of Transportation Procedure for Determining Moisture (Water) or Volatile Distillates Content of HMA

## MATERIAL REQUIREMENTS

ASTM D242	Standard Specification for Mineral Filler for Bituminous Paving Mixtures
ASTM D946	Standard Specification for Penetration-Graded Asphalt Cement for Use in Pavement Construction
ASTM D3381	Standard Specification for Viscosity-Graded Asphalt Cement for Use in Pavement Construction
ASTM D4552	Standard Practice for Classifying Hot-Mix Recycling Agents
ASTM D6373	Standard Specification for Performance Graded Asphalt Binder

**END OF ITEM P-403**

## ITEM P-501 PORTLAND CEMENT CONCRETE (PCC) PAVEMENT

### DESCRIPTION

**501-1.1** The work set forth in this section consists of the Contractor's preparation and submittal of an appropriate concrete mix design, discussion of appropriate equipment for use by the Contractor and the placement of pavement composed of portland cement concrete, with reinforcement and without reinforcement constructed on a prepared underlying surface in accordance with these specifications and shall conform to the lines, grades, thickness, and typical cross- sections shown on the plans.

Section headings used in this Section P-501 or any other part of this Contract are for convenience only and shall not be used in the interpretation of this Section P-501 or any other section or subsection of this Contract so as to indicate that phrases or clauses describing standards, tests, equipment, workmanship, material descriptions, characteristics or results to be achieved are confined to the Section heading under which they appear. Any requirement appearing in one location shall be as binding as if appearing in all. It is the intention of this contract that the work will result in an end concrete product which is dense, homogeneous, without segregation.

### MATERIALS

#### 501-2.1 AGGREGATES.

**a. Reactivity.** The laboratory performing the tests shall be accredited in accordance with ASTM C1077. The laboratory accreditation must be current and listed on the accrediting authority's website. Test method ASTM C1260 must be listed on the lab accreditation. A copy of the laboratory's current accreditation and accredited test methods shall be submitted to the DEN Project Manager prior to start of construction. Fine and Coarse aggregates to be used in all concrete shall be evaluated and tested by the Contractor for alkali-aggregate reactivity in accordance with both ASTM C1260 and ASTM C1567. Aggregate and mix proportion reactivity tests shall be performed for each project.

(1) Coarse and fine aggregate shall be tested separately in accordance with ASTM C1260. The aggregate shall be considered innocuous if the expansion of test specimens, tested in accordance with ASTM C1260, does not exceed 0.10% at 28 days (30 days from casting).

(2) Combined coarse and fine aggregate shall be tested in accordance with ASTM C1567, modified for combined aggregates, using the proposed mixture design proportions of aggregates, cementitious materials, and/or specific reactivity reducing chemicals. If lithium nitrate is proposed for use with or without supplementary cementitious materials, the aggregates shall be tested in accordance with Corps of Engineers (COE)

Concrete Research Division (CRD) C662. If lithium nitrate admixture is used, it shall be nominal 30%  $\pm$ 0.5% weight lithium nitrate in water.

(3) If the expansion of the proposed combined materials test specimens, tested in accordance with ASTM C1567, modified for combined aggregates, or COE CRD C662, does not exceed 0.10% at 28 days, the proposed combined materials will be accepted. If the expansion of the proposed combined materials test specimens is greater than 0.10% at 28 days, the aggregates will not be accepted unless adjustments to the combined materials mixture can reduce the expansion to less than 0.10% at 28 days, or new aggregates shall be evaluated and tested.

b. **Fine Aggregate.** Fine aggregate shall conform to the requirements of ASTM C33. Grading of the fine aggregate, as delivered to the mixer, shall conform to the requirements of ASTM C33 and shall have a fineness modulus of not less than 2.50 nor more than 3.40. The soundness loss shall not exceed 10% when sodium sulfate is used or 15% when magnesium sulfate is used, after five cycles, when tested per ASTM C88.

The amount of deleterious material in the fine aggregate shall not exceed the following limits:

**Limits for Deleterious Substances in Fine Aggregate for Concrete**

<b>Deleterious material</b>	<b>ASTM</b>	<b>Percentage by Mass</b>
Clay Lumps and friable particles	ASTM C142	1.0
Material finer than 0.075mm (No. 200 sieve)	ASTM C117	3.0
Lightweight particles	ASTM C123 using a medium with a density of Sp. Gr. of 2.0	0.5
Total of all deleterious Material		3.0

c. **Coarse Aggregate.** Gradation, within the separated size groups, shall meet the coarse aggregate grading requirements of ASTM C33 when tested in accordance with ASTM C136. When the nominal maximum size of the aggregate is greater than one inch, the aggregates shall be furnished in two size groups.

Aggregates delivered to the mixer shall consist of crushed stone, crushed or uncrushed gravel, air-cooled iron blast furnace slag, crushed recycled concrete pavement, or a combination. The aggregates should be free of ferrous sulfides, such as pyrite, that would cause “rust” staining that can bleed through pavement markings. Steel blast furnace slag shall not be permitted. The aggregate shall be composed of clean, hard, uncoated particles. Dust and other coating shall be removed from the aggregates by washing.

The percentage of wear shall be no more than 40 when tested in accordance with ASTM C131.

The quantity of flat, elongated, and flat and elongated particles in any size group coarser than 3/8 sieve (9 mm) shall not exceed 8% by weight when tested in accordance with ASTM D4791. A flat particle is defined as one having a ratio of width to thickness greater than 5. An elongated particle is one having a ratio of length to width greater than 5.

The soundness loss shall not exceed 12% when sodium sulfate is used or 18% when magnesium sulfate is used, after five cycles, when tested per ASTM C88.

The amount of deleterious material in the coarse aggregate shall not exceed the following limits:

**Limits for Deleterious Substances in Coarse Aggregate for Concrete**

<b>Deleterious Material</b>	<b>ASTM/COE</b>	<b>Percentage by Mass</b>
Clay lumps and friable particles	ASTM C142	0.2
Shale (a.)	ASTM C295	0.1
Material finer than No. 200 (0.075 mm) sieve (b.)	ASTM C117	0.5
Lightweight particles (c.)	ASTM C123	0.2
Clay ironstone (d.)	ASTM C295	0.1
Chert and cherty stone (less than 2.40 Mg/cubic meter density SSD (2.40 Sp. Gr.)) (e.)	ASTM C123 followed by ASTM C295	0.1
Claystone, mudstone, and siltstone (f.)	ASTM C295	0.1
Shaly and argillaceous limestone (g.)	ASTM C295	0.2
Other soft particles	COE CRD-C 130	1.0
Total of all deleterious substances exclusive of material finer than 0.075 mm (No. 200 sieve)		1.0

a. Shale is defined as a fine-grained, thinly laminated or fissile sedimentary rock. It is commonly composed of clay or silt or both. It has been indurated by compaction or by cementation, but not so much as to have become slate.

b. Limit for material finer than 0.075 mm (No. 200 sieve) will be increased to 1.5 percent for crushed aggregates if the fine material consists of crusher dust that is essentially free from clay or shale.

c. The separation medium shall have a density of 2.0 Mg/cubic meter (Sp. Gr. of 2.0). This limit does not apply to coarse aggregate manufactured from blast-furnace slag unless contamination is evident.

d. Clay ironstone is defined as an impure variety of iron carbonate, iron oxide, hydrous iron oxide, or combinations thereof, commonly mixed with clay, silt, or sand. It commonly occurs as dull, earthy particles, homogeneous concretionary masses, or hard-shell particles with soft interiors. Other names commonly used for clay ironstone are "chocolate bars" and limonite concretions.

e. Chert is defined as a rock composed of quartz, chalcedony or opal, or any mixture of these forms of silica. It is variable in color. The texture is so fine that the individual mineral grains are too small to be distinguished by the unaided eye. Its hardness is such that it scratches glass but is not scratched by a knife blade. It may contain impurities such as clay, carbonates, iron oxides, and other minerals. Cherty stone is defined as any type of rock (generally limestone) that contains chert as lenses and nodules, or irregular masses partially or completely replacing the original stone.

f. Claystone, mudstone, or siltstone, is defined as a massive fine-grained sedimentary rock that consists predominantly of indurated clay or silt without laminations or fissility. It may be indurated either by compaction or by cementation.

g. Shaly limestone is defined as limestone in which shale occurs as one or more thin beds or laminae. These laminae may be regular or very irregular and may be spaced from a few inches down to minute fractions of an inch. Argillaceous limestone is defined as a limestone in which clay minerals occur disseminated in the stone in the amount of 10 to 50 percent by weight of the rock; when these make up from 50 to 90 percent, the rock is known as calcareous (or dolomitic) shale (or claystone, mudstone, or siltstone).

**Table 1. Gradation For Coarse Aggregate  
 (ASTM C33)**

Sieve Designations (square openings)		Percentage by Weight Passing Sieves	
inch	mm		
2-1/2	60	---	---
2	50	100	---
1-1/2	38	90-100	---
1	25	20-55	100
3/4	19	0-15	90-100
1/2	13	---	---
3/8	9	0-5	20-55
No. 4	4.75	---	0-10
No. 8	2.36	---	0-5

(1) **Aggregate Susceptibility to Durability (D) Cracking.** Aggregates that have a history of D-cracking shall not be used.

Coarse aggregate may be accepted from sources that have a 20 year service history for the same gradation to be supplied with no durability issues. Aggregates that do not have a record of 20 years of service without major repairs (less than 5% of slabs replaced) in similar conditions without D-cracking shall not be used unless it meets the following:

(a) Material currently being produced shall have a durability factor  $\geq 95$  using ASTM C666 procedure B. Coarse aggregates that are crushed granite, calcite cemented sandstone, quartzite, basalt, diabase, rhyolite or trap rock are considered to meet the D-cracking test but must meet all other quality tests. Aggregates meeting State Highway Department material specifications may be acceptable.

(b) The Contractor shall submit a current certification that the aggregate does not have a history of D-cracking and that the aggregate meets the state specifications for use in PCC pavement for use on interstate highways. Certifications, tests and any history reports must be for the same gradation as being proposed for use on the project. Certifications which are not dated or which are over one (1) year old or which are for different gradations will not be accepted. Test results will only be accepted when tests were performed by a State Department of Transportation (DOT) materials laboratory or an accredited laboratory.

(2) **Combined Aggregate Gradation.** If substituted for the grading requirements specified for coarse aggregate and for fine aggregate and when approved by the DEN Project Manager, the combined aggregate grading shall meet the following requirements:

(a) The materials selected and the proportions used shall be such that when the Coarseness Factor (CF) and the Workability Factor (WF) are plotted on a diagram as described in d. below, the point thus determined shall fall within the parallelogram described therein.

(b) The CF shall be determined from the following equation:

$$CF = (\text{cumulative percent retained on the } 3/8 \text{ in. sieve})(100) / (\text{cumulative percent retained on the No. 8 sieve})$$

(c) The Workability Factor WF is defined as the percent passing the No. 8 (2.36 mm) sieve based on the combined gradation. However, WF shall be adjusted, upwards only, by 2.5 percentage points for each 94 pounds (42 kg) of cementitious material per cubic meter yard greater than 564 pounds per cubic yard (335 kg per cubic meter).

(d) A diagram shall be plotted using a rectangular scale with WF on the Y-axis with units from 20 (bottom) to 45 (top), and with CF on the X-axis with units from 80 (left side) to 30 (right side). On this diagram a parallelogram shall be plotted with corners at the following coordinates (CF-75, WF-28), (CF-75, WF-40), (CF-45, WF-32.5),



and (CF-45, WF-44.5). If the point determined by the intersection of the computed CF and WF does not fall within the above parallelogram, the grading of each size of aggregate used and the proportions selected shall be changed as necessary.

**501-2.2 CEMENT.** Cement shall conform to the requirements of ASTM C 150 Type V.

If cement becomes partially set or contains lumps of caked cement, it shall be rejected. Cement salvaged from discarded or used bags shall not be used.

**501-2.3 CEMENTITIOUS MATERIALS.**

**a. Fly Ash.** Fly ash shall meet the requirements of ASTM C618, with the exception of loss of ignition, where the maximum shall be less than 6%. Fly ash for use in mitigating alkali-silica reactivity shall have a Calcium Oxide (CaO) content of less than 13% and a total available alkali content less than 3% per ASTM C311. Fly ash produced in furnace operations using liming materials or soda ash (sodium carbonate) as an additive shall not be acceptable. The Contractor shall furnish the previous three most recent, consecutive ASTM C618 reports for each source of fly ash proposed in the mix design, and shall furnish each additional report as they become available during the project. The reports can be used for acceptance or the material may be tested independently by the DEN Project Manager.

**b. Slag Cement (Ground Granulated Blast Furnace(GGBF)).** Slag cement shall conform to ASTM C989, Grade 100 or Grade 120. Slag cement shall be used only at a rate between 25% and 55% of the total cementitious material by mass.

**c. Raw or Calcined Natural Pozzolan.** Natural pozzolan shall be raw or calcined and conform to ASTM C618, Class N, including the optional requirements for uniformity and effectiveness in controlling Alkali-Silica reaction and shall have a loss on ignition not exceeding 6%. Class N pozzolan for use in mitigating Alkali-Silica Reactivity shall have a total available alkali content less than 3%.

**501-2.4 JOINT SEAL.** The joint seal for the joints in the concrete pavement shall meet the requirements of Item P-604A, Item P-604B, or Item P-605 and shall be of the type specified in the plans.

**501-2.5 ISOLATION JOINT FILLER.** Premolded joint filler for isolation joints shall conform to the requirements of ASTM D1751 and shall be where shown on the plans. The filler for each joint shall be furnished in a single piece for the full depth and width required for the joint, unless otherwise specified by the DEN Project Manager. When the use of more than one piece is required for a joint, the abutting ends shall be fastened securely and held accurately to shape by stapling or other positive fastening means satisfactory to the DEN Project Manager.

**501-2.6 STEEL REINFORCEMENT.** Reinforcing shall consist of bar mats conforming to the requirements of ASTM A184.

**501-2.7 DOWEL AND TIE BARS.** Dowel bars shall be plain steel bars conforming to ASTM A615 and shall be free from burring or other deformation restricting slippage in the concrete. Before delivery to the construction site each dowel bar shall be epoxy coated per ASTM A1078. The dowels shall be coated with a bond-breaker recommended by the manufacturer. Grout retention rings shall be fully circular metal or plastic devices capable of supporting the dowel until the grout hardens.

Tie bars shall be deformed steel bars and conform to the requirements of ASTM A615. Tie bars designated as Grade 60 in ASTM A615 or ASTM A706 shall be used for construction requiring bent bars. Dowel assemblies, tie bars and other miscellaneous steel embedded in the concrete should be epoxy coated according to ASTM A1078.

**501-2.8 WATER.** Water used in mixing or curing shall be potable, clean, free of oil, salt, acid, alkali, sugar, vegetable, or other substances injurious to the finished product, except that non-potable water, or water from concrete production operations, may be used if it meets the requirements of ASTM C1602.

**501-2.9 MATERIAL FOR CURING CONCRETE.** Curing materials shall conform to one of the following specifications:

- a. Liquid membrane-forming compounds for curing concrete shall conform to the requirements of ASTM C309, Type 2, Class B, or Class A if wax base only.
- b. White polyethylene film for curing concrete shall conform to the requirements of ASTM C171.
- c. White burlap-polyethylene sheeting for curing concrete shall conform to the requirements of ASTM C171.
- d. Waterproof paper for curing concrete shall conform to the requirements of ASTM C171.

**501-2.10 ADMIXTURES.** The Contractor shall submit certificates indicating that the material to be furnished meets all of the requirements indicated below. In addition, the DEN Project Manager may require the Contractor to submit complete test data from an approved laboratory showing that the material to be furnished meets all of the requirements of the cited specifications. Subsequent tests may be made of samples taken by the DEN Project Manager from the supply of the material being furnished or proposed for use on the work to determine whether the admixture is uniform in quality with that approved.

a. **Air-Entraining Admixtures.** Air-entraining admixtures shall meet the requirements of ASTM C260 and shall consistently entrain the air content in the specified ranges under field conditions. The air-entrainment agent and any water reducer admixture shall be compatible.

**b. Water-Reducing Admixtures.** Water-reducing admixture shall meet the requirements of ASTM C494, Type A, B, or D. ASTM C494, Type F and G high range water reducing admixtures and ASTM C1017 flowable admixtures shall not be used.

**c. Other Admixtures.** The use of set retarding, and set-accelerating admixtures shall be approved by the DEN Project Manager. Retarding shall meet the requirements of ASTM C494, Type A, B, or D and set-accelerating shall meet the requirements of ASTM C494, Type C. Calcium chloride and admixtures containing calcium chloride shall not be used.

**d. Lithium Nitrate.** The lithium admixture shall be a nominal 30% aqueous solution of Lithium Nitrate, with a density of 10 pounds/gallon (1.2 kg/L), and shall have the approximate chemical form as shown below:

Constituent	Limit (Percent by Mass)
LiNO <sub>3</sub> (Lithium Nitrate)	30 ±0.5
SO <sub>4</sub> (Sulfate Ion)	0.1 (max)
Cl (Chloride Ion)	0.2 (max)
Na (Sodium Ion)	0.1 (max)
K (Potassium Ion)	0.1 (max)

Provide a trained manufacturer's representative to supervise the lithium nitrate admixture dispensing and mixing operations.

**501-2.11 EPOXY-RESIN.** All epoxy-resin materials shall be two-component materials conforming to the requirements of ASTM C881, Class as appropriate for each application temperature to be encountered, except that in addition, the materials shall meet the following requirements:

- a.** Material for use for embedding dowels and anchor bolts shall be Type IV, Grade 3.
- b.** Material for use as patching materials for complete filling of spalls and other voids and for use in preparing epoxy resin mortar shall be Type III, Grade as approved.
- c.** Material for use for injecting cracks shall be Type IV, Grade 1.
- d.** Material for bonding freshly mixed Portland cement concrete or mortar or freshly mixed epoxy resin concrete or mortar to hardened concrete shall be Type V, Grade as approved.

**501-2.12 MATERIAL ACCEPTANCE.** Prior to use of materials, the Contractor shall submit certified test reports to the DEN Project Manager for those materials proposed for use

during construction. The certification shall show the appropriate ASTM test for each material, the test results, and a statement that the material passed or failed.

The DEN Project Manager may request samples for testing, prior to and during production, to verify the quality of the materials and to ensure conformance with the applicable specifications.

### MIX DESIGN

**501-3.1 GENERAL.** No concrete shall be placed until the mix design has been submitted to the DEN Project Manager for review and the DEN Project Manager has taken appropriate action. The DEN Project Manager’s review shall not relieve the Contractor of the responsibility to select and proportion the materials to comply with this section.

**501-3.2 PROPORTIONS.** The laboratory preparing the mix design shall be accredited in accordance with ASTM C1077. The mix design for all Portland cement concrete placed under P-501 shall be stamped or sealed by the responsible professional Engineer of the laboratory. Concrete shall be proportioned to achieve a 28-day flexural strength that meets or exceeds the acceptance criteria contained in paragraph 501-5.2 for a flexural strength of 700 psi per ASTM C78. The mix shall be developed using the procedures contained in the Portland Cement Association’s (PCA) publication, “Design and Control of Concrete Mixtures”.

The minimum cementitious material shall be adequate to ensure a workable, durable mix. The minimum cementitious material (cement plus fly ash, or slag cement) shall be 517 pounds per cubic yard. The ratio of water to cementitious material, including free surface moisture on the aggregates but not including moisture absorbed by the aggregates shall not be more than 0.45 by weight.

Flexural strength test specimens shall be prepared in accordance with ASTM C192 and tested in accordance with ASTM C78. The mix determined shall be workable concrete having a maximum allowable slump between one and two inches as determined by ASTM C143. For slip-form concrete, the slump shall be between 1/2 inch and 1-1/2 inch. At the start of the project, the Contractor shall determine a maximum allowable slump for slip-form pavement which will produce in-place pavement to control the edge slump. The selected slump shall be applicable to both pilot and fill-in lanes.

Before the start of paving operations and after approval of all material to be used in the concrete, the Contractor shall submit a mix design showing the proportions and flexural strength obtained from the concrete at seven (7) and 28 days. The mix design shall include copies of test reports, including test dates, and a complete list of materials including type, brand, source, and amount of cement, fly ash, ground slag, coarse aggregate, fine aggregate, water, and admixtures. The mix design shall be submitted to the DEN Project Manager at least 30 days prior to the start of operations. The submitted mix design shall not be more than 90 days old. Production shall not begin until the mix design is approved in writing by the DEN Project Manager.

If a change in sources is made, or admixtures added or deleted from the mix, a new mix design must be submitted to the DEN Project Manager for approval.

The results of the mix design shall include a statement giving the maximum nominal coarse aggregate size and the weights and volumes of each ingredient proportioned on a one cubic yard basis. Aggregate quantities shall be based on the mass in a saturated surface dry condition. The recommended mixture proportions shall be accompanied by test results demonstrating that the proportions selected will produce concrete of the qualities indicated. Trial mixtures having proportions, slumps, and air content suitable for the work shall be based on methodology described in PCA's publication, Design and Control of Concrete Mixtures, modified as necessary to accommodate flexural strength.

The submitted mix design shall be stamped or sealed by the responsible professional Engineer of the laboratory and shall include the following items as a minimum:

- a. Coarse, fine, and combined aggregate gradations and plots including fineness modulus of the fine aggregate.
- b. Reactivity Test Results.
- c. Coarse aggregate quality test results, including deleterious materials.
- d. Fine aggregate quality test results, including deleterious materials.
- e. Mill certificates for cement and supplemental cementitious materials.
- f. Certified test results for all admixtures, including Lithium Nitrate if applicable.
- g. Specified flexural strength, slump, and air content.
- h. Recommended proportions/volumes for proposed mixture and trial water-cementitious materials ratio, including actual slump and air content.
- i. Flexural and compressive strength summaries and plots, including all individual beam and cylinder breaks.
- j. Correlation ratios for acceptance testing and Contractor Quality Control testing, when applicable.
- k. Historical record of test results documenting production standard deviation, when applicable.

### **501-3.3 CEMENTITIOUS MATERIALS.**

a. **Fly Ash.** When fly ash is used as a partial replacement for cement, the replacement rate shall be determined from laboratory trial mixes, and shall be between 20 and 30% by weight of the total cementitious material. If fly ash is used in conjunction with

slag cement the maximum replacement rate shall not exceed 10% by weight of total cementitious material.

**b. Slag Cement Ground Granulated Blast Furnace (GGBF).** Slag cement may be used. The slag cement, or slag cement plus fly ash if both are used, may constitute between 25 to 55% of the total cementitious material by weight. If the concrete is to be used for slipforming operations and the air temperature is expected to be lower than 55°F the percent slag cement shall not exceed 30% by weight.

**c. Raw or Calcined Natural Pozzolan.** Natural pozzolan may be used in the mix design. When pozzolan is used as a partial replacement for cement, the replacement rate shall be determined from laboratory trial mixes, and shall be between 20 and 30% by weight of the total cementitious material. If pozzolan is used in conjunction with slag cement the maximum replacement rate shall not exceed 10% by weight of total cementitious material.

#### **501-3.4 ADMIXTURES.**

**a. Air-Entraining Admixtures.** Air-entraining admixture are to be added in such a manner that will ensure uniform distribution of the agent throughout the batch. The air content of freshly mixed air-entrained concrete shall be based upon trial mixes with the materials to be used in the work adjusted to produce concrete of the required plasticity and workability. The percentage of air in the mix shall be 5.5%. Air content shall be determined by testing in accordance with ASTM C231 for gravel and stone coarse aggregate and ASTM C173 for slag and other highly porous coarse aggregate.

**b. Water-Reducing Admixtures.** Water-reducing admixtures shall be added to the mix in the manner recommended by the manufacturer and in the amount necessary to comply with the specification requirements. Tests shall be conducted on trial mixes, with the materials to be used in the work, in accordance with ASTM C494.

**c. Other Admixtures.** Set controlling, and other approved admixtures shall be added to the mix in the manner recommended by the manufacturer and in the amount necessary to comply with the specification requirements. Tests shall be conducted on trial mixes, with the materials to be used in the work, in accordance with ASTM C 494.

**d. Lithium Nitrate.** Lithium nitrate shall be added to the mix in the manner recommended by the manufacturer and in the amount necessary to comply with the specification requirements in accordance with paragraph 501-2.10d.

**501-3.5 CONCRETE MIX DESIGN LABORATORY.** The Contractor's laboratory used to develop the concrete mix design shall be accredited in accordance with ASTM C1077. The laboratory accreditation must be current and listed on the accrediting authority's website. All test methods required for developing the concrete mix design must be listed on the lab accreditation. A copy of the laboratory's current accreditation and accredited test methods shall be submitted to the DEN Project Manager prior to start of construction.

### **CONSTRUCTION METHODS**

**501-4.1 EQUIPMENT.** Equipment necessary for handling materials and performing all parts of the work shall be approved by the DEN Project Manager, but does not relieve the Contractor of the responsibility for the proper operation of equipment and maintaining the equipment in good working condition. The equipment shall be at the jobsite sufficiently ahead of the start of paving operations to be examined thoroughly and approved.

**a. Batch Plant and Equipment.** The batch plant and equipment shall conform to the requirements of ASTM C94.

**b. Mixers and Transportation Equipment.**

**(1) General.** Concrete may be mixed at a central plant, or wholly or in part in truck mixers. Each mixer shall have attached in a prominent place a manufacturer's nameplate showing the capacity of the drum in terms of volume of mixed concrete and the speed of rotation of the mixing drum or blades.

**(2) Central Plant Mixer.** Central plant mixers shall conform to the requirements of ASTM C94. The mixer shall be examined daily for changes in condition due to accumulation of hard concrete or mortar or wear of blades. The pickup and throwover blades shall be replaced when they have worn down 3/4 inch (19 mm) or more. The Contractor shall have a copy of the manufacturer's design on hand showing dimensions and arrangement of blades in reference to original height and depth.

**(3) Truck Mixers and Truck Agitators.** Truck mixers used for mixing and hauling concrete and truck agitators used for hauling central-mixed concrete shall conform to the requirements of ASTM C94.

**(4) Nonagitator Trucks.** Nonagitator hauling equipment shall conform to the requirements of ASTM C94.

**(5) Transfer and Spreading Equipment.** Equipment for transferring concrete from the transporting equipment to the paving lane in front of the paver shall be specially manufactured, self-propelled transfer equipment which will accept the concrete outside the paving lane and will transfer and spread it evenly across the paving lane in front of the paver and strike off the surface evenly to a depth which permits the paver to operate efficiently.

**c. Finishing Equipment.** The standard method of constructing concrete pavements shall be with an approved slip-form paving equipment designed and operated to spread, consolidate, screed, and float-finish the freshly placed concrete in one complete pass of the machine so that the end result is a dense and homogeneous pavement which is achieved with a minimum of hand finishing. The paver-finisher shall be a heavy duty, self-propelled machine designed specifically for paving and finishing high quality concrete pavements. It shall weigh at least 2,800 lbs per foot of paving lane width and powered by an engine having at least 6.0 horsepower per foot of lane width. Verification of operational frequencies of all vibrators shall be documented by Quality Control personnel at the beginning of each paving shift.

On projects requiring less than 500 square yard of cement concrete pavement or requiring individual placement areas of less than 500 square yard, or irregular areas at locations inaccessible to slip-form paving equipment, concrete pavement may be placed with approved placement and finishing equipment using stationary side forms. Hand screeding and float finishing may only be used on small irregular areas as allowed by the DEN Project Manager.

**d. Vibrators.** Vibrator shall be the internal type. Operating frequency for internal vibrators shall be between 8,000 and 12,000 vibrations per minute. Average amplitude for internal vibrators shall be 0.025-0.05 inch.

The number, spacing, and frequency shall be as necessary to provide a dense and homogeneous pavement and meet the recommendations of American Concrete Institute (ACI) 309, Guide for Consolidation of Concrete. Adequate power to operate all vibrators shall be available on the paver. The vibrators shall be automatically controlled so that they shall be stopped as forward motion ceases. The Contractor shall provide an electronic or mechanical means to monitor vibrator status. The checks on vibrator status shall occur a minimum of two times per day or when requested by the DEN Project Manager.

Hand held vibrators may be used in irregular areas only, but shall meet the recommendations of ACI 309R, Guide for Consolidation of Concrete.

**e. Concrete Saws.** The Contractor shall provide sawing equipment adequate in number of units and power to complete the sawing to the required dimensions. The Contractor shall provide at least one standby saw in good working order and a supply of saw blades at the site of the work at all times during sawing operations. Early-entry saws may be used, subject to demonstration and approval of the DEN Project Manager.

**f. Side Forms.** Straight side forms shall be made of steel and shall be furnished in sections not less than 10 feet in length. Forms shall have a depth equal to the pavement thickness at the edge, and a base width at least 80% of the specified pavement thickness. Flexible or curved forms of proper radius shall be used for curves of 100-foot radius or less. Forms shall be provided with adequate devices for secure settings so that when in place they will withstand, without visible spring or settlement, the impact and vibration of the consolidating and finishing equipment. Forms with battered top surfaces and bent, twisted or broken forms shall not be used. Built-up forms shall not be used, except as approved by the DEN Project Manager. The top face of the form shall not vary from a true plane more than 1/8 inch in 10 feet, and the upstanding leg shall not vary more than 1/4 inch. The forms shall contain provisions for locking the ends of abutting sections together tightly for secure setting. Wood forms may be used under special conditions, when approved by the DEN Project Manager.

**g. Pavers.** The paver shall be fully energized, self-propelled, and designed for the specific purpose of placing, consolidating, and finishing the concrete pavement, true to grade, tolerances, and cross-section. It shall be of sufficient weight and power to construct the maximum specified concrete paving lane width as shown in the plans, at adequate forward speed, without transverse, longitudinal or vertical instability or without



displacement. The paver shall be equipped with electronic or hydraulic horizontal and vertical control devices.

**501-4.2 FORM SETTING.** Forms shall be set sufficiently in advance of the concrete placement to ensure continuous paving operation. After the forms have been set to correct grade, the underlying surface shall be thoroughly tamped, either mechanically or by hand, at both the inside and outside edges of the base of the forms. Forms shall be staked into place sufficiently to maintain the form in position for the method of placement.

Form sections shall be tightly locked and shall be free from play or movement in any direction. The forms shall not deviate from true line by more than 1/8 inch at any joint. Forms shall be so set that they will withstand, without visible spring or settlement, the impact and vibration of the consolidating and finishing equipment. Forms shall be cleaned and oiled prior to the placing of concrete.

The alignment and grade elevations of the forms shall be checked and corrections made by the Contractor immediately before placing the concrete.

**501-4.3 CONDITIONING OF UNDERLYING SURFACE.** The compacted underlying surface on which the pavement will be placed shall be widened approximately 3 feet to extend beyond the paving machine track to support the paver without any noticeable displacement. After the underlying surface has been placed and compacted to the required density, the areas that will support the paving machine and the area to be paved shall be trimmed or graded to the plan grade elevation and profile by means of a properly designed machine. The grade of the underlying surface shall be controlled by a positive grade control system using lasers, stringlines, or guide wires. If the density of the underlying surface is disturbed by the trimming operations, it shall be corrected by additional compaction and retested at the option of the DEN Project Manager before the concrete is placed except when stabilized subbases are being constructed. If damage occurs on a stabilized subbase, it shall be corrected full depth by the Contractor. If traffic is allowed to use the prepared grade, the grade shall be checked and corrected immediately before the placement of concrete. The prepared grade shall be moistened with water, without saturating, immediately ahead of concrete placement to prevent rapid loss of moisture from concrete. The underlying surface shall be protected so that it will be entirely free of frost when concrete is placed.

**501-4.4 CONDITIONING OF UNDERLYING SURFACE, SIDE-FORM AND FILL-IN LANE CONSTRUCTION.** The prepared underlying surface shall be moistened with water, without saturating, immediately ahead of concrete placement to prevent rapid loss of moisture from the concrete. Damage caused by hauling or usage of other equipment shall be corrected and retested at the option of the DEN Project Manager. If damage occurs to a stabilized subbase, it shall be corrected full depth by the Contractor. A template shall be provided and operated on the forms immediately in advance of the placing of all concrete. The template shall be propelled only by hand and not attached to a tractor or other power unit. Templates shall be adjustable so that they may be set and maintained at the correct contour of the underlying surface. The adjustment and operation of the templates shall be such as will provide an accurate retest of the grade before placing the concrete thereon. All excess material shall be removed and wasted. Low areas shall be filled and compacted to a

condition similar to that of the surrounding grade. The underlying surface shall be protected so that it will be entirely free from frost when the concrete is placed. The use of chemicals to eliminate frost in the underlying surface shall not be permitted.

Any standing water shall be completely removed from the underlying surface prior to the installation of concrete. Displacement of excess water is not permitted during the installation of concrete.

The template shall be maintained in accurate adjustment, at all times by the Contractor, and shall be checked daily.

**501-4.5 HANDLING, MEASURING, AND BATCHING MATERIAL.** The batch plant site, layout, equipment, and provisions for transporting material shall assure a continuous supply of material to the work. Stockpiles shall be constructed in such a manner that prevents segregation and intermixing of deleterious materials. Aggregates from different sources shall be stockpiled, weighed and batched separately at the concrete batch plant.

Aggregates that have become segregated or mixed with earth or foreign material shall not be used. All aggregates produced or handled by hydraulic methods, and washed aggregates, shall be stockpiled or binned for draining at least 12 hours before being batched. Rail shipments requiring more than 12 hours will be accepted as adequate binning only if the car bodies permit free drainage.

Batching plants shall be equipped to proportion aggregates and bulk cement, by weight, automatically using interlocked proportioning devices of an approved type. When bulk cement is used, the Contractor shall use a suitable method of handling the cement from weighing hopper to transporting container or into the batch itself for transportation to the mixer, such as a chute, boot, or other approved device, to prevent loss of cement. The device shall be arranged to provide positive assurance that the cement content specified is present in each batch.

A copy of the proposed batch ticket shall be submitted to the DEN Project Manager for approval. Batch tickets shall include as a minimum the information required in ASTM C 94. Two copies of the batch tickets shall also be provided to the DEN Project Manager or his representative for each batch of concrete prior to unloading at the site.

**501-4.6 MIXING CONCRETE.** The concrete may be mixed at the work site, 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 emptied into the drum. All concrete shall be mixed and delivered to the site in accordance with the requirements of ASTM C94.

Mixed concrete from the central mixing plant shall be transported in truck mixers, truck agitators, or non-agitating trucks. The elapsed time from the addition of cementitious material to the mix until the concrete is deposited in place at the work site shall not exceed 30 minutes when the concrete is hauled in non-agitating trucks, nor 90 minutes when the concrete is hauled in truck mixers or truck agitators. Retempering concrete by adding water

or by other means will not be permitted. With transit mixers additional water may be added to the batch materials and additional mixing performed to increase the slump to meet the specified requirements provided the addition of water is performed within 45 minutes after the initial mixing operations and provided the water/cementitious ratio specified in the approved mix design is not exceeded, and approved by the DEN Project Manager.

**501-4.7 LIMITATIONS ON MIXING IN PLACE.** No concrete shall be mixed, placed, or finished when the natural light is insufficient, unless an adequate and approved artificial lighting system is operated.

**a. Cold Weather.** Unless authorized in writing by the DEN Project Manager, mixing and concreting operations shall be discontinued when a descending air temperature in the shade and away from artificial heat reaches 40°F and shall not be resumed until an ascending air temperature in the shade and away from artificial heat reaches 35°F.

The aggregate shall be free of ice, snow, and frozen lumps before entering the mixer. The temperature of the mixed concrete shall not be less than 50°F at the time of placement. Concrete shall not be placed on frozen material nor shall frozen aggregates be used in the concrete.

When concreting is authorized during cold weather, water and/or the aggregates may be heated to not more than 150°F. The apparatus used shall heat the mass uniformly and shall be arranged to preclude the possible occurrence of overheated areas which might be detrimental to the materials.

**b. Hot Weather.** During periods of hot weather when the maximum daily air temperature exceeds 85°F, the following precautions shall be taken.

The forms and/or the underlying surface shall be sprinkled with water immediately before placing the concrete. The concrete shall be placed at the coolest temperature practicable, and in no case shall the temperature of the concrete when placed exceed 90°F. The aggregates and/or mixing water shall be cooled as necessary to maintain the concrete temperature at or not more than the specified maximum.

The finished surfaces of the newly laid pavement shall be kept damp by applying a water-fog or mist with approved spraying equipment until the pavement is covered by the curing medium. When necessary, wind screens shall be provided to protect the concrete from an evaporation rate in excess of 0.2 psf per hour as determined in accordance with Figure 2.15 in ACI 305 R. When conditions are such that problems with plastic cracking can be expected, and particularly if any plastic cracking begins to occur, the Contractor shall immediately take such additional measures as necessary to protect the concrete surface. Such measures shall consist of wind screens, more effective fog sprays, and similar measures commencing immediately behind the paver. If these measures are not effective in preventing plastic cracking, paving operations shall be immediately stopped.

**c. Temperature Management Program.** Prior to the start of paving operation for each day of paving, the Contractor shall provide the DEN Project Manager with a

Temperature Management Program for the concrete to be placed to assure that uncontrolled cracking is avoided. As a minimum the program shall address the following items:

- (1) Anticipated tensile strains in the fresh concrete as related to heating and cooling of the concrete material.
- (2) Anticipated weather conditions such as ambient temperatures, wind velocity, and relative humidity; and anticipated evaporation rate using Figure 11-8, PCA, Design and Control of Concrete Mixtures.
- (3) Anticipated timing of initial sawing of joint.
- (4) Anticipated number and type of saws to be used.

**501-4.8 PLACING CONCRETE.** At any point in concrete conveyance, the free vertical drop of the concrete from one point to another or to the underlying surface shall not exceed 3 feet or as approved by the DEN Project Manager or their representative provided the aggregate and mortar are not separated during placement. Concrete may be dumped on grade from the hauling equipment provided that the dumping does not increase the segregation of the material. The finished concrete product must be dense and homogeneous, without segregation and conforming to the standards in this specification. Backhoes and grading equipment shall not be used to distribute the concrete in front of the paver. Front end loaders will not be used. The concrete adjacent to joints shall be compacted or firmly placed without voids or segregation against the joint material. All concrete shall be consolidated without voids or segregation, including under and around all load-transfer devices, joint assembly units, and other features embedded in the pavement. Hauling equipment or other mechanical equipment can be permitted on adjoining previously constructed pavement when the concrete strength reaches a flexural strength of 550 psi, based on the average of four field cured specimens per 2,000 cubic yards of concrete placed. Also, subgrade and subbase planers, concrete pavers, and concrete finishing equipment may be permitted to ride upon the edges of previously constructed pavement when the concrete has attained a minimum flexural strength of 400 psi. Results of the field cured specimens shall be provided to the DEN Project Manager prior to the pavement receiving any traffic.

The Contractor shall have available materials for the protection of the concrete during inclement weather. Such protective materials shall consist of rolled polyethylene sheeting at least 4 mils thick of sufficient length and width to cover the plastic concrete slab and any edges. The sheeting may be mounted on either the paver or a separate movable bridge from which it can be unrolled without dragging over the plastic concrete surface. When rain appears imminent, all paving operations shall stop and all available personnel shall begin covering the surface of the unhardened concrete with the protective covering.

**a. Slip-Form Construction.** The concrete shall be distributed uniformly into final position by a self-propelled slip-form paver without delay. The alignment and elevation of the paver shall be regulated from outside reference lines established for this purpose. The paver shall vibrate the concrete for the full width and depth of the strip of pavement being placed and the vibration shall be adequate to provide a consistency of concrete that will stand

normal to the surface with sharp well defined edges. The sliding forms shall be rigidly held together laterally to prevent spreading of the forms. The plastic concrete shall be effectively consolidated by internal vibration with transverse vibrating units for the full width of the pavement and/or a series of equally placed longitudinal vibrating units. The space from the outer edge of the pavement to longitudinal unit shall not exceed 9 inches for slipform and at the end of the dowels for the fill-in lanes. The spacing of internal units shall be uniform and shall not exceed 18 inches.

The term internal vibration means vibrating units located within the specified thickness of pavement section.

The rate of vibration of each vibrating unit shall be within 8000 to 12000 cycles per minute and the amplitude of vibration shall be sufficient to be perceptible on the surface of the concrete along the entire length of the vibrating unit and for a distance of at least one foot. The frequency of vibration or amplitude shall vary proportionately with the rate of travel to result in a uniform density and air content. The paving machine shall be equipped with a tachometer or other suitable device for measuring and indicating the actual frequency of vibrations.

The concrete shall be held at a uniform consistency. The slip-form paver shall be operated with as nearly a continuous forward movement as possible and all operations of mixing, delivering, and spreading concrete shall be coordinated to provide uniform progress with stopping and starting of the paver held to a minimum. If for any reason, it is necessary to stop the forward movement of the paver, the vibratory and tamping elements shall also be stopped immediately. No tractive force shall be applied to the machine, except that which is controlled from the machine.

When concrete is being placed adjacent to an existing pavement, that part of the equipment which is supported on the existing pavement shall be equipped with protective pads on crawler tracks or rubber-tired wheels on which the bearing surface is offset to run a sufficient distance from the edge of the pavement to avoid breaking the pavement edge.

Not more than 15% of the total free edge of each 500 foot segment of pavement, or fraction thereof, shall have an edge slump exceeding 1/4 inch, and none of the free edge of the pavement shall have an edge slump exceeding 3/8 inch. (The total free edge of 500 feet of pavement will be considered the cumulative total linear measurement of pavement edge originally constructed as nonadjacent to any existing pavement; that is, 500 feet of paving lane originally constructed as a separate lane will have 1,000 feet of free edge, 500 feet of fill-in lane will have no free edge, etc.). The area affected by the downward movement of the concrete along the pavement edge shall be limited to not more than 18 inches from the edge. When excessive edge slump cannot be corrected before the concrete has hardened, the area with excessive edge slump shall be removed and replaced at the expense of the Contractor as directed by the DEN Project Manager.

**b. Side-Form Construction.** Side form sections shall be straight, free from warps, bends, indentations, or other defects. Defective forms shall be removed from the

work. Metal side forms shall be used except at end closures and transverse construction joints where straight forms of other suitable material may be used.

Side forms may be built up by rigidly attaching a section to either top or bottom of forms. If such build-up is attached to the top of metal forms, the build-up shall also be metal.

Width of the base of all forms shall be equal to at least 80% of the specified pavement thickness.

Side forms shall be of sufficient rigidity, both in the form and in the interlocking connection with adjoining forms, that springing will not occur under the weight of subgrading and paving equipment or from the pressure of the concrete. The Contractor shall provide sufficient forms so that there will be no delay in placing concrete due to lack of forms.

Before placing side forms, the underlying material shall be at the proper grade. Side forms shall have full bearing upon the foundation throughout their length and width of base and shall be placed to the required grade and alignment of the finished pavement. They shall be firmly supported during the entire operation of placing, compacting, and finishing the pavement.

Forms shall be drilled in advance of being placed to line and grade to accommodate tie bars where these are specified.

Immediately in advance of placing concrete and after all subbase operations are completed, side forms shall be trued and maintained to the required line and grade for a distance sufficient to prevent delay in placing.

Side forms shall remain in place at least 12 hours after the concrete has been placed, and in all cases until the edge of the pavement no longer requires the protection of the forms. Curing compound shall be applied to the concrete immediately after the forms have been removed.

Side forms shall be thoroughly cleaned and oiled each time they are used and before concrete is placed against them.

Concrete shall be spread, screeded, shaped and consolidated by one or more self-propelled machines. These machines shall uniformly distribute and consolidate concrete without segregation so that the completed pavement will conform to the required cross-section with a minimum of handwork.

The number and capacity of machines furnished shall be adequate to perform the work required at a rate equal to that of concrete delivery.

Concrete for the full paving width shall be effectively consolidated by internal vibrators without causing segregation. Internal type vibrators' rate of vibration shall be not less than 7,000 cycles per minute. Amplitude of vibration shall be sufficient to be perceptible on the surface of the concrete more than one foot from the vibrating element. The Contractor shall

furnish a tachometer or other suitable device for measuring and indicating frequency of vibration.

Power to vibrators shall be connected so that vibration ceases when forward or backward motion of the machine is stopped.

The provisions relating to the frequency and amplitude of internal vibration shall be considered the minimum requirements and are intended to ensure adequate density in the hardened concrete.

**c. Consolidation.** Concrete shall be consolidated with the specified type of lane-spanning, gang-mounted, mechanical, immersion type vibrating equipment mounted in front of the paver, supplemented, in rare instances as specified, by hand-operated vibrators. The vibrators shall be inserted into the concrete to a depth that will provide the best full-depth consolidation but not closer to the underlying material than 2 inches. Excessive vibration shall not be permitted. If the vibrators cause visible tracking in the paving lane, the paving operation shall be stopped and equipment and operations modified to prevent it. Concrete in small, odd-shaped slabs or in isolated locations inaccessible to the gang-mounted vibration equipment shall be vibrated with an approved hand-operated immersion vibrator operated from a bridge spanning the area. Vibrators shall not be used to transport or spread the concrete. Hand-operated vibrators shall not be operated in the concrete at one location for more than 20 seconds. Insertion locations for hand-operated vibrators shall be between 6 to 15 inches (150 to 400 mm) on centers. For each paving train, at least one additional vibrator spud, or sufficient parts for rapid replacement and repair of vibrators shall be maintained at the paving site at all times. Any evidence of inadequate consolidation (honeycomb along the edges, large air pockets, or any other evidence) shall require the immediate stopping of the paving operation and adjustment of the equipment or procedures as approved by the DEN Project Manager.

If a lack of consolidation of the concrete is suspected by the DEN Project Manager, referee testing may be required. Referee testing of hardened concrete will be performed by the DEN Project Manager by cutting cores from the finished pavement after a minimum of 24 hours curing. Density determinations will be made by the DEN Project Manager based on the water content of the core as taken. ASTM C642 shall be used for the determination of core density in the saturated-surface dry condition. When required, referee cores will be taken at the minimum rate of one for each 500 cubic yards (382 m<sup>2</sup>) of pavement, or fraction. The Contractor shall be responsible for all referee testing cost if they fail to meet the required density.

The average density of the cores shall be at least 97% of the original mix design density, with no cores having a density of less than 96% of the original mix design density. Failure to meet the referee tests will be considered evidence that the minimum requirements for vibration are inadequate for the job conditions. Additional vibrating units or other means of increasing the effect of vibration shall be employed so that the density of the hardened concrete conforms to the above requirements.

All failing concrete shall be removed and replaced at the expense of the Contractor as directed by the DEN Project Manager.

**501-4.9 STRIKE-OFF OF CONCRETE AND PLACEMENT OF REINFORCEMENT.** Following the placing of the concrete, it shall be struck off to conform to the cross-section shown on the plans and to an elevation that when the concrete is properly consolidated and finished, the surface of the pavement shall be at the elevation shown on the plans. When reinforced concrete pavement is placed in two layers, the bottom layer shall be struck off to such length and depth that the sheet of reinforcing steel fabric or bar mat may be laid full length on the concrete in its final position without further manipulation. The reinforcement shall then be placed directly upon the concrete, after which the top layer of the concrete shall be placed, struck off, and screeded. If any portion of the bottom layer of concrete has been placed more than 30 minutes without being covered with the top layer or if initial set has taken place, it shall be removed and replaced with freshly mixed concrete at the Contractor's expense. When reinforced concrete is placed in one layer, the reinforcement may be positioned in advance of concrete placement or it may be placed in plastic concrete by mechanical or vibratory means after spreading.

Reinforcing steel, at the time concrete is placed, shall be free of mud, oil, or other organic matter that may adversely affect or reduce bond. Reinforcing steel with rust, mill scale or a combination of both will be considered satisfactory, provided the minimum dimensions, weight, and tensile properties of a hand wire-brushed test specimen are not less than the applicable ASTM specification requirements.

**501-4.10 JOINTS.** Joints shall be constructed as shown on the plans and in accordance with these requirements. All joints shall be constructed with their faces perpendicular to the surface of the pavement and finished or edged as shown on the plans. Joints shall not vary more than 1/2 inch from their designated position and shall be true to line with not more than 1/4 inch variation in 10 feet. The surface across the joints shall be tested with a 12 feet (3 m) straightedge as the joints are finished and any irregularities in excess of 1/4 inch (6 mm) shall be corrected before the concrete has hardened. All joints shall be so prepared, finished, or cut to provide a groove of uniform width and depth as shown on the plans.

**a. Construction.** Longitudinal construction joints shall be slip-formed or formed against side forms as shown in the plans, without keyways.

Transverse construction joints shall be installed at the end of each day's placing operations and at any other points within a paving lane when concrete placement is interrupted for more than 30 minutes or it appears that the concrete will obtain its initial set before fresh concrete arrives. The installation of the joint shall be located at a planned contraction or expansion joint. If placing of the concrete is stopped, the Contractor shall remove the excess concrete back to the previous planned joint.

**b. Contraction.** Contraction joints shall be installed at the locations and spacing as shown on the plans. Contraction joints shall be installed to the dimensions required by forming a groove or cleft in the top of the slab while the concrete is still plastic or by sawing a groove into the concrete surface after the concrete has hardened. When the groove is



formed in plastic concrete the sides of the grooves shall be finished even and smooth with an edging tool. If an insert material is used, the installation and edge finish shall be according to the manufacturer's instructions. The groove shall be finished or cut clean so that spalling will be avoided at intersections with other joints. Grooving or sawing shall produce a slot at least 1/8 inch (3 mm) wide and to the depth shown on the plans.

**c. Isolation (Expansion).** Isolation joints shall be installed as shown on the plans. The premolded filler of the thickness as shown on the plans, shall extend for the full depth and width of the slab at the joint, except for space for sealant at the top of the slab. The filler shall be securely staked or fastened into position perpendicular to the proposed finished surface. A cap shall be provided to protect the top edge of the filler and to permit the concrete to be placed and finished. After the concrete has been placed and struck off, the cap shall be carefully withdrawn leaving the space over the premolded filler. The edges of the joint shall be finished and tooled while the concrete is still plastic. Any concrete bridging the joint space shall be removed for the full width and depth of the joint. The premolded filler shall be removed, full depth, prior to joint seal installation.

**d. Tie Bars.** Tie bars shall consist of deformed bars installed in joints as shown on the plans. Tie bars shall be placed at right angles to the centerline of the concrete slab and shall be spaced at intervals shown on the plans. They shall be held in position parallel to the pavement surface and in the middle of the slab depth. When tie bars extend into an unpaved lane, they may be bent against the form at longitudinal construction joints, unless threaded bolt or other assembled tie bars are specified. Tie bars shall not be painted, greased, or enclosed in sleeves. When slip-form operations call for tie bars, two-piece hook bolts can be installed.

**e. Dowel Bars.** Dowel bars or other load-transfer units of an approved type shall be placed across joints as shown on the plans. They shall be of the dimensions and spacings as shown and held rigidly in the middle of the slab depth in the proper horizontal and vertical alignment by an approved assembly device to be left permanently in place. The dowel or load-transfer and joint devices shall be rigid enough to permit complete assembly as a unit ready to be lifted and placed into position. The dowels shall be coated with a bond-breaker or other lubricant recommended by the manufacturer and approved by the DEN Project Manager.

Dowels bars at longitudinal construction joints shall be bonded in drilled holes.

**f. Placing Dowels and Tie Bars.** The method used in installing and holding dowels in position shall ensure that the error in alignment of any dowel from its required horizontal and vertical alignment after the pavement has been completed will not be greater than 1/8 inch per foot. Except as otherwise specified below, horizontal spacing of dowels shall be within a tolerance of  $\pm 5/8$  inch. The vertical location on the face of the slab shall be within a tolerance of  $\pm 1/2$  inch. The vertical alignment of the dowels shall be measured parallel to the designated top surface of the pavement, except for those across the crown or other grade change joints. Dowels across crowns and other joints at grade changes shall be measured to a level surface. Horizontal alignment shall be checked perpendicular to the joint edge. The horizontal alignment shall be checked with a framing square. Dowels shall not be

placed closer than 0.6 times the dowel bar length to the planned joint line. If the last regularly spaced longitudinal dowel is closer than that dimension, it shall be moved away from the joint to a location 0.6 times the dowel bar length, but not closer than 6 inches to its nearest neighbor. The portion of each dowel intended to move within the concrete or expansion cap shall be wiped clean and coated with a thin, even film of lubricating oil or light grease before the concrete is placed. Dowels shall be installed as specified in the following subparagraphs.

(1) **Contraction Joints.** Dowels and tie bars in longitudinal and transverse contraction joints within the paving lane shall be held securely in place, as indicated, by means of rigid metal frames or basket assemblies of an approved type. The basket assemblies shall be held securely in the proper location by means of suitable pins or anchors. Do not cut or crimp the dowel basket tie wires. At the Contractor's option, in lieu of the above, dowels and tie bars in contraction joints shall be installed near the front of the paver by insertion into the plastic concrete using approved equipment and procedures. Approval will be based on the results of a preconstruction demonstration, showing that the dowels and tie bars are installed within specified tolerances.

(2) **Construction Joints.** Install dowels and tie bars by the cast-in- place or the drill-and-dowel method. Installation by removing and replacing in preformed holes will not be permitted. Dowels and tie bars shall be prepared and placed across joints where indicated, correctly aligned, and securely held in the proper horizontal and vertical position during placing and finishing operations, by means of devices fastened to the forms. The spacing of dowels and tie bars in construction joints shall be as indicated.

(3) **Dowels Installed in Isolation Joints and Other Hardened Concrete.** Install dowels for isolation joints and in other hardened concrete by bonding the dowels into holes drilled into the hardened concrete. The concrete shall have cured for seven (7) days or reached a minimum flexural strength of 450 psi before drilling commences. Holes 1/8 inch greater in diameter than the dowels shall be drilled into the hardened concrete using rotary-core drills. Rotary-percussion drills may be used, provided that excessive spalling does not occur to the concrete joint face. Modification of the equipment and operation shall be required if, in the DEN Project Manager's opinion, the equipment and/or operation is causing excessive damage. Depth of dowel hole shall be within a tolerance of  $\pm 1/2$  inch of the dimension shown on the drawings. On completion of the drilling operation, the dowel hole shall be blown out with oil-free, compressed air. Dowels shall be bonded in the drilled holes using epoxy resin. Epoxy resin shall be injected at the back of the hole before installing the dowel and extruded to the collar during insertion of the dowel so as to completely fill the void around the dowel. Application by buttering the dowel will not be permitted. The dowels shall be held in alignment at the collar of the hole, after insertion and before the grout hardens, by means of a suitable metal or plastic grout retention ring fitted around the dowel. Dowels required to be installed in any joints between new and existing concrete shall be grouted in holes drilled in the existing concrete, all as specified above.

g. **Sawing of Joints.** Joints shall be cut as shown on the plans. Equipment shall be as described in paragraph 501-4.1. The circular cutter shall be capable of cutting a groove in a straight line and shall produce a slot at least 1/8 inch wide and to the depth shown on the

plans. The top of the slot shall be widened by sawing to provide adequate space for joint sealers as shown on the plans. Sawing shall commence, without regard to day or night, as soon as the concrete has hardened sufficiently to permit cutting without chipping, spalling, or tearing and before uncontrolled shrinkage cracking of the pavement occurs and shall continue without interruption until all joints have been sawn. The joints shall be sawn at the required spacing. All slurry and debris produced in the sawing of joints shall be removed by vacuuming and washing. Curing compound or system shall be reapplied in the initial sawcut and maintained for the remaining cure period.

**501-4.11 FINISHING.** Finishing operations shall be a continuing part of placing operations starting immediately behind the strike-off of the paver. Initial finishing shall be provided by the transverse screed or extrusion plate. The sequence of operations shall be transverse finishing, longitudinal machine floating if used, straightedge finishing, texturing, and then edging of joints. Finishing shall be by the machine method. The hand method shall be used only on isolated areas of odd slab widths or shapes and in the event of a breakdown of the mechanical finishing equipment. Supplemental hand finishing for machine finished pavement shall be kept to an absolute minimum. Any machine finishing operation which requires appreciable hand finishing, other than a moderate amount of straightedge finishing, shall be immediately stopped and proper adjustments made or the equipment replaced. Any operations which produce more than 1/8 inch of mortar-rich surface (defined as deficient in plus U.S. No. 4 (4.75 mm) sieve size aggregate) shall be halted immediately and the equipment, mixture, or procedures modified as necessary. Compensation shall be made for surging behind the screeds or extrusion plate and settlement during hardening and care shall be taken to ensure that paving and finishing machines are properly adjusted so that the finished surface of the concrete (not just the cutting edges of the screeds) will be at the required line and grade. Finishing equipment and tools shall be maintained clean and in an approved condition. At no time shall water be added to the surface of the slab with the finishing equipment or tools, or in any other way, except for fog (mist) sprays specified to prevent plastic shrinkage cracking.

**a. Machine Finishing With Slipform Pavers.** The slipform paver shall be operated so that only a very minimum of additional finishing work is required to produce pavement surfaces and edges meeting the specified tolerances. Any equipment or procedure that fails to meet these specified requirements shall immediately be replaced or modified as necessary. A self-propelled non-rotating pipe float may be used while the concrete is still plastic, to remove minor irregularities and score marks. Only one pass of the pipe float shall be allowed. If there is concrete slurry or fluid paste on the surface that runs over the edge of the pavement, the paving operation shall be immediately stopped and the equipment, mixture, or operation modified to prevent formation of such slurry. Any slurry which does run down the vertical edges shall be immediately removed by hand, using stiff brushes or scrapers. No slurry, concrete or concrete mortar shall be used to build up along the edges of the pavement to compensate for excessive edge slump, either while the concrete is plastic or after it hardens.

**b. Machine Finishing With Fixed Forms.** The machine shall be designed to straddle the forms and shall be operated to screed and consolidate the concrete. Machines

that cause displacement of the forms shall be replaced. The machine shall make only one pass over each area of pavement. If the equipment and procedures do not produce a surface of uniform texture, true to grade, in one pass, the operation shall be immediately stopped and the equipment, mixture, and procedures adjusted as necessary.

**c. Other Types of Finishing Equipment.** Clary screeds, other rotating tube floats, or bridge deck finishers are not allowed on mainline paving, but may be allowed on irregular or odd-shaped slabs, and near buildings or trench drains, subject to the DEN Project Manager's approval.

Bridge deck finishers shall have a minimum operating weight of 7500 pounds and shall have a transversely operating carriage containing a knock-down auger and a minimum of two immersion vibrators. Vibrating screeds or pans shall be used only for isolated slabs where hand finishing is permitted as specified, and only where specifically approved.

**d. Hand Finishing.** Hand finishing methods will not be permitted, except under the following conditions: (1) in the event of breakdown of the mechanical equipment, hand methods may be used to finish the concrete already deposited on the grade and (2) in areas of narrow widths or of irregular dimensions where operation of the mechanical equipment is impractical. Use hand finishing operations only as specified below.

**(1) Equipment and Screed.** In addition to approved mechanical internal vibrators for consolidating the concrete, provide a strike-off and tamping screed and a longitudinal float for hand finishing. The screed shall be at least one foot longer than the width of pavement being finished, of an approved design, and sufficiently rigid to retain its shape, and shall be constructed of metal or other suitable material shod with metal. The longitudinal float shall be at least 10 feet long, of approved design, and rigid and substantially braced, and shall maintain a plane surface on the bottom. Grate tampers (jitterbugs) shall not be used.

**(2) Finishing and Floating.** As soon as placed and vibrated, the concrete shall be struck off and screeded to the crown and cross-section and to such elevation above grade that when consolidated and finished, the surface of the pavement will be at the required elevation. In addition to previously specified complete coverage with handheld immersion vibrators, the entire surface shall be tamped with the strike-off and tamping template, and the tamping operation continued until the required compaction and reduction of internal and surface voids are accomplished. Immediately following the final tamping of the surface, the pavement shall be floated longitudinally from bridges resting on the side forms and spanning but not touching the concrete. If necessary, additional concrete shall be placed, consolidated and screeded, and the float operated until a satisfactory surface has been produced. The floating operation shall be advanced not more than half the length of the float and then continued over the new and previously floated surfaces.

**e. Straightedge Testing and Surface Correction.** After the pavement has been struck off and while the concrete is still plastic, it shall be tested for trueness with a Contractor furnished 12-foot straightedge swung from handles 3 feet longer than one-half the width of the slab. The straightedge shall be held in contact with the surface in successive

positions parallel to the centerline and the whole area gone over from one side of the slab to the other, as necessary. Advancing shall be in successive stages of not more than one-half the length of the straightedge. Any excess water and laitance in excess of 1/8 inch thick shall be removed from the surface of the pavement and wasted. Any depressions shall be immediately filled with freshly mixed concrete, struck off, consolidated, and refinished. High areas shall be cut down and refinished. Special attention shall be given to assure that the surface across joints meets the smoothness requirements of paragraph 501-5.2e(3). Straightedge testing and surface corrections shall continue until the entire surface is found to be free from observable departures from the straightedge and until the slab conforms to the required grade and cross-section. The use of long-handled wood floats shall be confined to a minimum; they may be used only in emergencies and in areas not accessible to finishing equipment. This straight-edging is not a replacement for the straightedge testing of paragraph 501-5.2e(3), Smoothness.

**501-4.12 SURFACE TEXTURE.** The surface of the pavement shall be finished with either a brush or broom, burlap drag, or artificial turf finish for all newly constructed concrete pavements. It is important that the texturing equipment not tear or unduly roughen the pavement surface during the operation. Any imperfections resulting from the texturing operation shall be corrected to the satisfaction of the DEN Project Manager.

**a. Brush or broom finish.** If the pavement surface texture is to be a type of brush or broom finish, it shall be applied when the water sheen has practically disappeared. The equipment shall operate transversely across the pavement surface, providing corrugations that are uniform in appearance and approximately 1/16 inch in depth.

**b. Burlap drag finish.** If a burlap drag is used to texture the pavement surface, it shall be at least 15 ounces per square yard. To obtain a textured surface, the transverse threads of the burlap shall be removed approximately one foot from the trailing edge. A heavy buildup of grout on the burlap threads produces the desired wide sweeping longitudinal striations on the pavement surface. The corrugations shall be uniform in appearance and approximately 1/16 inch in depth.

**501-4.13 CURING.** Immediately after finishing operations are completed and marring of the concrete will not occur, the entire surface of the newly placed concrete shall be cured for a 7-day cure period in accordance with one of the methods below. Failure to provide sufficient cover material of whatever kind the Contractor may elect to use, 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 1/2 hour during the curing period.

When a two-sawcut method is used to construct the contraction joint, the curing compound shall be applied to the sawcut immediately after the initial cut has been made. The sealant reservoir shall not be sawed until after the curing period has been completed. When the one cut method is used to construct the contraction joint, the joint shall be cured with wet rope, wet rags, or wet blankets. The rags, ropes, or blankets shall be kept moist for the duration of the curing period.

**a. Impervious Membrane Method.** The entire surface of the pavement shall be sprayed uniformly with white pigmented curing compound immediately after the finishing of the surface and before the set of the concrete has taken place. The curing compound shall not be applied during rainfall. Curing compound shall be applied by mechanical sprayers under pressure at the rate of one gallon to not more than 150 sq ft. The spraying equipment shall be of 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 mechanical means. Hand spraying of odd widths or shapes and concrete surfaces exposed by the removal of forms will be permitted. When hand spraying is approved by the DEN Project Manager, a double application rate shall be used to ensure coverage. The curing compound shall be of such character that the film will harden within 30 minutes after application. Should the film become damaged from any cause, including sawing operations, within the required curing period, the damaged portions shall be repaired immediately with additional compound or other approved means. Upon removal of side forms, the sides of the exposed slabs shall be protected immediately to provide a curing treatment equal to that provided for the surface. Curing shall be applied immediately after the bleed water is gone from the surface. The use of flyash or set-retarding admixtures may delay the occurrence of bleed water.

**b. White Burlap-Polyethylene Sheets.** The surface of the pavement shall be entirely covered with the sheeting. The sheeting used shall be such length (or width) that it will extend at least twice the thickness of the pavement beyond the edges of the slab. The sheeting shall be placed so that the entire surface and both edges of the slab are completely covered. The sheeting shall be placed and weighted to remain in contact with the surface covered, and the covering shall be maintained fully saturated and in position for seven (7) days after the concrete has been placed.

**c. Water Method.** The entire area shall be covered with burlap or other water absorbing material. The material shall be of sufficient thickness to retain water for adequate curing without excessive runoff. The material shall be kept wet at all times and maintained for seven (7) days. When the forms are stripped, the vertical walls shall also be kept moist. It shall be the responsibility of the Contractor to prevent ponding of the curing water on the subbase.

**d. Concrete Protection for Cold Weather.** The concrete shall be maintained at an ambient temperature of at least 50°F for a period of 72 hours after placing and at a temperature above freezing for the remainder of the curing time. The Contractor shall be responsible for the quality and strength of the concrete placed during cold weather; and any concrete damaged shall be removed and replaced at the Contractor's expense. Additional requirements for cold weather concreting can be found in ACI 306 R.

**e. Concrete Protection for Hot Weather.** Concrete should be continuous moisture cured for the entire curing period and shall commence as soon as the surfaces are finished and continue for at least 24 hours. However, if moisture curing is not practical beyond 24 hours, the concrete surface shall be protected from drying with application of a liquid membrane-forming curing compound while the surfaces are still damp. Other curing

methods may be approved by the DEN Project Manager. Additional requirements for hot weather concreting can be found in ACI 305 R.

**501-4.14 REMOVING FORMS.** Unless otherwise specified, forms shall not be removed from freshly placed concrete until it has hardened sufficiently to permit removal without chipping, spalling, or tearing. After the forms have been removed, the sides of the slab shall be cured as per the methods indicated in paragraph 501-4.13. Major honeycombed areas shall be considered as defective work and shall be removed and replaced in accordance with paragraph 501-5.2(f).

**501-4.15 SAW-CUT GROOVING.** If shown on the plans, grooved surfaces shall be provided in accordance with the requirements of Item P-621.

**501-4.16 SEALING JOINTS.** The joints in the pavement shall be sealed in accordance with Item P-604A, P-604B, and P-605.

**501-4.17 PROTECTION OF PAVEMENT.** The Contractor shall protect the pavement and its appurtenances against both public traffic and traffic caused by the Contractor's employees and agents until accepted by the DEN Project Manager. This shall include watchmen to direct traffic and the erection and maintenance of warning signs, lights, pavement bridges, crossovers, and protection of unsealed joints from intrusion of foreign material, etc. The Contractor shall have available at all times, materials for the protection of the edges and surface of the unhardened concrete. Such protective materials shall consist of rolled polyethylene sheeting at least 4 mils thick of sufficient length and width to cover the plastic concrete slab and any edges. The sheeting may be mounted on either the paver or a separate movable bridge from which it can be unrolled without dragging over the plastic concrete surface. When rain appears imminent, all paving operations shall stop and all available personnel shall begin covering the surface of the unhardened concrete with the protective covering. The DEN Project Manager may evaluate the damage to determine if diamond grinding can correct the surface and provide the required smoothness, grade, and thickness required by the Contract.

Aggregates, rubble, or other similar construction materials shall not be placed on airfield pavements. Traffic shall be excluded from the new pavement by erecting and maintaining barricades and signs until the concrete meets the requirements of (501-4.18).

In paving intermediate lanes between newly paved pilot lanes, operation of the hauling and paving equipment will be permitted on the new pavement after the pavement has been cured to the requirements of (501-4.18).

All new and existing pavement carrying construction traffic or equipment shall be continuously kept completely clean, and spillage of concrete or other materials shall be cleaned up immediately upon occurrence.

Damaged pavements shall be removed and replaced at the Contractor's expense. Slabs shall be removed to the full depth, width, and length of the slab.

**501-4.18 OPENING TO CONSTRUCTION TRAFFIC.** The pavement shall not be opened to traffic until test specimens molded and cured in accordance with ASTM C31 have attained a flexural strength of 550 lb / square inch when tested in accordance with ASTM C78. If such tests are not conducted, the pavement shall not be opened to traffic until 14 days after the concrete was placed. Prior to opening the pavement to construction traffic, all joints shall either be sealed or protected from damage to the joint edge and intrusion of foreign materials into the joint. As a minimum, backer rod or tape may be used to protect the joints from foreign matter intrusion.

**501-4.19 REPAIR, REMOVAL, OR REPLACEMENT OF SLABS.**

**a. General.** New pavement slabs that are broken or contain cracks or are otherwise defective or unacceptable shall be removed and replaced or repaired, as directed by the DEN Project Manager and as specified hereinafter at no cost to the Owner. Spalls along joints shall be repaired as specified. Removal of partial slabs is not permitted. Removal and replacement shall be full depth, shall be full width of the slab, and the limit of removal shall be normal to the paving lane and to each original transverse joint. The DEN Project Manager will determine whether cracks extend full depth of the pavement and may require cores to be drilled on the crack to determine depth of cracking. Such cores shall be 4 inch diameter, shall be drilled by the Contractor and shall be filled by the Contractor with a well consolidated concrete mixture bonded to the walls of the hole with epoxy resin, using approved procedures. Drilling of cores and refilling holes shall be at no expense to the Owner. All epoxy resin used in this work shall conform to ASTM C881, Type V. Repair of cracks as described in this section shall not be allowed if in the opinion of the DEN Project Manager the overall condition of the pavement indicates that such repair is unlikely to achieve an acceptable and durable finished pavement. No repair of cracks shall be allowed in any panel that demonstrates segregated aggregate with an absence of coarse aggregate in the upper 1/8 inch (3 mm) of the pavement surface.

**b. Shrinkage cracks.** Shrinkage cracks, which do not exceed 4 inches in depth, shall be cleaned and then pressure injected with epoxy resin, Type IV, Grade 1, using procedures as approved by the DEN Project Manager. Care shall be taken to assure that the crack is not widened during epoxy resin injection. All epoxy resin injection shall take place in the presence of the DEN Project Manager. Shrinkage cracks, which exceed 4 inches in depth, shall be treated as full depth cracks in accordance with paragraphs 4.19b and 4.19c.

**c. Slabs with cracks through interior areas.** Interior area is defined as that area more than 6 inches from either adjacent original transverse joint. The full slab shall be removed and replaced at no cost to the Owner, when there are any full depth cracks, or cracks greater than 4 inches in depth, that extend into the interior area.

**d. Cracks close to and parallel to joints.** All cracks essentially parallel to original joints, extending full depth of the slab, and lying wholly within 6 inches (150 mm) either side of the joint shall be treated as specified here. Any crack extending more than 6 inches (150 mm) from the joint shall be treated as specified above in subparagraph c.



(1) **Full depth cracks present, original joint not opened.** When the original un-cracked joint has not opened, the crack shall be sawed and sealed, and the original joint filled with epoxy resin as specified below. The crack shall be sawed with equipment specially designed to follow random cracks. The reservoir for joint sealant in the crack shall be formed by sawing to a depth of 3/4 inches (19 mm),  $\pm 1/16$  inch (2 mm), and to a width of 5/8 inch (16 mm),  $\pm 1/8$  inch (3 mm). Any equipment or procedure which causes raveling or spalling along the crack shall be modified or replaced to prevent such raveling or spalling. The joint sealant shall be a liquid sealant as specified. Installation of joint seal shall be as specified for sealing joints or as directed. If the joint sealant reservoir has been sawed out, the reservoir and as much of the lower saw cut as possible shall be filled with epoxy resin, Type IV, Grade 2, thoroughly tooled into the void using approved procedures.

If only the original narrow saw cut has been made, it shall be cleaned and pressure injected with epoxy resin, Type IV, Grade 1, using approved procedures. If filler type material has been used to form a weakened plane in the transverse joint, it shall be completely sawed out and the saw cut pressure injected with epoxy resin, Type IV, Grade 1, using approved procedures. Where a parallel crack goes part way across paving lane and then intersects and follows the original joint which is cracked only for the remained of the width, it shall be treated as specified above for a parallel crack, and the cracked original joint shall be prepared and sealed as originally designed.

Where a full depth crack is present but the original joint has not opened and a compression joint seal for concrete pavements is being installed, the entire slab containing the crack shall be removed and replaced for the full lane width and length.

(2) **Full depth cracks present, original joint also cracked.** At a joint, if there is any place in the lane width where a parallel crack and a cracked portion of the original joint overlap, the entire slab containing the crack shall be removed and replaced for the full lane width and length.

e. **Removal and replacement of full slabs.** Where it is necessary to remove full slabs, unless there are dowels present, all edges of the slab shall be cut full depth with a concrete saw. All saw cuts shall be perpendicular to the slab surface. If dowels, or tie bars are present along any edges, these edges shall be sawed full depth just beyond the end of the dowels or tie bars. These joints shall then be carefully sawed on the joint line to within one inch of the depth of the dowel or tie bar.

The main slab shall be further divided by sawing full depth, at appropriate locations, and each piece lifted out and removed. Suitable equipment shall be used to provide a truly vertical lift, and approved safe lifting devices used for attachment to the slabs. The narrow strips along doweled edges shall be carefully broken up and removed using light, hand-held jackhammers, 30 lb or less, or other approved similar equipment.

Care shall be taken to prevent damage to the dowels, tie bars, or to concrete to remain in place. The joint face below dowels shall be suitably trimmed so that there is not abrupt offset in any direction greater than 1/2 inch and no gradual offset greater than one inch when tested in a horizontal direction with a 12-foot straightedge.

No mechanical impact breakers, other than the above hand-held equipment shall be used for any removal of slabs. If underbreak between 1-1/2 and 4 inches deep occurs at any point along any edge, the area shall be repaired as directed before replacing the removed slab. Procedures directed will be similar to those specified for surface spalls, modified as necessary.

If underbreak over 4 inches deep occurs, the entire slab containing the underbreak shall be removed and replaced. Where there are no dowels or tie bars, or where they have been damaged, dowels or tie bars of the size and spacing as specified for other joints in similar pavement shall be installed by epoxy grouting them into holes drilled into the existing concrete using procedures as specified. Original damaged dowels or tie bars shall be cut off flush with the joint face. Protruding portions of dowels shall be painted and lightly oiled. All four (4) edges of the new slab shall contain dowels or original tie bars.

Placement of concrete shall be as specified for original construction. Prior to placement of new concrete, the underlying material (unless it is stabilized) shall be re-compacted and shaped as specified in the appropriate section of these specifications. The surfaces of all four joint faces shall be cleaned of all loose material and contaminants and coated with a double application of membrane forming curing compound as bond breaker. Care shall be taken to prevent any curing compound from contacting dowels or tie bars. The resulting joints around the new slab shall be prepared and sealed as specified for original construction.

**f. Repairing Spalls Along Joints.** Where directed, spalls along joints of new slabs, and along parallel cracks used as replacement joints, shall be repaired by first making a vertical saw cut at least one inch outside the spalled area and to a depth of at least 4 inches. Saw cuts shall be straight lines forming rectangular areas. The concrete between the saw cut and the joint, or crack, shall be chipped out to remove all unsound concrete and at least 1/2 inch of visually sound concrete. The cavity thus formed shall be thoroughly cleaned by sandblasting to remove all loose material. Immediately before filling the cavity, a prime coat of epoxy resin, Type III, Grade I, shall be applied to the dry cleaned surface of all sides and bottom of the cavity, except any joint face. The prime coat shall be applied in a thin coating and scrubbed into the surface with a stiff-bristle brush. Pooling of epoxy resin shall be avoided. The cavity shall be filled with an appropriate spall repair material from the CDOT Approved Products List (APL). The spall repair material shall be approved by the DEN Project Manager prior to installation. Epoxy resin mortars shall be made with Type III, Grade 1, epoxy resin, using proportions and mixing and placing procedures as recommended by the manufacturer and approved by the DEN Project Manager. The epoxy resin materials shall be placed in the cavity in layers not over 2 inches thick. The time interval between placement of additional layers shall be such that the temperature of the epoxy resin material does not exceed 140°F at any time during hardening. Mechanical vibrators and hand tampers shall be used to consolidate the material. Any repair material on the surrounding surfaces of the existing concrete shall be removed before it hardens. Where the spalled area abuts a joint, an insert or other bond-breaking medium shall be used to prevent bond at the joint face. A reservoir for the joint sealant shall be sawed to the dimensions required for other joints, or as required to be routed for cracks. The reservoir shall be thoroughly cleaned and sealed with the sealer specified for the joints. If any spall penetrates half the depth of the slab or more,

the entire slab shall be removed and replaced as previously specified. If any spall would require over 25% of the length of any single joint to be repaired, the entire slab shall be removed and replaced. Repair of spalls as described in this section shall not be allowed if in the opinion of the DEN Project Manager the overall condition of the pavement indicates that such repair is unlikely to achieve an acceptable and durable finished pavement. No repair of spalls shall be allowed in any panel that demonstrates segregated aggregate with a significant absence of coarse aggregate in the upper one-eighth (1/8th) inch of the pavement surface.

**g. Diamond grinding of PCC surfaces.** Diamond grinding of the hardened concrete with an approved diamond grinding machine should not be performed until the concrete has reached minimum strength specified in Paragraph 501-4.8. When required, diamond grinding shall be accomplished by sawing with saw blades impregnated with industrial diamond abrasive. The saw blades shall be assembled in a cutting head mounted on a machine designed specifically for diamond grinding that will produce the required texture and smoothness level without damage to the pavement. The saw blades shall be 1/8-inch wide and there shall be a minimum of 55 to 60 blades per 12 inches of cutting head width; the actual number of blades will be determined by the Contractor and depend on the hardness of the aggregate. The surface of the ground pavement shall have a texture consisting of grooves between 0.090 and 0.130 inches wide. The peaks and ridges shall be approximately 1/32 inch higher than the bottom of the grooves. Each machine shall be capable of cutting a path at least 3 feet wide. Equipment that causes ravels, aggregate fractures, spalls or disturbance to the joints will not be permitted. The area corrected by diamond grinding the surface of the hardened concrete should not exceed 10% of the total area of any subplot. The depth of diamond grinding shall not exceed 1/2 inch and all areas in which diamond grinding has been performed will be subject to the final pavement thickness tolerances specified. Grinding will be tapered in all directions to provide smooth transitions to areas not requiring grinding. All pavement areas requiring plan grade or surface smoothness corrections in excess of the limits specified shall be removed and replaced in conformance with Paragraph 501-4.19. The pavement shall be left in a clean condition. The removal of all of the slurry resulting from the grinding operation shall be continuous. The grinding operation should be controlled so the residue from the operation does not flow across other lanes of pavement.

**h. Weak Surfaces.** Weak surfaces are defined as mortar-rich, rain damaged, uncured, or containing exposed voids or deleterious materials. Weak surfaces are considered defective. The corrective action shall be as determined by the DEN Project Manager.

#### **501-4.20 EXISTING CONCRETE PAVEMENT REMOVAL AND REPAIR.**

All operations shall be carefully controlled to prevent damage to the concrete pavement and to the underlying material to remain in place. All saw cuts shall be made perpendicular to the slab surface.

**a. Removal of existing pavement slab.**

When it is necessary to remove existing concrete pavement and leave adjacent concrete in place, unless there are dowels present, the joint between the removal area and adjoining pavement to stay in place, including dowels or tie bars, shall first be cut full depth with a

standard diamond-type concrete saw. If dowels are present at this joint, the saw cut shall be made full depth just beyond the end of dowels. The edge shall then be carefully sawed on the joint line to within one inch of the top of the dowel. Next, a full depth saw cut shall be made parallel to the joint at least 24 inches from the joint and at least 12 inches from the end of any dowels. All pavement between this last saw cut and the joint line shall be carefully broken up and removed using hand-held jackhammers, 30 lb or less, or the approved light-duty equipment which will not cause stress to propagate across the joint saw cut and cause distress in the pavement which is to remain in place. Where dowels are present, care shall be taken to produce an even, vertical joint face below the dowels. If the Contractor is unable to produce such a joint face, or if underbreak or other distress occurs, the Contractor shall saw the dowels flush with the joint. The Contractor shall then install new dowels, of the size and spacing used for other similar joints, by epoxy resin bonding them in holes drilled in the joint face as specified in paragraph 501-4.10g. All this shall be at no additional cost to the Owner. Dowels of the size and spacing indicated shall be installed as shown on the drawings by epoxy resin bonding them in holes drilled in the joint face as specified in paragraph 501-4.10g. The joint face shall be sawed or otherwise trimmed so that there is no abrupt offset in any direction greater than 1/2 inches and no gradual offset greater than one inch when tested in a horizontal direction with a 12-foot straightedge.

**b. Edge Repair.**

The edge of existing concrete pavement against which new pavement abuts shall be protected from damage at all times. Areas that are damaged during construction shall be repaired at no cost to the Owner.

(1) **Spall repair.** Spalls shall be repaired where indicated and where directed by the DEN Project Manager. Repair materials and procedures shall be as previously specified in subparagraph 501-4.19f.

(2) **Underbreak repair.** All underbreak shall be repaired. First, all delaminated and loose material shall be carefully removed. Next, the underlying material shall be recompacted, without addition of any new material. Finally, the void shall be completely filled with paving concrete, thoroughly consolidated. Care shall be taken to produce an even joint face from top to bottom. Prior to placing concrete, the underlying material shall be thoroughly moistened. After placement, the exposed surface shall be heavily coated with curing compound.

(3) **Underlying material.** The underlying material adjacent to the edge and under the existing pavement which is to remain in place shall be protected from damage or disturbance during removal operations and until placement of new concrete, and shall be shaped as shown on the drawings or as directed. Sufficient material shall be kept in place outside the joint line to prevent disturbance (or sloughing) of material under the pavement that is to remain in place. Any material under the portion of the concrete pavement to remain in place, which is disturbed or loses its compaction shall be carefully removed and replaced with concrete as specified in paragraph 501-4.20b(2). The underlying material outside the joint line shall be thoroughly compacted and moist when new concrete is placed.

**c. Crack Repair.**

(1) **Cracks less than 3/8” wide.** Cracks less than 3/8” wide shall be routed to the depth and width recommended by the sealant manufacturer. The routed groove shall be cleaned by pressure washing. The groove shall be allowed to dry, prior to installation of sealant. The routed groove shall be sealed in accordance with Item P-605.

(2) **Cracks greater than 3/8” wide.** Cracks greater than 3/8” wide shall be routed to the depth and width recommended by the sealant manufacturer. The routed groove shall be cleaned by pressure washing. The groove shall be allowed to dry, prior to installation of the backer rod and sealant. A closed cell backer rod which is compatible with the sealant shall be installed and shall be 1/8” greater in diameter than the width of the routed groove. The routed groove shall be sealed in accordance with Item P-605.

**d. Spall Repair.**

(1) **Material Requirements.** PCCP spall repairs in existing slabs shall be completed with a multi-purpose, high-strength, non-shrink, epoxy patching mortar. The material shall contain a combination of a high-quality epoxy resin, curing agent, and graded aggregates, meeting the requirements of Unitex “Pro-Poxy 2500,” or approved equal.

(2) **Surface Preparation.** Sawcut approximately 1-inch around the perimeter of the area to be patched and remove all deteriorated and unsound concrete with chipping hammers, not-to-exceed 30 lbs. Thoroughly clean the patch area by water blasting, or other method approved by the Engineer, and let repair area dry. Remove all dust and loose particles from the repair area.

(3) **Spall Material Placement.** Mix patching mortar per manufacturer’s instructions. Immediately place the material, following mixing, to prevent setup before finishing of the product. Set screeds or float to desired level, strike off, thoroughly compact and finish the surface. The material shall not be placed when the surface temperature is below 40 degrees F. The material shall be protected during cure time (5 – 7 days).

## MATERIAL ACCEPTANCE

**501-5.1 ACCEPTANCE SAMPLING AND TESTING.** All acceptance sampling and testing necessary to determine conformance with the requirements specified in this section, with the exception of coring for thickness determination, will be performed by the Engineer at no cost to the Contractor. The Contractor shall bear the cost of coring and filling operations, per paragraph 501-5.1b(1). Curing facilities will be provided by the Owner. Testing organizations performing these tests shall be accredited in accordance with ASTM C1077. The laboratory accreditation must be current and listed on the accrediting authority’s website. All test methods required for acceptance sampling and testing must be listed on the lab accreditation. A copy of the laboratory’s current accreditation and accredited test methods shall be submitted to the DEN Project Manager prior to start of construction.

A Pre-Work meeting will be held with the Contractor, Quality Control Lab, Quality Acceptance, and the DEN Project Manager to discuss the sampling and testing of the flexural strength specimens. The meeting shall include, but not be limited to, procedures for sampling, fabrication, handling, initial and final curing, and strength testing.

Concrete shall be accepted for strength and thickness on a lot basis.

A lot shall consist of a day's production not to exceed 4,000 square yards.

**a. Flexural Strength.**

(1) **Sampling.** Each lot shall be divided into four equal sublots. One sample shall be taken for each subplot from the plastic concrete delivered to the job site. Sampling locations shall be determined by the DEN Project Manager in accordance with random sampling procedures contained in ASTM D3665. The concrete shall be sampled in accordance with ASTM C172.

(2) **Testing.** Three (3) flexural strength specimens shall be made from each sample. The flexural strength specimens shall be fabricated in steel molds in accordance with ASTM C 31. If the flexural strength specimens are initially cured in the field, they shall be transported to the laboratory (for final curing and testing) while in the molds. The flexural strength specimens shall be standard cured including storage, initial curing, and final curing (for beams) in accordance with ASTM C 31 and tested for flexural strength in accordance with ASTM C 78. The flexural strength for each subplot shall be computed by averaging the results of the two test specimens representing that subplot. If a specimen tests abnormally low in strength indicating possible damage to that specimen, the hold specimen shall be tested and its results used in the average. Slump, air content, unit weight, and temperature tests in accordance with ASTM C 143, C 231, C 138 and C 1064 will also be conducted by the quality assurance laboratory for each set of flexural strength test samples.

(3) **Acceptance.** Acceptance of pavement for flexural strength will be determined by the DEN Project Manager in accordance with paragraph 501-5.2b.

**b. Pavement Thickness.**

(1) **Sampling.** Each lot shall be divided into four equal sublots and one core shall be taken by the Contractor for each subplot. Sampling locations shall be determined by the DEN Project Manager in accordance with random sampling procedures contained in ASTM D3665. Areas, such as thickened edges, with planned variable thickness, shall be excluded from sample locations.

Cores shall be neatly cut with a core drill. The Contractor shall furnish all tools, labor, and materials for cutting samples and filling the cored hole. Core holes shall be filled by the Contractor with a non-shrink grout approved by the DEN Project Manager within one day after sampling.

(2) **Testing.** The length of the cores shall be determined by the DEN Project Manager by the average caliper measurement in accordance with ASTM C174.

(3) **Acceptance.** Acceptance of pavement for thickness shall be determined by the DEN Project Manager in accordance with paragraph 501-5.2c.

**c. Partial Lots.** When operational conditions cause a lot to be terminated before the specified number of tests have been made for the lot, or when the Contractor and DEN Project Manager agree in writing to allow overages or minor placements to be considered as partial lots, the following procedure will be used to adjust the lot size and the number of tests for the lot.

Where three sublots have been produced, they shall constitute a lot. Where one or two sublots have been produced, they shall be incorporated into the next lot or the previous lot and the total number of sublots shall be used in the acceptance criteria calculation, that is,  $n=5$  or  $n=6$ .

**d. Outliers.** All individual flexural strength tests within a lot shall be checked for an outlier (test criterion) in accordance with ASTM E178, at a significance level of 5%. Outliers shall be discarded, and the percentage of material within specification limits (PWL) shall be determined using the remaining test values.

#### **501-5.2 ACCEPTANCE CRITERIA.**

**a. General.** Acceptance will be based on the following characteristics of the completed pavement discussed in paragraph 501-5.2e:

- (1) Flexural strength
- (2) Thickness
- (3) Smoothness
- (4) Grade
- (5) Edge slump

Flexural strength and thickness shall be evaluated for acceptance on a lot basis using the method of estimating PWL. Acceptance using PWL considers the variability (standard deviation) of the material and the testing procedures, as well as the average (mean) value of the test results to calculate the percentage of material that is above the lower specification tolerance limit (L).

Acceptance for flexural strength will be based on the criteria contained in accordance with paragraph 501-5.2e(1). Acceptance for thickness will be based on the criteria contained in paragraph 501-5.2e(2). Acceptance for smoothness will be based on the criteria contained in paragraph 501-5.2e(3). Acceptance for grade will be based on the criteria contained in paragraph 501-5.2e(4).

The DEN Project Manager may at any time, notwithstanding previous plant acceptance, reject and require the Contractor to dispose of any batch of concrete mixture which is rendered unfit for use due to contamination, segregation, or improper slump. Such rejection may be based on only visual inspection. In the event of such rejection, the Contractor may

take a representative sample of the rejected material in the presence of the DEN Project Manager, and if it can be demonstrated in the laboratory, in the presence of the DEN Project Manager, that such material was erroneously rejected, payment will be made for the material at the contract unit price.

**b. Flexural strength.** Acceptance of each lot of in-place pavement for flexural strength shall be based on PWL. The Contractor shall target production quality to achieve 90 PWL or higher.

**c. Pavement thickness.** Acceptance of each lot of in-place pavement shall be based on PWL. The Contractor shall target production quality to achieve 90 PWL or higher.

**d. Percentage of material within limits (PWL).** The PWL shall be determined in accordance with procedures specified in Section 110 of the General Provisions.

The lower specification tolerance limit (L) for flexural strength and thickness shall be:

**Lower Specification Tolerance Limit (L)**

Flexural Strength	0.93 × strength specified in paragraph 501-3.1
Thickness	Lot Plan Thickness in inches - 0.50 in

**e. Acceptance criteria.**

**(1) Flexural Strength.** If the PWL of the lot equals or exceeds 90%, the lot shall be acceptable. Acceptance and payment for the lot shall be determined in accordance with paragraph 501-8.1.

**(2) Thickness.** If the PWL of the lot equals or exceeds 90%, the lot shall be acceptable. Acceptance and payment for the lot shall be determined in accordance with paragraph 501-8.1.

**(3) Smoothness.** As soon as the concrete has hardened sufficiently, but not later than 48 hours after placement, the surface of each lot shall be tested in both longitudinal and transverse directions for smoothness to reveal all surface irregularities exceeding the tolerances specified. The Contractor shall furnish paving equipment and employ methods that produce a surface for each section of pavement having an average profile index meeting the requirements of paragraph 501-8.1c when evaluated with a profilograph; and the finished surface of the pavement shall not vary more than 1/4 inch when evaluated with a 12-foot straightedge. When the surface smoothness exceeds specification tolerances which cannot be corrected by diamond grinding of the pavement, full depth removal and replacement of pavement shall be to the limit of the longitudinal placement. Corrections involving diamond grinding will be subject to the final pavement thickness tolerances specified.

**(a) Transverse measurements.** Transverse measurements will be taken for each lot placed. Transverse measurements will be taken perpendicular to the pavement centerline each 50 feet or more often as determined by the DEN Project Manager.



i) Testing shall be continuous across all joints, starting with one-half the length of the straight edge at the edge of pavement section being tested and then moved ahead one-half the length of the straight edge for each successive measurement. Smoothness readings will not be made across grade changes or cross slope transitions; at these transition areas, the straightedge position shall be adjusted to measure surface smoothness and not design grade or cross slope transitions. The amount of surface irregularity shall be determined by placing the freestanding (unleveled) straightedge on the pavement surface and allowing it to rest upon the two highest spots covered by its length, and measuring the maximum gap between the straightedge and the pavement surface in the area between these two high points. Deviations on final pavement  $> 1/4$  inch in transverse direction shall be corrected with diamond grinding per paragraph 501-4.19g or by removing and replacing full depth of pavement. Grinding will be tapered in all directions to provide smooth transitions to areas not requiring grinding. The area corrected by grinding should not exceed 10% of the total area and these areas shall be retested after grinding. Each measurement shall be recorded and a copy of the data shall be furnished to the DEN Project Manager at the end of each days testing.

ii) The joint between lots shall be tested separately to facilitate smoothness between lots. The amount of surface irregularity shall be determined by placing the freestanding (unleveled) straightedge on the pavement surface, with half the straightedge on one side of the joint and the other half of the straightedge on the other side of the joint. Measure the maximum gap between the straightedge and the pavement surface in the area between these two high points. One measurement shall be taken at the joint every 50 feet or more often if directed by the DEN Project Manager. Maximum gap on final pavement surface  $> 1/4$  inch in transverse direction shall be corrected with diamond grinding per paragraph 501-4.19g or by removing and replacing full depth of surface. Each measurement shall be recorded and a copy of the data shall be furnished to the DEN Project Manager at the end of each days testing. Each measurement shall be recorded and a copy of the data shall be furnished to the DEN Project Manager at the end of each days testing.

**(b) Longitudinal measurements.** Longitudinal measurements will be taken for each lot placed. Longitudinal tests will be parallel to the centerline of paving; at the center of paving lanes when widths of paving lanes are less than 20 feet; and at the one third points of paving lanes when widths of paving lanes are 20 ft or greater.

i) **Longitudinal Short Sections.** Longitudinal Short Sections are when the longitudinal lot length is less than 200 feet and areas not requiring a profilograph. When approved by the DEN Project Manager, the first and last 15 feet of the lot can also be considered as short sections for smoothness. The finished surface shall not vary more than  $1/4$  inch when evaluated with a 12-foot straightedge. Smoothness readings will not be made across grade changes or cross slope transitions, at these transition areas, the straightedge position shall be adjusted to measure surface smoothness and not design grade or cross slope transitions. Testing shall be continuous across all joints, starting with one-half the length of the straight edge at the edge of pavement section being tested and then moved ahead one-half the length of the straight edge for each successive measurement. The amount of surface irregularity shall be determined by placing the freestanding (unleveled)

straightedge on the pavement surface and allowing it to rest upon the two highest spots covered by its length, and measuring the maximum gap between the straightedge and the pavement surface in the area between these two high points. Deviations on final pavement surface > 1/4 inch in longitudinal direction will be corrected with diamond grinding per paragraph 501-4.19g or by removing and replacing full depth of surface. Grinding will be tapered in all directions to provide smooth transitions to areas not requiring grinding. The area corrected by grinding should not exceed 10% of the total area and these areas shall be retested after grinding.

(4) **Grade.** An evaluation of the surface grade shall be made by the DEN Project Manager for compliance to the tolerances contained below. The finished grade of each lot will be determined by running levels at all joint intersections to determine the alignment and elevation of the completed pavement. Vertical survey shall be conducted on the high point of each joint intersection and compared to the plan elevations to determine the vertical deviation. The Contractor shall pay the cost of surveying and the surveying shall be performed by a licensed surveyor. The documentation, stamped and signed by a licensed surveyor, shall be provided by the Contractor to the DEN Project Manager.

When the grade exceeds specification tolerances which cannot be corrected by diamond grinding, full depth removal and replacement of pavement shall be to the limit of the pavement that allows for grade correction in accordance with Section 501-4.19. Corrections involving diamond grinding will be subject to the final pavement thickness tolerances specified. Patching shall not be permitted.

Grade shall be evaluated on the first day of placement and then every 5 days or less, so adjustments can be made to paving operations if measurements do not meet specification requirements. The contractor must submit the survey data to the DEN Project Manager by the following day after measurements have been taken. The DEN Project Manager must compare the surveyed grades with the grades shown on the contract drawings and document the analysis.

(a) **Lateral deviation.** Lateral deviation from established alignment of the pavement edge shall not exceed  $\pm 0.10$  feet in any lane.

(b) **Vertical deviation.** Vertical deviation from established grade shall not exceed  $\pm 0.04$  feet at any point.

When more than 15 percent of all the measurements within a lot are outside the specified tolerance, or if any one shot within the lot deviates  $\frac{3}{4}$  inch or more from planned grade, the Contractor shall remove and replace the deficient slabs to the full width, length and depth of the slab. Patching shall not be permitted. Isolated high points may be ground off provided that the course thickness is not greater than  $\frac{1}{4}$  inch deficient in the design thickness.

(5) **Edge slump.** When excessive edge slump cannot be corrected before the concrete has hardened, the area with excessive edge slump shall be removed and replaced at the expense of the Contractor as directed by the DEN Project Manager in accordance with paragraph 501-4.8a.

**f. Removal and replacement of concrete.** Any area or section of concrete that is removed and replaced shall be removed and replaced back to planned joints. The Contractor shall replace damaged dowels and the requirements for doweled longitudinal construction joints in paragraph 501-4.10 shall apply to all contraction joints exposed by concrete removal. Removal and replacement shall be in accordance with paragraph 501-4.20.

## CONTRACTOR QUALITY CONTROL

**501-6.1 QUALITY CONTROL PROGRAM.** The Contractor shall develop a Quality Control Program in accordance with Section 100 of the General Provisions. The program shall address all elements that affect the quality of the pavement including but not limited to:

- a. Mix Design
- b. Aggregate Gradation
- c. Quality of Materials
- d. Stockpile Management
- e. Proportioning
- f. Mixing and Transportation
- g. Placing and Consolidation
- h. Joints
- i. Dowel Placement and Alignment
- j. Flexural or Compressive Strength
- k. Finishing and Curing
- l. Surface Smoothness

**501-6.2 QUALITY CONTROL TESTING.** The Contractor shall perform all quality control tests necessary to control the production and construction processes applicable to this specification and as set forth in the Quality Control Program. The testing program shall include, but not necessarily be limited to, tests for aggregate gradation, aggregate moisture content, slump, and air content.

A Quality Control Testing Plan shall be developed as part of the Quality Control Program.

The Independent Testing Agency shall meet the requirements of Section 014525 including ASTM C 1077.

**a. Fine Aggregate.**

(1) **Gradation.** A sieve analysis shall be made at least twice daily in accordance with ASTM C136 from randomly sampled material taken from the discharge gate of storage bins or from the conveyor belt.

(2) **Moisture Content.** If an electric moisture meter is used, at least two direct measurements of moisture content shall be made per week to check the calibration. If direct measurements are made in lieu of using an electric meter, two tests shall be made per day. Tests shall be made in accordance with ASTM C70 or ASTM C566.

**b. Coarse Aggregate.**

(1) **Gradation.** A sieve analysis shall be made at least twice daily for each size of aggregate. Tests shall be made in accordance with ASTM C136 from randomly sampled material taken from the discharge gate of storage bins or from the conveyor belt.

(2) **Moisture Content.** If an electric moisture meter is used, at least two direct measurements of moisture content shall be made per week to check the calibration. If direct measurements are made in lieu of using an electric meter, two tests shall be made per day. Tests shall be made in accordance with ASTM C566.

**c. Slump.** After the start of each day's production and after batch plant shut down, the first three truckloads of concrete shall be tested for slump until three consecutive loads meet the project requirements. In addition, slump tests shall be performed at a minimum frequency of one test for every 100 cubic yards. Slump tests shall also be performed in conjunction with the DEN Project Manager's Quality Assurance Lab's sampling for flexural strength. The samples shall be obtained in accordance with ASTM C 172 from material discharged from trucks at the paving site and tested in accordance with ASTM C 143.

**d. Air Content.** After the start of each day's production and after batch plant shut down, the first three truckloads of concrete shall be tested for air content until three consecutive loads meet the project requirements. In addition, air content tests shall be performed at a minimum frequency of one test for every 100 cubic yards. Air content tests shall also be performed in conjunction with the DEN Project Manager's Quality Assurance Lab's sampling for flexural strength. The samples shall be obtained in accordance with ASTM C 172 from material discharged from trucks at the paving site and tested in accordance with ASTM C 231 for gravel and stone coarse aggregate and ASTM C 173 for slag or other porous coarse aggregate.

**e.** Unit weight and yield tests shall be made in conjunction with slump and air content tests. The samples shall be obtained in accordance with ASTM C 172 from material discharged from trucks at the paving site and tested in accordance with ASTM C 138.

**501-6.3 CONTROL CHARTS.** The Contractor shall maintain linear control charts for fine and coarse aggregate gradation, slump, moisture content and air content.

Control charts shall be posted in a location satisfactory to the DEN Project Manager and shall be kept up to date at all times. As a minimum, the control charts shall identify the project number, the contract item number, the test number, each test parameter, the Action and suspension Limits, or Specification limits, applicable to each test parameter, and the Contractor’s test results. The Contractor shall use the control charts as part of a process control system for identifying potential problems and assignable causes before they occur. If the Contractor’s projected data during production indicates a potential problem and the Contractor is not taking satisfactory corrective action, the DEN Project Manager may halt production or acceptance of the material.

**a. Fine and Coarse Aggregate Gradation.** The Contractor shall record the running average of the last five gradation tests for each control sieve on linear control charts. Specification limits contained in the Lower Specification Tolerance Limit (L) table above and the Control Chart Limits table below shall be superimposed on the Control Chart for job control.

**b. Slump and Air Content.** The Contractor shall maintain linear control charts both for individual measurements and range (that is, difference between highest and lowest of 2 consecutive tests) for slump and air content in accordance with the following Action and Suspension Limits.

**Control Chart Limits**

Control Parameter	Individual Measurements		Range Suspension Limit
	Action Limit	Suspension Limit	
<b>Slip Form:</b>			
Slump	+0 to -1 inch	+0.5 to -1.5 inch	±1.5 inch
Air Content	±1.2%	±1.8%	±2.5%
<b>Side Form:</b>			
Slump	+0.5 to -1 inch (13-25 mm)	+1 to -1.5 inch (25-38 mm)	±1.5 inch (38 mm)
Air Content	±1.5%	±1.8%	±2.5%

The individual measurement control charts shall use the mix design target values as indicators of central tendency.

**501-6.4 CORRECTIVE ACTION.** The Contractor Quality Control Program shall indicate that appropriate action shall be taken when the process is believed to be out of control. The Contractor Quality Control Program shall detail what action will be taken to bring the process into control and shall contain sets of rules to gauge when a process is out of control. As a minimum, a process shall be deemed out of control and corrective action taken if any one of the following conditions exists.

**a. Fine and Coarse Aggregate Gradation.** When two consecutive averages of five tests are outside of the specification limits in paragraph 501-2.1, immediate steps, including a halt to production, shall be taken to correct the grading.

**b. Fine and Coarse Aggregate Moisture Content.** Whenever the moisture content of the fine or coarse aggregate changes by more than 0.5%, the scale settings for the aggregate batcher and water batcher shall be adjusted.

**c. Slump.** The Contractor shall halt production and make appropriate adjustments whenever:

(1) One point falls outside the Action Limit line for individual measurements. The next load shall be tested. If its test falls outside the Action and Suspension Limits this load may be placed however; production is in Suspension and the process shall be brought into control in accordance with the Quality Control Plan. As a minimum testing during Suspension shall be performed at both the batch plant and at the point of placement until three (3) subsequent loads in succession meet the slump specifications at the point of placement. Any load not meeting slump specifications under Suspension shall not be placed

OR

(2) One point falls outside the Suspension Limit line for individual measurements or range. This load may remain in place. The process shall be brought into control in accordance with the Quality Control Plan. As a minimum testing during Suspension shall be performed at both the batch plant and at the point of placement until three (3) subsequent loads in succession meet the slump specifications at the point of placement. Any load not meeting slump specifications under Suspension shall not be placed.

**d. Air Content.** The Contractor shall halt production and adjust the amount of air-entraining admixture whenever:

(1) One point falls outside the Action Limit line for individual measurements, the next load shall be tested. If its test falls outside the Action and Suspension Limit this load may be placed however; production is in Suspension and the process shall be brought into control in accordance with the Quality Control Plan. As a minimum testing during Suspension shall be performed at both the batch plant and at the point of placement until three (3) subsequent loads in succession meet the air content specifications at the point of placement. Any load not meeting air content specifications under Suspension shall not be placed one point falls outside the Suspension Limit line for individual measurements or range

OR

(2) One point falls outside the Suspension Limit line for individual measurements or range. This load may remain in place. The process shall be brought into control in accordance with the Quality Control Plan. As a minimum testing during

Suspension shall be performed at both the batch plant and at the point of placement until three (3) subsequent loads in succession meet the air content specifications at the point of placement. Any load not meeting air content specifications under Suspension shall not be placed two points in a row fall outside the Action Limit line for individual measurements.

Whenever a point falls outside the Action Limits line, the air-entraining admixture dispenser shall be calibrated to ensure that it is operating correctly and with good reproducibility.

### **BASIS OF PAYMENT**

No measurement for payment is associated with this specification section. Payment will be made under specification section 31 23 23 Backfill and Surface Restoration.

### **TESTING REQUIREMENTS**

ASTM C31	Standard Practice for Making and Curing Concrete Test Specimens in the Field
ASTM C39	Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens
ASTM C70	Standard Test Method for Surface Moisture in Fine Aggregate
ASTM C78	Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)
ASTM C88	Standard Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate
ASTM C117	Standard Test Method for Materials Finer Than 75- $\mu$ m (No. 200) Sieve in Mineral Aggregates by Washing
ASTM C131	Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
ASTM C136	Standard Test Method for Sieve or Screen Analysis of Fine and Coarse Aggregates
ASTM C138	Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete
ASTM C142	Standard Test Method for Clay Lumps and Friable Particles in Aggregates
ASTM C143	Standard Test Method for Slump of Hydraulic-Cement Concrete
ASTM C172	Standard Practice for Sampling Freshly Mixed Concrete
ASTM C173	Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method

ASTM C174	Standard Test Method for Measuring Thickness of Concrete Elements Using Drilled Concrete Cores
ASTM C227	Standard Test Method for Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method)
ASTM C231	Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
ASTM C289	Standard Test Method for Potential Alkali-Silica Reactivity of Aggregates (Chemical Method)
ASTM C295	Standard Guide for Petrographic Examination of Aggregates for Concrete
ASTM C114	Standard Test Methods for Chemical Analysis of Hydraulic Cement
ASTM C311	Standard Test Methods for Sampling and Testing Fly Ash or Natural Pozzolans for Use in Portland Cement Concrete
ASTM C566	Standard Test Method for Total Evaporable Moisture Content of Aggregates by Drying
ASTM C642	Standard Test Method for Density, Absorption, and Voids in Hardened Concrete
ASTM C666	Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing
ASTM C1077	Standard Practice for Agencies Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Testing Agency Evaluation
ASTM C1260	Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)
ASTM C1567	Standard Test Method for Determining the Potential Alkali-Silica Reactivity of Combinations of Cementitious Materials and Aggregate (Accelerated Mortar-Bar Method)
ASTM C1602	Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete
ASTM D3665	Standard Practice for Random Sampling of Construction Materials
ASTM D4791	Standard Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate
ASTM E178	Standard Practice for Dealing With Outlying Observations
ASTM E1274	Standard Test Method for Measuring Pavement Roughness Using a Profilograph
U.S. Army Corps of Engineers (USACE) Concrete Research Division (CRD) C662	Determining the Potential Alkali-Silica Reactivity of Combinations of



Cementitious Materials, Lithium Nitrate Admixture and Aggregate  
(Accelerated Mortar-Bar Method)

### **MATERIAL REQUIREMENTS**

ASTM A184	Standard Specification for Welded Deformed Steel Bar Mats for Concrete Reinforcement
ASTM A615	Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement
ASTM A704	Standard Specification for Welded Steel Plain Bar or Rod Mats for Concrete Reinforcement
ASTM A706	Standard Specification for Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement
ASTM A714	Standard Specification for High-Strength Low-Alloy Welded and Seamless Steel Pipe
ASTM A775	Standard Specification for Epoxy-Coated Steel Reinforcing Bars
ASTM A934	Standard Specification for Epoxy-Coated Prefabricated Steel Reinforcing Bars
ASTM A996	Standard Specification for Rail-Steel and Axle-Steel Deformed Bars for Concrete Reinforcement
ASTM A1064	Standard Specification for Carbon-Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete
ASTM A1078	Standard Specification for Epoxy-Coated Steel Dowels for Concrete Pavement
ASTM C33	Standard Specification for Concrete Aggregates
ASTM C94	Standard Specification for Ready-Mixed Concrete
ASTM C150	Standard Specification for Portland Cement
ASTM C171	Standard Specification for Sheet Materials for Curing Concrete
ASTM C260	Standard Specification for Air-Entraining Admixtures for Concrete
ASTM C309	Standard Specification for Liquid Membrane-Forming Compounds for Curing Concrete
ASTM C494	Standard Specification for Chemical Admixtures for Concrete
ASTM C595	Standard Specification for Blended Hydraulic Cements
ASTM C618	Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
ASTM C881	Standard Specification for Epoxy-Resin-Base Bonding Systems for Concrete

ASTM C989	Standard Specification for Slag Cement for Use in Concrete and Mortars
ASTM D1751	Standard Specification for Preformed Expansion Joint Filler for Concrete Paving and Structural Construction (Non-extruding and Resilient Bituminous Types)
ASTM D1752	Standard Specification for Preformed Sponge Rubber and Cork and Recycled PVC Expansion Joint Fillers for Concrete Paving And Structural Construction
ACI 211.1	Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete
ACI 305R	Guide to Hot Weather Concreting
ACI 306R	Guide to Cold Weather Concreting
ACI 309R	Guide for Consolidation of Concrete
AC 150/5320-6	Airport Pavement Design and Evaluation
PCA	Design and Control of Concrete Mixtures

**END ITEM P-501**

## ITEM P-603 BITUMINOUS TACK COAT

### DESCRIPTION

**603-1.1** This item shall consist of preparing and treating a bituminous or concrete surface with bituminous material in accordance with these specifications and in reasonably close conformity to the lines shown on the plans.

### MATERIALS

**603-2.1 BITUMINOUS MATERIALS.** The bituminous material shall be an emulsified asphalt indicated in ASTM D3628 as a bituminous application for tack coat appropriate to local conditions or as designated by the DEN Project Manager.

### CONSTRUCTION METHODS

**603-3.1 WEATHER LIMITATIONS.** The tack coat shall be applied only when the existing surface is dry and the atmospheric temperature is 50°F or above; the temperature has not been below 35°F for the 12 hours prior to application; and when the weather is not foggy or rainy. The temperature requirements may be waived when directed by the DEN Project Manager.

**603-3.2 EQUIPMENT.** The Contractor shall provide equipment for heating and applying the bituminous material.

Provide a distributor with pneumatic tires of such size and number that the load produced on the base surface does not exceed 65.0 psi of tire width to prevent rutting, shoving or otherwise damaging the base, surface or other layers in the pavement structure. Design and equip the distributor to spray the bituminous material in a uniform coverage at the specified temperature, at readily determined and controlled rates from 0.05 to 2.0 gallons per square yard, with a pressure range of 25 to 75 psi and with an allowable variation from the specified rate of not more than  $\pm 5\%$ , and at variable widths. Include with the distributor equipment a separate power unit for the bitumen pump, full-circulation spray bars, tachometer, pressure gauges, volume-measuring devices, adequate heaters for heating of materials to the proper application temperature, a thermometer for reading the temperature of tank contents, and a hand hose attachment suitable for applying bituminous material manually to areas inaccessible to the distributor. Equip the distributor to circulate and agitate the bituminous material during the heating process. If the distributor is not equipped with an operable quick shutoff valve, the tack operations shall be started and stopped on building paper. The Contractor shall remove blotting sand prior to asphalt concrete lay down operations at no additional expense to the Owner.

A power broom and/or power blower suitable for cleaning the surfaces to which the bituminous tack coat is to be applied shall be provided.

**603-3.3 APPLICATION OF BITUMINOUS MATERIAL.** Immediately before applying the tack coat, the full width of surface to be treated shall be swept with a power broom and/or power blower to remove all loose dirt and other objectionable material.

Emulsified asphalt shall be diluted by the addition of water when directed by the DEN Project Manager and shall be applied a sufficient time in advance of the paver to ensure that all water has evaporated before the overlying mixture is placed on the tacked surface.

The bituminous material including vehicle shall be uniformly applied with a bituminous distributor at the rate of 0.05 to 0.10 gallons per square yard depending on the condition of the existing surface. The type of bituminous material and application rate shall be approved by the DEN Project Manager prior to application.

After application of the tack coat, the surface shall be allowed to cure without being disturbed for the period of time necessary to permit drying and setting of the tack coat. This period shall be determined by the DEN Project Manager. The Contractor shall protect the tack coat and maintain the surface until the next course has been placed.

**603-3.4 BITUMINOUS MATERIAL CONTRACTOR'S RESPONSIBILITY.** The Contractor shall provide a statement of source and character of the proposed bituminous material which must be submitted and approved by the DEN Project Manager before any shipment of bituminous materials to the project.

The Contractor shall furnish the vendor's certified test reports for each carload, or equivalent, of bituminous material shipped to the project. The DEN Project Manager may use the local state DOT agency supplier certification program for approval instead of the test reports. The tests reports shall be provided to and approved by the DEN Project Manager before the bituminous material is applied. If the bituminous material does not meet the specifications, it shall be replaced at the Contractor's expense. Furnishing the vendor's certified test report for the bituminous material shall not be interpreted as a basis for final acceptance. Samples may be taken and tested for verification by the DEN Project Manager when material is delivered to the site.

**603-3.5 FREIGHT AND WEIGH BILLS.** The Contractor shall submit waybills and delivery tickets, during progress of the work. Before the final statement is allowed, file with the DEN Project Manager certified waybills and certified delivery tickets for all bituminous materials used in the construction of the pavement covered by the contract. Do not remove bituminous material from storage until the initial outage and temperature measurements have been taken. The delivery or storage units will not be released until the final outage has been taken.

### **BASIS OF PAYMENT**

No measurement for payment is associated with this specification section. Payment will be made under specification section 31 23 23 Backfill and Surface Restoration.

### **MATERIAL REQUIREMENTS**

ASTM D633	Standard Volume Correction Table for Road Tar
ASTM D977	Standard Specification for Emulsified Asphalt
ASTM D1250	Standard Guide for Use of the Petroleum Measurement Tables
ASTM D2028	Standard Specification for Cutback Asphalt (Rapid-Curing Type)
ASTM D2397	Standard Specification for Cationic Emulsified Asphalt
ASTM D3628	Standard Practice for Selection and Use of Emulsified Asphalts

**END ITEM P-603**

## ITEM P-604A PREFORMED EXPANSION JOINT COMPRESSION SEALS

### DESCRIPTION

**604A-1.1** This item shall consist of a moisture tight sealing system for structural sealing of expansion joints in concrete pavement. The seal shall consist of an impermeable closed-cell, closed link, ethylene vinyl acetate, low-density polyethylene copolymer, nitrogen blown resilient, nonextrudable foam material with a Ultraviolet (UV) stabilizer added.

### MATERIALS

**604A-2.1 GENERAL.** The material shall be meet the following physical requirements in Table 1. The material must be jet fuel resistant, glycol compatible, and include a UV stabilizer.

**Table 1. Physical Requirements**

Test	Test Method	Requirements
Compression Set	ASTM D3575 Suffix B	10% - 2 Hr Recovery 9% - 24 Hr Recovery
Elongation at break	ASTM D3575 Suffix T	185% - 280%
Tensile Strength	ASTM D3575 Suffix T	92 - 140 psi
Tear Resistance	ASTM D624	10-20 lbs/in
Density	ASTM D3575 Suffix W	2.7 -3.4 lbs/ft <sup>3</sup>
Water Absorption	ASTM D3575 Suffix L	0.02 lbs/ft <sup>2</sup>
Weather/Deterioration	AASHTO T42	No Deterioration

**604A-2.2 ADHESIVE.** Adhesive used for the preformed foam compression seal shall be as recommended by the manufacturer.

**604A-2.3 DELIVERY AND STORAGE.** Materials delivered to the job site shall be inspected for defects, unloaded, and stored with a minimum of handling to avoid damage. Storage facilities shall be provided at the job site to protect materials from weather and to maintain them at temperatures as recommended by the manufacturer.

**604A-2.4 SUBMITTALS.** Certified copies of test results shall be provided in accordance with Section 013300 Submittal Procedures and 013325 Shop and Working Drawings, Product Data and Samples.

**a. Construction Equipment List.** List of proposed equipment to be used in the performance of construction work, including descriptive data, shall be provided in accordance with Section 013300 and Section 013325.

**b. Manufacturer's Instructions.** Where installation procedures, or any part thereof, are required to be in accordance with the manufacturer's recommendations, printed copies of the recommendations shall be furnished in accordance with Section 013300 and Section 013325. Installation of the material will not be allowed until the recommendations are received. Failure to furnish these recommendations can be a cause for rejection of the material.

**c. Test Reports/Samples.** The Contractor shall submit certified copies of the test reports and samples of the materials for approval in accordance with Section 013300 and Section 013325. Printed directions from the manufacturer on recommended installation criteria shall be furnished with the test reports, plus the manufacturer's certification that the selected seal is recommend for the installation on this project. No material will be used until it has been approved by the DEN Project Manager.

## EQUIPMENT

**604A-3.1** Machines, tools, and equipment used in the performance of the work required by this section shall be approved before the work is started and shall be maintained in satisfactory condition at all times.

**a. Joint Cleaning Equipment:**

(1) **Concrete Saw.** A self-propelled power saw with water cooled diamond or abrasive saw blades shall be provided for cutting joints to the depths and widths specified and for removing filler (existing old joint seal) or other material embedded in the joints or adhered to the joint faces.

(2) **Sandblasting Equipment.** Sandblasting shall not be permitted.

(3) **Waterblasting Equipment.** Waterblasting equipment shall include a trailer mounted water tank, pumps, high pressure hose, and a wand with safety release cutoff controls, nozzle, and auxiliary water resupply equipment. The water tank and auxiliary water resupply equipment shall be sufficient capacity to permit continuous operations. The pumps, hoses, wand, and nozzle shall be of sufficient capacity to permit the cleaning of both walls of the joint and the pavement surface for a width of at least 1/2 inch on either side of the joint. The pump shall be capable of supplying a pressure of at least 3,000 psi. A pressure gauge mounted at the pump shall show at all times the pressure in pounds per square inch at which the equipment is operating.

## CONSTRUCTION METHODS

**604A-4.1 GENERAL.** Installation of foam joint sealant shall comply with Manufacturer's instructions and recommendations for foam joint sealant installation complete with a compatible epoxy adhesive for adhesion to all surfaces.

Prior to installing foam joint sealant, make certain that surfaces to which adhesive will adhere are clean and free of dust, dirt and other residues that would inhibit a proper bond.

The Contractor shall make arrangements for the Manufacturer's representative to meet with the Contractor and the DEN Project Manager prior to the start of sealing operations to ensure the installation procedures are in accordance with the Manufacturer's direction. A representative of the joint sealant manufacturer shall visit the job-site a sufficient number of times during the sealing operations and after the sealing is completed to certify that the joint sealant was installed in accordance with the manufacturer's recommended methods and procedures

**604A-4.2 PREPARATION OF JOINTS.** Immediately before installation of the preformed joint seal, the joints shall be thoroughly cleaned full depth to remove all laitance, filler, old existing sealant, foreign material and protrusions of hardened concrete from the sides and upper edges of the joint space to be sealed. Any irregularity in the joint face, which would prevent uniform contact between the joint seal and the joint face shall be corrected prior to the installation of the joint seal. All joint faces shall be vertical.

**a. Sawing.** Joints shall be sawed to clean and to open them to the full specified width and depth. Immediately following the sawing operation, the joint faces and opening shall be thoroughly cleaned using a water jet to remove all saw cuttings or debris remaining on the faces or in the joint opening. Compression seal shall be installed within 3 calendar days of the time the individual joint cavity is sawed. Depth of sawing the cavity shall be between  $\frac{3}{4}$  and 1 inch deeper than the uncompressed depth of the seal, or otherwise recommended by the manufacturer. The saw cut for the joint seal cavity shall at all locations be centered over the joint line. The nominal width of the sawed joint seal cavity shall be as follows; the actual width shall be within a tolerance of plus or minus 1/16 inch or as noted in the details.

**b. Sandblast Cleaning.** Sandblasting shall not be permitted.

**c. Waterblast Cleaning.** The concrete joint faces and pavement surfaces extending at least 1/2 inch from the joint edges shall be water blasted clean. A multiple pass technique shall be used until the surfaces are free of dust, dirt, curing compound, or any residue that might prevent ready insertion or uniform contact of the seal and bonding of the adhesive to the concrete. After final cleaning and immediately prior to sealing, the joints shall be blown out with compressed air and left completely free of debris and water. When waterblast cleaning is used, slurry residue must be removed to provide a relatively dust free concrete surface.



**d. Rate of Progress.** The stages of joint preparation which includes waterblasting of the joint faces and air pressure cleaning of the joints shall be limited to only the linear footage of joint that can be sealed during the same workday.

**604A-4.3 TIME OF INSTALLATION.** Joints shall be sealed within 3 calendar days of sawing the joint seal cavity and immediately following concrete cure and the final cleaning of the joint walls. Open joints ready for sealing that cannot be sealed under the conditions specified herein shall be provided with an approved temporary seal to prevent infiltration of foreign material. When rain interrupts the sealing operations, the joints shall be washed, air pressure cleaned and allowed to dry prior to installing the lubricant/adhesive and preformed seal.

**604A-4.4 CLEAN UP.** Prior to Substantial Completion, all unused materials shall be removed from the site, any adhesive on the pavement surface shall be removed, and the pavement shall be left in clean condition.

**604A-4.5 WARRANTY.** The Manufacturer shall provide a warranty on the materials furnished for a minimum of 5 years from the date of acceptance by the DEN Project Manager. The Contractor shall provide a warranty on the installation for a minimum of 5 years from the date of acceptance by the DEN Project Manager.

### QUALITY CONTROL

**604A-5.1 PROCEDURES.** Quality control provisions shall be provided during the joint cleaning process to prevent or correct improper equipment and cleaning techniques that damages the concrete in any manner. Cleaned joints shall be approved by the DEN Project Manager prior to installation of the adhesive and preformed joint seal.

**604A-5.2 PRODUCT.** The joint sealing system (preformed seal) shall be inspected for proper rate of cure and bonding to the concrete, cuts, twists, nicks, and other deficiencies. Seals exhibiting any defects, at any time prior to final acceptance of the project, shall be removed from the joint, wasted, and replaced in a satisfactory manner.

### BASIS OF PAYMENT

No measurement for payment is associated with this specification section. Payment will be made under specification section 31 23 23 Backfill and Surface Restoration.

### TESTING REQUIREMENTS

AASHTO T42	Standard Specification for Preformed Expansion Joint Filler for Concrete Construction
ASTM D 6211	Test Strength of Conventional Vulcanized Rubber and Thermoplastic Elastomers
ASTM D 3575 SUFFIX B	Flexible Cellular Materials Made from Olefin Polymers
ASTM D 3575 SUFFIX L	Flexible Cellular Materials Made from Olefin Polymers

ASTM D 3575 SUFFIX T Flexible Cellular Materials Made from Olefin Polymers  
ASTM D 3575 SUFFIX W Flexible Cellular Materials Made from Olefin Polymers

**END OF ITEM P-604A**

## ITEM P-604B POLYCHLOROPRENE COMPRESSION JOINT SEALS

### DESCRIPTION

**604B-1.1** This item shall consist of preformed polychloroprene compression seals used for sealing joints of rigid pavements.

### MATERIALS

**604B-2.1 PREFORMED SEALS.** Preformed joint seal materials shall be a vulcanized elastomeric compound using polychloroprene as the only base polymer. The material and the manufactured seal itself shall conform to ASTM D 2628 and CRD C 548. The joint seal shall be a labyrinth type seal with the uncompressed depth of the seal greater than the uncompressed width of the seal. The actual width of the uncompressed seal shall be per manufacturer's recommendation for the widths of joint as shown on the Contract Drawings.

**604B-2.2 LUBRICANT/ADHESIVE.** Lubricant/adhesive used for the preformed elastomeric joint seal shall be a one component compound conforming to ASTM D 2835.

**604B-2.3 DELIVERY AND STORAGE.** Materials delivered to the job site shall be inspected for defects, unloaded, and stored with a minimum of handling to avoid damage. Storage facilities shall be provided at the job site to protect materials from weather and to maintain them at temperatures as recommended by the manufacturer.

**604B-2.4 SUBMITTALS.** Certified copies of test results shall be provided in accordance with Section 013300 Submittal Procedures and Section 013325 Shop and Working Drawings, Product Data and Samples.

**a. Construction Equipment List.** List of proposed equipment to be used in the performance of construction work, including descriptive data, shall be provided in accordance with Section 013300 and Section 013325.

**b. Manufacturer's Instructions.** Where installation procedures, or any part thereof, are required to be in accordance with the manufacturer's recommendations, printed copies of the recommendations shall be furnished in accordance with Section 013300 and Section 013325. Installation of the material will not be allowed until the recommendations are received. Failure to furnish these recommendations can be a cause for rejection of the material.

**c. Test Reports/Samples.** The Contractor shall submit certified copies of the test reports and samples of the materials for approval in accordance with Section 013300 and Section 013325. Printed directions from the manufacturer on recommended installation criteria shall be furnished with the test reports, plus the manufacturer's certification that the

selected seal is recommend for the installation on this project. No material will be used until it has been approved by the DEN Project Manager.

**604B-2.5 TEST REQUIREMENTS.** Each lot of compression joint seal and lubricant/adhesive shall be sampled, identified, and tested for conformance with the applicable material specification. A lot of preformed seal shall consist of one day's production or 20,000 linear feet for each cross-section, whichever is less. A lot of lubricant/adhesive shall consist of one day's production. No material shall be used at the project prior to receipt of written notice that the materials meet the laboratory requirements.

Testing of the preformed joint and lubricant/adhesive material shall be the responsibility of the Contractor and shall be performed in an approved independent laboratory and certified copies of the test reports shall be submitted for approval in accordance with Section 013300 and Section 013325, prior to the use of the materials at the job site. Samples of each lot of material shall also be submitted and will be retained by the DEN Project Manager for possible future testing should the materials appear defective during or after application. The Contractor shall furnish additional samples of materials, in sufficient quantity to be tested, upon request. Final acceptance will be based on conformance to the specified test requirements and the performance of the in-place materials.

## EQUIPMENT

**604B-3.1** Machines, tools, and equipment used in the performance of the work required by this section shall be approved before the work is started and shall be maintained in satisfactory condition at all times.

### a. Joint Cleaning Equipment

(1) **Concrete saw.** A self-propelled power saw with water cooled diamond or abrasive saw blades shall be provided for cutting joints to the depths and widths specified and for removing filler, existing old joint seal or other material embedded in the joints or adhered to the joint faces.

(2) **Sandblasting Equipment.** Sand blasting shall not be permitted.

(3) **Waterblasting Equipment.** Waterblasting equipment shall include a trailer mounted water tank, pumps, high pressure hose, a wand with safety release cutoff controls, nozzle, and auxiliary water resupply equipment. The water tank and auxiliary water resupply equipment shall be sufficient capacity to permit continuous operations. The pumps, hoses, wand, and nozzle shall be of sufficient capacity to permit the cleaning of both walls of the joint and the pavement surface for a width of at least 1/2 inch on either side of the joint. The pump shall be capable of supplying a pressure of at least 3,000 psi. A pressure gauge mounted at the pump shall show at all times the pressure in pounds per square inch at which the equipment is operating.

**b. Sealing Equipment.** Equipment used to install the preformed seal shall place the preformed seal to the prescribed depths within the specified tolerances without cutting, nicking, twisting, or otherwise damaging the seal. The equipment shall not stretch or compress the seal more than 1.5 percent longitudinally during installation. The machine shall be an automatic self-propelled joint seal application equipment and shall be engine powered. The machine shall include a reservoir for the lubricant/adhesive, a device for conveying the lubricant/adhesive in the proper quantities to the sides the preformed seal or the sidewalls of the joint, a reel capable of holding one full spool of compression seal, and a power-driven apparatus for feeding the joint seal through a compression device and inserting the seal into the joint. The equipment shall also include a guide to maintain the proper course along the joint being sealed. The machine shall at all times be operated by an experienced operator

Single axle type seal application equipment will not be permitted.

## CONSTRUCTION METHODS

**604B-4.1 ENVIRONMENTAL CONDITIONS.** The ambient temperature and the pavement temperature within the joint wall shall be at least 35°F and rising at the time of installation of the materials or per manufacturer’s installation procedures. Sealant application will not be permitted if moisture or any foreign material is observed in the joint.

**604B-4.2 TRIAL JOINT SEAL AND LUBRICANT/ADHESIVE INSTALLATION.** Prior to the cleaning and sealing of the joints for the entire project, a test section at least 200 feet long shall be prepared at a location directed in the project pavement using the specified materials and the approved equipment, so as to demonstrate the proposed joint preparation and sealing of all types of joints in the project. Following the completion of the trial length and before any other joint is sealed; the trial joints will be inspected by the DEN Project Manager and Manufacturer’s representative to determine that the materials and installation meet the requirements specified. If materials or installation do not meet requirements the materials shall be removed, and the joints shall be re-cleaned and resealed at no cost to the owner. No other joints shall be sealed until the test installation has been approved. If the trial section is approved, it may be incorporated into the permanent work. All other joints shall be sealed in the manner approved for sealing the trial joints.

**604B-4.3 PREPARATION OF JOINTS.** Immediately before installation of the compression joint seal, the joints shall be thoroughly cleaned to remove all laitance, filler, existing sealer, foreign material and protrusions of hardened concrete from the sides and upper edges of the joint space to be sealed. Cleaning shall be performed using equipment in accordance with paragraph 604B3.1a and shall extend along pavement surfaces at least 1/2 inch on either side of the joint. After final cleaning and immediately prior to sealing, the joints shall be blown out with compressed air and left completely free of debris and water. Demonstrate that the selected cleaning operation meets the cleanliness requirements. Any irregularity in the joint face that would prevent uniform contact between the joint seal and the joint face shall be corrected prior to the installation of the joint seal.

**a. Sawing.** Joints shall be sawed to clean and to open them to the full specified width and depth. Immediately following the sawing operation, the joint faces and opening shall be thoroughly cleaned using a water jet to remove all saw cuttings or debris remaining on the faces or in the joint opening. Compression seal shall be installed within 3 calendar days of the time the individual joint cavity is sawed. Depth of sawing the cavity shall be between  $\frac{3}{4}$  and 1 inch deeper than the uncompressed depth of the seal, or otherwise recommended by the manufacturer. The saw cut for the joint seal cavity shall at all locations be centered over the joint line. The nominal width of the sawed joint seal cavity shall be as follows; the actual width shall be within a tolerance of plus or minus 1/16 inch.

**b. Sandblast Cleaning.** Sandblasting shall not be permitted.

**c. Waterblast Cleaning.** The concrete joint faces and pavement surfaces extending at least 1/2 inch from the joint edges shall be water blasted clean. A multiple pass technique shall be used until the surfaces are free of dust, direct, curing compound, or any residue that might prevent ready insertion or uniform contact of the seal and bonding of the lubricant/adhesive to the concrete. After final cleaning and immediately prior to sealing, the joints shall be blown out with compressed air and left completely free of debris and water. When waterblast cleaning is used, slurry residue must be removed to provide a relatively dust free concrete surface.

**d. Rate of Progress.** Waterblasting of the joint faces and air pressure cleaning of the joints shall be limited to the linear footage of joint that can be sealed during the same workday.

#### **604B-4.4 INSTALLATION OF THE PREFORMED SEAL.**

**a. Time of Installation.** Joints shall be sealed within 3 calendar days of sawing the joint seal cavity and immediately following concrete cure and the final cleaning of the joint walls. Open joints ready for sealing that cannot be sealed under the conditions specified herein shall be provided with an approved temporary seal to prevent infiltration of foreign material. When rain interrupts the sealing operations, the joints shall be washed, air pressure cleaned and allowed to dry prior to installing the lubricant/adhesive and preformed seal.

**b. Sequence of Installation.** Longitudinal joints shall be sealed first, followed by transverse joints and then all other joints. Seals in longitudinal joints shall be cut so that all transverse joint seals will be intact from edge to edge of the pavement. Intersections shall be made monolithic by use of joint seal adhesive and care in fitting the intersection parts together. Extender pieces of seal shall not be used at intersections. Any seal falling short of the intersection shall be removed and replaced with new seal at no additional cost to the airport.

**604B-4.5 SEALING OF JOINTS.** The joint seal shall be installed using the equipment specified in paragraph 604B-3.1b. The sides of the joint seal or the sides of the joint shall be covered with a coating of lubricant/adhesive and the seal installed in such a manner as to conform to all requirements specified. Butt joints and seal intersections shall be sealed with sealant recommended by sealant Manufacturer. Lubricant/adhesive/sealant spilled on the pavement shall be removed immediately to prevent setting on the pavement. The in-place joint seal shall be in an upright position and free from twisting, distortion, and cuts. Adjustments shall be made to the installation equipment and procedure, if the stretch exceeds 1%. Any seal exceeding 2% stretch shall be removed and replaced. The joint seal shall be placed at a uniform depth within the tolerances specified. In-place joint seal which fails to meet the specified requirements shall be removed and replaced with new joint seal in a satisfactory manner at no additional cost to the owner. The preformed joint seal shall be placed to a depth as shown on the Contract Drawings. For chamfered joints or joints with a radius at the surface, the preformed joint seal shall be installed at a depth of 1/8 inch (3 mm), plus or minus 1/8 inch (3 mm), below the bottom of the edge of the chamfer or radius. No part of the seal shall be allowed to project above the surface of the pavement or above the edge of the chamfer or radius. The seal shall be installed in the longest practicable lengths in longitudinal joints and shall be cut at the joint intersections so as to provide continuous installation of the seal in the transverse joints. The lubricant/adhesive in the longitudinal shall be allowed to set for 1 hour prior to cutting at the joint intersections to reduce the possibility of shrinkage. For all transverse joints, the minimum length of the preformed joint seal shall be the pavement width form edge to edge.

**604B-4.6 CLEANUP.** Prior to Substantial Completion, all unused materials shall be removed from the site, any lubricant/adhesive on the pavement surface shall be removed, and the pavement shall be left in clean condition.

**604B-4.7 WARRANTY.** The Manufacturer shall provide a warranty on the materials furnished for a minimum of 5 years from the date of acceptance by the DEN Project Manager. The Contractor shall provide a warranty on the installation for a minimum of 2 years from the date of acceptance by the DEN Project Manager.

## QUALITY CONTROL

### 604B-5.1 QUALITY CONTROL PROVISIONS.

**a. Equipment.** The application equipment shall be inspected to assure uniform application of lubricant/adhesive to the sides of the preformed joint seal or the walls of the joint. If any equipment causes cutting, twisting, nicking, excessive stretching or compressing of the preformed seal, or improper application of the lubricant/adhesive the operation shall be suspended until causes of the deficiencies are determined and corrected.

**b. Procedures**

(1) Quality control provisions shall be provided during the joint cleaning process to prevent or correct improper equipment and cleaning techniques that damage the concrete in any manner. Cleaned joints shall be approved by the DEN Project Manager prior to installation of the lubricant/adhesive and preformed joint seal.

(2) Conformance to stretching and compression limitations shall be determined. After installation, the distance between the marks shall be measured on the pavement. If the stretching or compression exceeds the specified limit, the seal shall be removed and replaced with new joint seal at no additional cost to the owner. The seal shall be removed up to the last correct measurement. The seal shall be inspected a minimum of once per 100 feet (30 m) of seal for compliance to the shrinkage or compression requirements. Measurements shall also be made as directed to determine conformance with depth and width installation requirements. All preformed seal that is not in conformance with specification requirements shall be removed and replaced with new joint seal at no additional cost to the owner.

**c. Inspection.** The joint sealing system (preformed seal and lubricant/adhesive) shall be inspected by the DEN Project Manager for proper rate of cure and bonding to the concrete, cuts, twists, nicks, and other deficiencies. Seals exhibiting any defects, at any time prior to final acceptance of the project, shall be removed from the joint, wasted, and replaced in a satisfactory manner, as determined by the DEN Project Manager.

**BASIS OF PAYMENT**

No measurement for payment is associated with this specification section. Payment will be made under specification section 31 23 23 Backfill and Surface Restoration.

**TESTING REQUIREMENTS**

**U.S. ARMY CORPS OF ENGINEERS**

CRD C 548 Standard Specification for Jet Fuel and Heat Resistant Preformed Polychloroprene Elastomeric Joint Seals for Rigid Pavements.

**AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)**

ASTM D 2628 Preformed Polychloroprene Elastomeric Joint Seals for Concrete Pavements

ASTM D 2835 Lubricant for Installation of Preformed Compression Seals in Concrete Pavements.

**END OF ITEM P-604B**



## ITEM P-605 JOINT SEALANTS FOR CONCRETE PAVEMENTS

### DESCRIPTION

**605-1.1** This item shall consist of providing and installing a resilient and adhesive joint sealing material capable of effectively sealing joints and cracks in rigid pavements.

### MATERIALS

**605-2.1 JOINT SEALERS.** Joint sealant materials shall meet the requirements of ASTM D 5893.

Each lot or batch of sealant shall be delivered to the jobsite in the manufacturer's original sealed container. Each container shall be marked with the manufacturer's name, batch or lot number, the safe heating temperature, and shall be accompanied by the manufacturer's certification stating that the sealant meets the requirements of this specification.

**605-2.2 BACKER ROD.** The material furnished shall be a compressible, non-shrinking, non-staining, non-absorbing material that is non-reactive with the joint sealant. The material shall have a water absorption of not more than 5% when tested in accordance with ASTM C509. The backer-rod material shall be  $25\% \pm 5\%$  larger in diameter than the nominal width of the crack.

**605-2.3 BACKUP MATERIALS.** Provide backup material that is a compressible, non-shrinking, non-staining, non-absorbing material, nonreactive with the joint sealant. The material shall have a melting point at least  $5^{\circ}\text{F}$  ( $3^{\circ}\text{C}$ ) greater than the pouring temperature of the sealant being used when tested in accordance with ASTM D789. The material shall have a water absorption of not more than 5% of the sample weight when tested in accordance with ASTM C509. The backup material shall be  $25 \pm 5\%$  larger in diameter than the nominal width of the crack.

**605-2.4 BOND BREAKING TAPES.** Provide a bond breaking tape or separating material that is a flexible, non-shrinkable, non-absorbing, non-staining, and non-reacting adhesive-backed tape. The material shall have a melting point at least  $5^{\circ}\text{F}$  ( $3^{\circ}\text{C}$ ) greater than the pouring temperature of the sealant being used when tested in accordance with ASTM D789. The bond breaker tape shall be approximately 1/8 inch (3 mm) wider than the nominal width of the joint and shall not bond to the joint sealant.

## CONSTRUCTION METHODS

**605-3.1 TIME OF APPLICATION.** Joints shall be sealed as soon after completion of the curing period as feasible and before the pavement is opened to traffic, including construction equipment. The pavement temperature shall be 50°F (10°C) and rising at the time of application of the poured joint sealing material. Do not apply sealant if moisture is observed in the joint.

**605-3.2 EQUIPMENT.** Machines, tools, and equipment used in the performance of the work required by this section shall be approved before the work is started and maintained in satisfactory condition at all times. Submit a list of proposed equipment to be used in performance of construction work including descriptive data, [ ] days prior to use on the project.

**a. Concrete saw.** Provide a self-propelled power saw, with water-cooled diamond or abrasive saw blades, for cutting joints to the depths and widths specified or for refacing joints or cleaning sawed joints where water blasting does not provide a clean joint.

**b. Sandblasting equipment.** Sandblasting is not allowed.

**c. Waterblasting equipment.** Include with the waterblasting equipment a trailer-mounted water tank, pumps, high-pressure hose, wand with safety release cutoff control, nozzle, and auxiliary water resupply equipment. Provide water tank and auxiliary resupply equipment of sufficient capacity to permit continuous operations. The nozzle shall have an adjustable guide that will hold the nozzle aligned with the joint approximately one inch (25 mm) above the pavement surface. Adjust the height, angle of inclination and the size of the nozzle as necessary to obtain satisfactory results. A pressure gauge mounted at the pump shall show at all times the pressure in psi (kPa) at which the equipment is operating.

**d. Hand tools.** Hand tools may be used, when approved, for removing defective sealant from a crack and repairing or cleaning the crack faces.

**e. Cold-applied, single-component sealing equipment.** The equipment for installing ASTM D5893 single component joint sealants shall consist of an extrusion pump, air compressor, following plate, hoses, and nozzle for transferring the sealant from the storage container into the joint opening. The dimension of the nozzle shall be such that the tip of the nozzle will extend into the joint to allow sealing from the bottom of the joint to the top. Maintain the initially approved equipment in good working condition, serviced in accordance with the supplier's instructions, and unaltered in any way without obtaining prior approval. Small hand-held air-powered equipment (i.e., caulking guns) may be used for small applications.

### 605-3.3 PREPARATION OF JOINTS.

a. **Sawing.** All joints shall be sawed in accordance with specifications and plan details. Immediately after sawing the joint, the resulting slurry shall be completely removed from joint and adjacent area by flushing with a jet of water, and by use of other tools as necessary.

b. **Sealing.** Immediately before sealing, the joints shall be thoroughly cleaned of all remaining laitance, curing compound, filler, protrusions of hardened concrete, old sealant and other foreign material from the sides and upper edges of the joint space to be sealed. Cleaning shall be accomplished by concrete saw or water blaster, as specified in paragraph 605-3.2. The newly exposed concrete joint faces and the pavement surface extending a minimum of 1/2 inch (12 mm) from the joint edge shall be water blasted clean. Water blasting shall be accomplished in a minimum of two passes. One pass per joint face with the nozzle held at an angle directly toward the joint face and not more than 3 inches (75 mm) from it. After final cleaning and immediately prior to sealing, blow out the joints with compressed air and leave them completely free of debris and water. The joint faces shall be surface dry when the seal is applied.

c. **Back-up material.** When the joint opening is of a greater depth than indicated for the sealant depth, plug or seal off the lower portion of the joint opening using a back-up material to prevent the entrance of the sealant below the specified depth. Take care to ensure that the backup material is placed at the specified depth and is not stretched or twisted during installation.

d. **Bond-breaking tape.** Where inserts or filler materials contain bitumen, or the depth of the joint opening does not allow for the use of a backup material, insert a bond-breaker separating tape to prevent incompatibility with the filler materials and three-sided adhesion of the sealant. Securely bond the tape to the bottom of the joint opening so it will not float up into the new sealant.

**605-3.4 INSTALLATION OF SEALANTS.** Joints shall be inspected for proper width, depth, alignment, and preparation, and shall be approved by the DEN Project Manager before sealing is allowed. Sealants shall be installed in accordance with the following requirements:

Immediately preceding, but not more than 50 feet (15 m) ahead of the joint sealing operations, perform a final cleaning with compressed air. Fill the joints from the bottom up to 1/4 inch  $\pm$  1/16 inch (2 mm) below the pavement surface. Remove and discard excess or spilled sealant from the pavement by approved methods. Install the sealant in such a manner as to prevent the formation of voids and entrapped air. In no case shall gravity methods or pouring pots be used to install the sealant material. Traffic shall not be permitted over newly sealed pavement until authorized by the Contracting Officer. When a primer is recommended by the manufacturer, apply it evenly to the joint faces in accordance with the manufacturer's instructions. Check the joints frequently to ensure that the newly installed sealant is cured to a tack-free condition within the time specified.

**605-3.5 INSPECTION.** The Contractor shall inspect the joint sealant for proper rate of cure and set, bonding to the joint walls, cohesive separation within the sealant, reversion to liquid, entrapped air and voids. Sealants exhibiting any of these deficiencies at any time prior to the final acceptance of the project shall be removed from the joint, wasted, and replaced as specified at no additional cost to the airport.

**605-3.6 CLEAN-UP.** Upon completion of the project, remove all unused materials from the site and leave the pavement in a clean condition.

**605-3.7 FIELD TEST.** Before sealing the joints, the Contractor shall demonstrate that the equipment and procedures for preparing, mixing, and placing the sealant will produce a satisfactory joint seal. The demonstration shall include the preparation of at least two small batches and the application of the resulting material in five joints of at least 25 feet in length each. A representative of the joint sealant manufacturer shall be present at the demonstration to ensure that the installation procedures are in accordance with the manufacturer's recommended installation instructions.

**a. Testing For Cold-Applied Silicone Sealants.** When checking for adhesions of silicone, a pull test may be performed on the job site 21 days after the sealant has been placed.

(1) Make a knife cut horizontally across and through the silicone from one side of the joint to the other.

(2) Make a vertical cut approximately 2-3 inches long on each side of the joint starting at the horizontal cut, keeping the cuts the same length on each side.

(3) Hold the piece of silicone firmly and slowly pull at a 90° angle stretching the silicone not more than 10" per minute as if trying to pull the adhered silicone out of the joint.

(4) If adhesion is proper, the silicone will not pull out of the joint, but will eventually tear cohesively across the joint at the base of the knife cut.

**b.** If the silicone releases from the joint, adhesion has been affected. Several possible causes are:

- (1) Moisture in the joint during sealant application
- (2) Dirty or dusty joint sidewalls
- (3) Improper application (overfilling, etc.)
- (4) Spalling of the joint walls. (pieces of the concrete will be adhered to the silicone)

c. **Repair Of Sealant In Areas Of Adhesion Test.** The silicone sealant may be replaced by simply applying additional new silicone (normally using a tube of like silicone) in the same manner as it was originally placed, providing good adhesion was achieved. Proper preparation of the area should be performed prior to reapplying the silicone assuring the original silicone and the newly applied silicone are in good contact with each other.

**605-3.8 WARRANTY.** The manufacturer shall provide a warranty on the materials furnished for a minimum of 5 years from the date of acceptance by the Project Manager. The Contractor shall provide a warranty on the installation for a minimum of 2 years from the date of acceptance by the Project Manager.

### **BASIS OF PAYMENT**

No measurement for payment is associated with this specification section. Payment will be made under specification section 31 23 23 Backfill and Surface Restoration.

### **TESTING REQUIREMENTS**

ASTM D412	Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers – Tension
ASTM C509	Standard Specification for Elastomeric Cellular Preformed Gasket and Sealing Material
ASTM D1644	Standard Test Methods for Nonvolatile Content of Varnishes

### **MATERIAL REQUIREMENTS**

AC 150/5340-30	Design and Installation Details for Airport Visual Aids
ASTM D789	Standard Test Method for Determination of Relative Viscosity of Polyamide (PA)
ASTM D5893	Standard Specification for Cold Applied, Single Component, Chemically Curing Silicone Joint Sealant for Portland Cement Concrete Pavements
ASTM D6690	Standard Specification for Joint and Crack Sealants, Hot Applied, for Concrete and Asphalt Pavements

**END ITEM P-605**

## ITEM P-610 STRUCTURAL PORTLAND CEMENT CONCRETE

### DESCRIPTION

**610-1.1** This item shall consist of plain and reinforced structural portland cement concrete (PCC), prepared and constructed in accordance with these specifications, at the locations and of the form and dimensions shown on the plans. This specification shall be used for all structural and miscellaneous concrete including signage bases.

### MATERIALS

**610-2.1 GENERAL.** Only approved materials, conforming to the requirements of these specifications, shall be used in the work. Materials may be subject to inspection and tests at any time during their preparation or use. The source of all materials shall be approved by the DEN Project Manager before delivery or use in the work. Representative preliminary samples of the materials shall be submitted by the Contractor, when required, for examination and test. Materials shall be stored and handled to ensure preservation of their quality and fitness for use and shall be located to facilitate prompt inspection. All equipment for handling and transporting materials and concrete must be clean before any material or concrete is placed in them.

The use of pit-run aggregates shall not be permitted unless the pit-run aggregate has been screened and washed, and all fine and coarse aggregates stored separately and kept clean. The mixing of different aggregates from different sources in one storage stockpile or alternating batches of different aggregates shall not be permitted.

**a. Reactivity.** Fine and Coarse aggregates to be used in all concrete shall be evaluated and tested by the Contractor for alkali-aggregate reactivity in accordance with both ASTM C1260 and C1567. The laboratory performing the tests shall be accredited in accordance with ASTM C1077. The laboratory accreditation must be current and listed on the accrediting authority's website. Test method ASTM C1260 must be listed on the lab accreditation. A copy of the laboratory's current accreditation and accredited test methods shall be submitted to the DEN Project Manager prior to start of construction. Aggregate and mix proportion reactivity tests shall be performed for each project.

(1) Coarse and fine aggregate shall be tested separately in accordance with ASTM C1260. The aggregate shall be considered innocuous if the expansion of test specimens, tested in accordance with ASTM C1260, does not exceed 0.10% at 28 days (30 days from casting).

(2) Combined coarse and fine aggregate shall be tested in accordance with ASTM C1567, modified for combined aggregates, using the proposed mixture design proportions of aggregates, cementitious materials, and/or specific reactivity reducing

chemicals. If lithium nitrate is proposed for use with or without supplementary cementitious materials, the aggregates shall be tested in accordance with Corps of Engineers (COE) CRD C662. If lithium nitrate admixture is used, it shall be nominal 30% ±0.5% weight lithium nitrate in water.

(3) If the expansion of the proposed combined materials test specimens, tested in accordance with ASTM C1567, modified for combined aggregates, or COE CRD C662, does not exceed 0.10% at 28 days, the proposed combined materials will be accepted. If the expansion of the proposed combined materials test specimens is greater than 0.10% at 28 days, the aggregates will not be accepted unless adjustments to the combined materials mixture can reduce the expansion to less than 0.10% at 28 days, or new aggregates shall be evaluated and tested.

**610-2.2 COARSE AGGREGATE.** The coarse aggregate for concrete shall meet the requirements of ASTM C33. Crushed stone aggregate shall have a durability factor, as determined by ASTM C666, greater than or equal to 95. The DEN Project Manager may consider and reserve final approval of other State classification procedures addressing aggregate durability.

Coarse aggregate shall be well graded from coarse to fine and shall meet the following gradation shown in the table below when tested per ASTM C136.

**Gradation For Coarse Aggregate**

Sieve Designation (square openings)	Percentage by Weight Passing Sieves						
	2" (50 mm)	1-1/2" (38 mm)	1" (25 mm)	3/4" (19 mm)	1/2" (12 mm)	3/8" (9 mm)	No. 4
No. 4 to 3/4 in. (4.75-19 mm)			100	90-100		20-55	0-10
No. 4 to 1 in. (4.75-25 mm)		100	90-100		25-60		0-10
No. 4 to 1-1/2 in. (4.75-38 mm)	100	95-100		35-70		10-30	0-5

**a. Aggregate Susceptibility to Durability (D) Cracking.** Aggregates that have a history of D-cracking shall not be used.

**b.** Coarse aggregate may be accepted from sources that have a 20 year service history for the same gradation to be supplied with no durability issues.

(1) Material currently being produced shall have a durability factor ≥ 95 using ASTM C666. Coarse aggregates that are crushed granite, calcite cemented sandstone, quartzite, basalt, diabase, rhyolite or trap rock are considered to meet the D-cracking test but must meet all other quality tests. Aggregates meeting State Highway Department material specifications may be acceptable with concurrence of the FAA.

(2) The Contractor shall submit a current certification that the aggregate does not have a history of D-cracking and that the aggregate meets the state specifications for use in PCC pavement for use on interstate highways. Certifications, tests and any history reports must be for the same gradation as being proposed for use on the project. Certifications which are not dated or which are over one (1) year old or which are for different gradations will not be accepted. Test results will only be accepted when tests were performed by a State Department of Transportation (DOT) materials laboratory or an accredited laboratory.

**610-2.3 Fine Aggregate.** The fine aggregate for concrete shall meet the requirements of ASTM C33.

The fine aggregate shall be well graded from fine to coarse and shall meet the requirements of the table below when tested in accordance with ASTM C136:

**Gradation For Fine Aggregate**

<b>Sieve Designation (square openings)</b>	<b>Percentage by Weight Passing Sieves</b>
3/8 inch (9 mm)	100
No. 4 (4.75 mm)	95-100
No. 16 (1.18 mm)	45-80
No. 30 (0.60 mm)	25-55
No. 50 (0.30 mm)	10-30
No. 100 (0.15 mm)	2-10

Blending will be permitted, if necessary, to meet the gradation requirements for fine aggregate. Fine aggregate deficient in the percentage of material passing the No. 50 mesh sieve may be accepted, if the deficiency does not exceed 5% and is remedied by the addition of pozzolanic or cementitious materials other than Portland cement, as specified in paragraph 610-2.6, Admixtures, in sufficient quantity to produce the required workability as approved by the DEN Project Manager.

**610-2.4 CEMENT.** Cement shall conform to the requirements of ASTM C150 Type V.

If aggregates are deemed innocuous when tested in accordance with paragraph 610-2.1.a.1 and accepted in accordance with paragraph 610-2.1.a.3, higher equivalent alkali content in the cement may be allowed if approved by the DEN Project Manager and FAA. If cement becomes partially set or contains lumps of caked cement, it shall be rejected. Cement salvaged from discarded or used bags shall not be used.

The Contractor shall furnish vendors' certified test reports for each carload, or equivalent, of cement shipped to the project. The report shall be delivered to the DEN Project Manager



before use of the cement is granted. All test reports shall be subject to verification by testing sample materials received for use on the project.

**610-2.5 WATER.** The water used in concrete shall be fresh, clean and potable; free from injurious amounts of oils, acids, alkalis, salts, organic materials or other substances deleterious to concrete.

**610-2.6 ADMIXTURES.** The Contractor shall submit certificates indicating that the material to be furnished meets all of the requirements indicated below. In addition, the DEN Project Manager may require the Contractor to submit complete test data from an approved laboratory showing that the material to be furnished meets all of the requirements of the cited specifications. Subsequent tests may be made of samples taken by the DEN Project Manager from the supply of the material being furnished or proposed for use on the work to determine whether the admixture is uniform in quality with that approved.

**a. Air-Entraining Admixtures.** Air-entraining admixtures shall meet the requirements of ASTM C260 and shall consistently entrain the air content in the specified ranges under field conditions. The air-entrainment agent and any water reducer admixture shall be compatible.

**b. Water-Reducing Admixtures.** Water-reducing admixture shall meet the requirements of ASTM C494, Type A, B, or D. ASTM C494, Type F and G high range water reducing admixtures and ASTM C1017 flowable admixtures shall not be used.

**c. Other Chemical Admixtures.** The use of set retarding, and set-accelerating admixtures shall be approved by the DEN Project Manager. Retarding shall meet the requirements of ASTM C494, Type A, B, or D and set-accelerating shall meet the requirements of ASTM C494, Type C. Calcium chloride and admixtures containing calcium chloride shall not be used.

**d. Lithium Nitrate.** The lithium admixture shall be a nominal 30% aqueous solution of Lithium Nitrate, with a density of 10 pounds/gallon (1.2 kg/L), and shall have the approximate chemical form as shown below:

<u>Constituent</u>	<u>Limit (Percent by Mass)</u>
LiNO <sub>3</sub> (Lithium Nitrate)	30 ±0.5
SO <sub>4</sub> (Sulfate Ion)	0.1 (max)
Cl (Chloride Ion)	0.2 (max)
Na (Sodium Ion)	0.1 (max)
K (Potassium Ion)	0.1 (max)

Provide a trained representative to supervise the lithium nitrate admixture dispensing and mixing operations.

**e. Fly ash.** Fly ash shall meet the requirements of ASTM C618, with the exception of loss of ignition, where the maximum shall be less than 6%. Fly ash for use in mitigating alkali-silica reactivity shall have a Calcium Oxide (CaO) content of less than 13%.

**610-2.7 PREMOLDED JOINT MATERIAL.** Premolded joint material for expansion joints shall meet the requirements of ASTM D1751.

**610-2.8 JOINT FILLER.** The filler for joints shall meet the requirements of Item P-605, unless otherwise specified.

**610-2.9 STEEL REINFORCEMENT.** Reinforcing shall consist of bar mats conforming to the requirements of ASTM A184.

**610-2.10 MATERIALS FOR CURING CONCRETE.** Curing materials shall conform to ASTM C309.

### CONSTRUCTION METHODS

**610-3.1 GENERAL.** The Contractor shall furnish all labor, materials, and services necessary for, and incidental to, the completion of all work as shown on the drawings and specified here. All machinery and equipment used by the Contractor on the work, shall be of sufficient size to meet the requirements of the work. All work shall be subject to the inspection and approval of the DEN Project Manager.

**610-3.2 CONCRETE COMPOSITION.** The concrete shall develop a compressive strength of identified below in 28 days as determined by test cylinders made in accordance with ASTM C31 and tested in accordance with ASTM C39.

a. 3000 psi for concrete encased lighting ducts and light cans under P-401 asphalt or P-501 concrete paving, within econocrete/CTB or ATPB, and elsewhere as noted in the plans and specifications

b. 4,000 psi for structural concrete and elsewhere as noted in the plans and specifications

c. 1,200 psi at 7 days for repair of cement treated base course

The concrete shall contain not less than 470 pounds of cementitious material (cement plus fly ash) per cubic yard. The concrete shall contain 5% of entrained air,  $\pm 1\%$ , as determined by ASTM C231 and shall have a slump of not more than 4 inches as determined by ASTM C143.

**610-3.3 ACCEPTANCE SAMPLING AND TESTING.** Concrete for each structure will be accepted on the basis of the compressive strength specified in paragraph 610-3.2. The concrete shall be sampled in accordance with ASTM C172. The first load of concrete, per mix, delivered each day will be sampled and tested.

Concrete placed for structures will be sampled and tested for each additional 50 cubic yards per day with a minimum one test per structure. When a single load of concrete is used for more than one structure, that load will be sampled and tested once.

Concrete placed for light cans will be sampled and tested for each additional 50 cubic yards per day.

Lean concrete will be sampled and tested for each additional 50 cubic yards per day.

Concrete cylindrical compressive strength specimens shall be made in accordance with ASTM C31 and tested in accordance with ASTM C39. Concrete strengths for acceptance shall be the average of at least two 6 by 12 inch or at least three 4 by 8 inch cylinders tested at 28 days. Contractor shall provide the initial on-site storage facilities for the specimens. The on-site storage facilities shall be capable of maintaining a temperature range of 60 to 80°F. The Contractor shall cure and store the test specimens under such conditions as directed by the Engineer. The DEN Project Manager will make the actual tests on the specimens at no expense to the Contractor.

**610-3.4 QUALIFICATIONS FOR CONCRETE TESTING SERVICE.** Perform concrete testing by an approved laboratory and inspection service experienced in sampling and testing concrete. Testing agency must meet the requirements of ASTM C1077 or ASTM E329.

**610-3.5 PROPORTIONING AND MEASURING DEVICES.** When package cement is used, the quantity for each batch shall be equal to one or more whole sacks of cement. The aggregates shall be measured separately by weight. If aggregates are delivered to the mixer in batch trucks, the exact amount for each mixer charge shall be contained in each batch compartment. Weighing boxes or hoppers shall be approved by the DEN Project Manager and shall provide means of regulating the flow of aggregates into the batch box so the required, exact weight of aggregates is obtained.

**610-3.6 CONSISTENCY.** The consistency of the concrete shall be determined by the slump test specified in ASTM C143.

**610-3.7 MIXING.** Concrete may be mixed at the construction site, at a central point, or wholly or in part in truck mixers. The concrete shall be mixed and delivered in accordance with the requirements of ASTM C94.

**610-3.8 MIXING CONDITIONS.** The concrete shall be mixed only in quantities required for immediate use. Concrete shall not be mixed while the air temperature is below 40°F without permission of the DEN Project Manager. If permission is granted for mixing under such conditions, aggregates or water, or both, shall be heated and the concrete shall be placed at a temperature not less than 50°F nor more than 100°F. The Contractor shall be held responsible for any defective work, resulting from freezing or injury in any manner during placing and curing, and shall replace such work at his expense.

Retempering of concrete by adding water or any other material shall not be permitted.

The rate of delivery of concrete to the job shall be sufficient to allow uninterrupted placement of the concrete.

**610-3.9 FORMS.** Concrete shall not be placed until all the forms and reinforcements have been inspected and approved by the DEN Project Manager. Forms shall be of suitable material and shall be of the type, size, shape, quality, and strength to build the structure as shown on the plans. The forms shall be true to line and grade and shall be mortar-tight and sufficiently rigid to prevent displacement and sagging between supports. The surfaces of forms shall be smooth and free from irregularities, dents, sags, and holes. The Contractor shall be responsible for their adequacy.

The internal form ties shall be arranged so no metal will show in the concrete surface or discolor the surface when exposed to weathering when the forms are removed. All forms shall be wetted with water or with a non-staining mineral oil, which shall be applied immediately before the concrete is placed. Forms shall be constructed so they can be removed without injuring the concrete or concrete surface. The forms shall not be removed until at least 30 hours after concrete placement for vertical faces, walls, slender columns, and similar structures. Forms supported by falsework under slabs, beams, girders, arches, and similar construction shall not be removed until tests indicate the concrete has developed at least 60% of the design strength.

**610-3.10 PLACING REINFORCEMENT.** All reinforcement shall be accurately placed, as shown on the plans, and shall be firmly held in position during concrete placement. Bars shall be fastened together at intersections. The reinforcement shall be supported by approved metal chairs. Shop drawings, lists, and bending details shall be supplied by the Contractor when required.

**610-3.11 EMBEDDED ITEMS.** Before placing concrete, all embedded items shall be firmly and securely fastened in place as indicated. All embedded items shall be clean and free from coating, rust, scale, oil, or any foreign matter. The concrete shall be spaded and consolidated around and against embedded items. The embedding of wood shall not be allowed.

**610-3.12 PLACING CONCRETE.** All concrete shall be placed during daylight hours, unless otherwise approved. The concrete shall not be placed until the depth and condition of foundations, the adequacy of forms and falsework, and the placing of the steel reinforcing have been approved by the DEN Project Manager. Concrete shall be placed as soon as practical after mixing, but in no case later than one (1) hour after water has been added to the mix. The method and manner of placing shall avoid segregation and displacement of the reinforcement. Troughs, pipes, and chutes shall be used as an aid in placing concrete when necessary. The concrete shall not be dropped from a height of more than 5 feet. Concrete shall be deposited as nearly as practical in its final position to avoid segregation due to rehandling or flowing. Do not subject concrete to procedures which cause segregation. Concrete shall be placed on clean, damp surfaces, free from running water, or on a properly consolidated soil foundation.

**610-3.13 VIBRATION.** Vibration shall follow the guidelines in American Concrete Institute (ACI) Committee 309, Guide for Consolidation of Concrete. Where bars meeting ASTM A775 or A934 are used, the vibrators shall be equipped with rubber or non-metallic vibrator heads. Furnish a spare, working, vibrator on the job site whenever concrete is placed.

Consolidate concrete slabs greater than 4 inches in depth with high frequency mechanical vibrating equipment supplemented by hand spading and tamping. Consolidate concrete slabs 4 inches or less in depth by wood tampers, spading, and settling with a heavy leveling straightedge. Operate internal vibrators with vibratory element submerged in the concrete, with a minimum frequency of not less than 6000 cycles per minute when submerged. Do not use vibrators to transport the concrete in the forms. Penetrate the previously placed lift with the vibrator when more than one lift is required. Use external vibrators on the exterior surface of the forms when internal vibrators do not provide adequate consolidation of the concrete. Vibrators shall be manipulated to work the concrete thoroughly around the reinforcement and embedded fixtures and into corners and angles of the forms. The vibration at any point shall be of sufficient duration to accomplish compaction but shall not be prolonged to where segregation occurs. Concrete deposited under water shall be carefully placed in a compact mass in its final position by means of a tremie or other approved method and shall not be disturbed after placement.

**610-3.14 CONSTRUCTION JOINTS.** If the placement of concrete is suspended, necessary provisions shall be made for joining future work before the placed concrete takes its initial set. For the proper bonding of old and new concrete, provisions shall be made for grooves, steps, reinforcing bars or other devices as specified. The work shall be arranged so that a section begun on any day shall be finished during daylight of the same day. Before depositing new concrete on or against concrete that has hardened, the surface of the hardened concrete shall be cleaned by a heavy steel broom, roughened slightly, wetted, and covered with a neat coating of cement paste or grout.

**610-3.15 EXPANSION JOINTS.** Expansion joints shall be constructed at such points and dimensions as indicated on the drawings. The premolded filler shall be cut to the same shape as the surfaces being joined. The filler shall be fixed firmly against the surface of the concrete already in place so that it will not be displaced when concrete is deposited against it.

**610-3.16 DEFECTIVE WORK.** Any defective work discovered after the forms have been removed, which in the opinion of the DEN Project Manager cannot be repaired satisfactorily, shall be immediately removed and replaced at the expense of the Contractor. Defective work shall include deficient dimensions, or bulged, uneven, or honeycomb on the surface of the concrete.

**610-3.17 SURFACE FINISH.** All exposed concrete surfaces shall be true, smooth, and free from open or rough areas, depressions, or projections. All concrete horizontal plane surfaces shall be brought flush to the proper elevation with the finished top surface struck-off with a straightedge and floated. Mortar finishing shall not be permitted, nor shall dry cement or sand-cement mortar be spread over the concrete during the finishing of horizontal plane surfaces.

The surface finish of exposed concrete shall be a rubbed finish. If forms can be removed while the concrete is still green, the surface shall be wetted and then rubbed with a wooden float until all irregularities are removed. If the concrete has hardened before being rubbed, a carborundum stone shall be used to finish the surface. When approved, the finishing can be done with a finishing machine.

**610-3.18 CURING AND PROTECTION.** All concrete shall be properly cured and protected by the Contractor. The concrete shall be protected from the weather, flowing water, and from defacement of any nature during the project. The concrete shall be cured by covering with an approved material as soon as it has sufficiently hardened. Water-absorptive coverings shall be thoroughly saturated when placed and kept saturated for at least three (3) days following concrete placement. All curing mats or blankets shall be sufficiently weighted or tied down to keep the concrete surface covered and to prevent the surface from being exposed to air currents. Wooden forms shall be kept wet at all times until removed to prevent opening of joints and drying out of the concrete. Traffic shall not be allowed on concrete surfaces for seven (7) days after the concrete has been placed.

**610-3.19 DRAINS OR DUCTS.** Drainage pipes, conduits, and ducts that are to be encased in concrete shall be installed by the Contractor before the concrete is placed. The pipe shall be held rigidly so that it will not be displaced or moved during the placing of the concrete.

**610-3.20 COLD WEATHER PROTECTION.** When concrete is placed at temperatures below 40°F, the Contractor shall provide satisfactory methods and means to protect the mix from injury by freezing. The aggregates, or water, or both, shall be heated to place the concrete at temperatures between 50°F and 100°F.

Calcium chloride may be incorporated in the mixing water when directed by the DEN Project Manager. Not more than 2 pounds of Type 1 nor more than 1.6 pounds of Type 2 shall be added per bag of cement. After the concrete has been placed, the Contractor shall provide sufficient protection such as cover, canvas, framework, heating apparatus, etc., to enclose and protect the structure and maintain the temperature of the mix at not less than 50°F until at least 60% of the designed strength has been attained.

**610-3.21 HOT WEATHER PLACING.** Concrete shall be properly placed and finished with procedures previously submitted. The concrete-placing temperature shall not exceed 85°F when measured in accordance with ASTM C1064. Cooling of the mixing water and aggregates, or both, may be required to obtain an adequate placing temperature. A retarder meeting the requirements of paragraph 610-2.6 may be used to facilitate placing and finishing. Steel forms and reinforcement shall be cooled prior to concrete placement when steel temperatures are greater than 120°F. Conveying and placing equipment shall be cooled if necessary to maintain proper concrete-placing temperature. Submit the proposed materials and methods for review and approval by the DEN Project Manager, if concrete is to be placed under hot weather conditions.

**610-3.22 FILLING JOINTS.** All joints that require filling shall be thoroughly cleaned, and any excess mortar or concrete shall be cut out with proper tools. Joint filling shall not start until after final curing and shall be done only when the concrete is completely dry. The cleaning and filling shall be done with proper equipment to obtain a neat looking joint free from excess filler.

## BASIS OF PAYMENT

No measurement for payment is associated with this specification section. Payment will be made under specification section 31 23 23 Backfill and Surface Restoration.

## TESTING REQUIREMENTS

ASTM C31	Standard Practice for Making and Curing Concrete Test Specimens in the Field
ASTM C39	Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens
ASTM C136	Standard Test Method for Sieve or Screen Analysis of Fine and Coarse Aggregates
ASTM C138	Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete
ASTM C143	Standard Test Method for Slump of Hydraulic-Cement Concrete
ASTM C231	Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
ASTM C666	Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing
ASTM C1017	Standard Specification for Chemical Admixtures for Use in Producing Flowing Concrete
ASTM C1064	Standard Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete
ASTM C1077	Standard Practice for Agencies Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Testing Agency Evaluation
ASTM C1260	Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)
ASTM C1567	Standard Test Method for Determining the Potential Alkali-Silica Reactivity of Combinations of Cementitious Materials and Aggregates (Accelerated Mortar-Bar Method)
ASTM E329	Standard Specification for Agencies Engaged in Construction Inspection, Testing, or Special Inspection
U.S. Army Corps of Engineers (USACE) Concrete Research Division (CRD) C662	Determining the Potential Alkali-Silica Reactivity of Combinations of Cementitious Materials, Lithium Nitrate Admixture and Aggregate (Accelerated Mortar-Bar Method)

## MATERIAL REQUIREMENTS

ASTM A184	Standard Specification for Welded Deformed Steel Bar Mats for Concrete Reinforcement
ASTM A185	Standard Specification for Steel Welded Wire Reinforcement, Plain, for Concrete
ASTM A615	Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement
ASTM A704	Standard Specification for Welded Steel Plain Bar or Rod Mats for Concrete Reinforcement
ASTM A706	Standard Specification for Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement
ASTM A775	Standard Specification for Epoxy-Coated Steel Reinforcing Bars
ASTM A934	Standard Specification for Epoxy-Coated Prefabricated Steel Reinforcing Bars
ASTM A1064	Standard Specification for Carbon-Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete
ASTM C33	Standard Specification for Concrete Aggregates
ASTM C94	Standard Specification for Ready-Mixed Concrete
ASTM C150	Standard Specification for Portland Cement
ASTM C171	Standard Specification for Sheet Materials for Curing Concrete
ASTM C172	Standard Practice for Sampling Freshly Mixed Concrete
ASTM C260	Standard Specification for Air-Entraining Admixtures for Concrete
ASTM C309	Standard Specification for Liquid Membrane-Forming Compounds for Curing Concrete
ASTM C494	Standard Specification for Chemical Admixtures for Concrete
ASTM C595	Standard Specification for Blended Hydraulic Cements
ASTM C618	Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
ASTM D1751	Standard Specification for Preformed Expansion Joint Filler for Concrete Paving and Structural Construction (Nonextruding and Resilient Asphalt Types)
ASTM D1752	Standard Specification for Preformed Sponge Rubber Cork and Recycled PVC Expansion Joint Fillers for Concrete Paving and Structural Construction
ACI 305R	Hot Weather Concreting
ACI 306R	Cold Weather Concreting
ACI 309R	Guide for Consolidation of Concrete



**END OF ITEM P-610**