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SECTION 600 STRUCTURAL CONCRETE

Scope: The work under this section includes the furnishing of all labor and materials necessary for the construction of the reinforced concrete structures according to the plans and these specifications. Structural concrete shall be defined as mass concrete with steel reinforcement exceeding 0.3% of concrete cross sectional area.

601 SUBMITTALS

Detailed shop drawings and schedules shall be submitted as required by the Engineer covering all reinforcement in ample time to be checked and to permit corrected drawings to be delivered to the Engineer well in advance of the time for proceeding with the work. These drawings shall show the size, number, exact position and spacing of steel reinforcement and the exact location of all openings, framing, or special conditions affecting the work. Detailing of reinforcement shall conform to ACI 315.

602 PREPARATION FOR PLACEMENT

602.01 General

Before placement, all equipment for mixing and transporting the concrete shall be cleaned, and all debris and ice shall be removed from the places to be occupied by the concrete. Forms shall be thoroughly oiled, and masonry filler units that will be in contact with concrete shall be water saturated (except in freezing weather). The reinforcement shall be free of ice, dirt, rust, mill scale, or other coatings.

Water shall be removed from place of deposit before the concrete is placed unless otherwise permitted by the Architect or the Engineer. All laitance and other unsound material shall be removed from hardened concrete before additional concrete is added.

Preparation prior to concreting includes compacting, trimming, and moistening the subgrade, erecting the forms, and setting the reinforcing steel. A moist subgrade is especially important in hot weather to prevent extraction of water from the concrete. Where concrete is to be deposited on rock, all loose material should be removed before concrete is placed. When rock must be cut out, the surfaces in general should be vertical or horizontal rather than sloping. Forms shall be clean, tight, adequately braced, and constructed of materials that will impart the desired texture to the finished concrete. Sawdust, nails, and other debris shall be removed before concrete is placed. Wood forms shall be oiled before placing concrete.

602.02 Placement on Hardened Concrete

When fresh concrete is placed on hardened concrete, certain precautions shall be taken to secure well-bonded, watertight joint. The hardened concrete should be fairly level, reasonably rough, clean, and moist. Some coarse aggregate particles shall be exposed and any laitance or soft mortar shall be removed from the top surface of the hardened concrete.

For structures requiring more than one lift, the top of the lower course shall be broomed, just before it sets, with a steel or stiff fiber broom. The surface shall be level but heavily scored and free of laitance. It must then be protected and thoroughly cleaned just before the grout coat and top course are placed. Hardened concrete shall be moistened thoroughly before new concrete is placed on it. Where the surface has dried out it shall be saturated for 24 hours. No pools of water shall be left standing on the wetted surface when the new concrete is placed.

602.03 Structural Concrete on Rock

Where concrete is to be placed on rock, the rock should be thoroughly cleaned and concrete placed so as to fill all irregularities in its surface.

603 REINFORCEMENT

The reinforcing bars shall be in conformity with ASTM A-615 SI Grade 40 and Grade 60 and the general notes on the structural drawings. Welded wire fabric for concrete reinforcing shall conform to ASTM A-82 and A-185. Dowels, conforming to the requirements of ASTM A-15, shall be intermediate grade plain bars rolled from billet stock.

603.01 Cleaning

Reinforcement prior to depositing of concrete shall be free from rust, scale, oil, ice, or other coatings that will destroy or reduce the bond, including mortar from previous concrete pours.

603.02 Bending

Reinforcement shall be bent cold. Bars shall be full length required and accurately bent to details. No bars partially embedded in concrete shall be field bent except as shown on the drawings or specifically permitted by the Engineer.

603.03 Placing

Reinforcement shall be accurately located in forms and firmly held in place before and during the depositing of concrete by means of metallic supports, metal chairs, spacer bars, tie wire or other devices adequate to insure against displacement during the course of construction.

Reinforcement shall be protected by the thickness of concrete cover as follows:

- A. Where concrete is deposited against the ground without the use of forms not less than 3 inches.
- B. Where concrete is exposed to weather or ground but placed in forms not less than two inches (2") for bars larger than No. 5 and 1-1/2 inch for No. 5 or smaller.
- C. Slabs and walls not exposed to ground or weather not less than 3/4 inch.
- D. Beams, girders, and columns not exposed to ground or weather not less than 1-1/2 inches. Where the above requirements conflict with the ASI Handbook, the greater requirement shall govern.

Exposed reinforcing bars intended for bonding with future extensions shall be protected from corrosion by adequate covering.

603.04 Splicing

Wherever it is necessary to splice reinforcement other than as shown on the drawings, the character of the splice shall be approved by the Engineer on the basis of allowable bond stress in the reinforcement at the splice. Splicing shall not be made at points of maximum stress nor shall adjacent bars be spliced at the same point. (Lap distance shall be 24 diameters, or as specified).

603.05 Welded Wire Fabric

Welded wire fabric shall be laid continuously with edges and ends overlapping adjoining sheets a minimum of 6" tied and placed over all piping and conduits. The fabric shall be lifted by approved methods to the designed location of all slabs during the depositing of concrete, or properly supported in this position. Where required, bulkheads at construction joints and all screeds shall be constructed in such a manner as to place the fabric in the proper position.

604 CONSTRUCTION JOINTS

Construction joints will occur at 10' intervals unless otherwise specified in plans.

A delay until the concrete is no longer plastic in columns or walls must occur before concrete is placed in the beams, girders, or slabs to be supported. Beams, girders, brackets, column capitals, and haunches shall be considered as part of the floor system and shall be placed integrally with it.

Construction joints in floors shall be located near the middle of the spans of slabs, beams, or girders. If a beam intersects a girder at this point, the joint in the girder shall be offset a distance equal to twice the beam width and adequate shear reinforcement provided.

605 DEPOSITING THE CONCRETE

Concrete should be placed as nearly as possible in its final position. In slab construction, placing shall be started around the perimeter at one end of the work with each batch dumped against previously placed concrete. The concrete shall not be dumped in separate piles and the piles then leveled and worked together; nor shall the concrete be deposited in big piles and moved horizontally to its final position.

In walls, the first batches in each lift shall be placed at either end of the section; the placing shall then be toward the center.

In general, concrete shall be placed in horizontal layers of uniform thickness, each layer being thoroughly consolidated before the next is placed. Layers shall be 6 to 20 inches thick for reinforced members, 15 to 20 inches thick for mass work - the thickness depending on the width between forms and the amount of reinforcement.

Concrete shall not be moved horizontally over ten feet (10') within forms or in slabs. The height of free fall of concrete shall be a maximum of four (4') feet unless otherwise approved by the Engineer.

606 CONSOLIDATING CONCRETE

Consolidation shall be by vibration. Immersion type vibrators shall be used to consolidate concrete in walls, columns, beams, and slabs. The vibrator shall be lowered vertically into the concrete and should be allowed to descend by gravity. The vibrator shall penetrate to the bottom of the lift and penetrate into the previous lift enough to ensure a monolithic homogeneity between the top and bottom lifts.

When the paste first appears near the top of the vibrator head, the vibrator should be withdrawn vertically at about the same rate that it descended. The vibrator shall be reimmersed at such intervals that the "spheres of influence" overlap. Vibrators shall not be used to move concrete horizontally. The length of time that the vibrator should be left in the concrete is a function of the slump of the concrete; high slump concrete requires little or no vibration.

607 CURING

607.01 General

Immediately after forms have been removed, all concrete shall be cured by one of the following methods. When the temperature is expected to fall below 35 degrees Fahrenheit, the Contractor shall provide suitable measures to maintain the concrete surface temperature between 50 degrees Fahrenheit and 90 degrees Fahrenheit during the curing period.

- A. Water method. All surfaces other than slabs shall be protected from the sun and the whole structure shall be kept wet for a period of at least 5 days. All concrete slabs shall be covered as soon as possible with suitable material so that concrete is kept thoroughly wet for at least 5 days.
- B. Membrane Forming Curing Compound. All surfaces shall be given the required surface finish prior to application of the curing compound. During the finishing period, the concrete shall be protected by the water method of curing. The rate of application of curing compound will be as directed by the Engineer, but shall not be more than 200 square feet per gallon. All concrete cured by this method shall receive two applications of the curing compound. The first coat shall be applied immediately after stripping of forms and acceptance of the concrete finish. If the surface is dry, the concrete shall be thoroughly wet with water and the curing compound applied just as the surface film of water disappears. The second application shall be applied after the first application has set. During curing operations, any unsprayed surfaces shall be kept wet with water. When using a curing compound, the compound shall be thoroughly mixed within an hour before use.
- C. Form Method. Concrete shall be protected by forms for at least 7 days unless otherwise approved by the Engineer. Forms shall be kept moist, when necessary, during the curing period.

607.02 Cold Weather Requirements

- A. Adequate equipment shall be provided for heating concrete materials and protecting concrete during freezing or near freezing weather. No frozen materials or materials containing snow or ice shall be used.
- B. All reinforcement, forms, fillers, and ground with which the concrete is to come in contact with shall be free from snow and ice. All concrete placed in forms shall have a temperature of 50 degrees Fahrenheit, or higher, after placement. Adequate means shall be provided for maintaining this temperature for seven (7) days.
- C. When high-early-strength concrete is used, a temperature of at least 50 degrees Fahrenheit shall be maintained for three (3) days. In either case, additional time necessary to ensure proper curing of the concrete shall be provided as directed by the Engineer. The housing, covering, or other protection used in curing shall remain intact at least 24 hours after artificial heating is discontinued. If insulation is removed before the recommended time, the concrete shall be covered with an impervious sheet and the artificial heat continued for the required time. No dependence shall be placed on salt or other chemicals for the prevention of freezing. In no case shall concrete be heated to more than 70 degrees Fahrenheit.

608 REMOVAL OF FORMS

Forms shall be removed in such a manner as to ensure the complete safety of the structure. Where the structure is supported on shores, the removable floor forms, beams, columns, and other vertical forms may be removed after 24 hours, providing the concrete will not be injured. In no case shall supporting forms or shoring be removed until members have acquired sufficient strength to support their weight and imposed loads safely.

609 CONCRETE SURFACE FINISHES

- A. General. Unless otherwise authorized, all formed surfaces shall be finished with Class 1 finish. For form cured surfaces, this finish will be constructed immediately following curing.

The Class 1 finish shall be applied immediately after the forms are removed and forms may be removed for only that portion of the work that can be finished in the remainder of a work day. The exposed concrete shall be kept damp during the finishing period and covered with the curing compound immediately following the completion of the finishing.

Culvert headwalls and wingwall surfaces above ground, retaining walls and any other structure where visible from a traveled way, shall receive a Class 2 finish.

Surfaces other than listed herein or surfaces requiring special consideration shall receive the finish shown on the plans or called for in the specifications.

The various classes of finish are described as follows:

1. Class 1, Ordinary Surface Finish. All fins and irregular projections shall be removed from all surfaces except from those which are not to be exposed or are not to be waterproofed. On all surfaces, the cavities produced by form ties, honeycomb spots, broken corners or edges and other defects shall be thoroughly cleaned, moistened with water and carefully pointed and trued with a mortar consisting of cement and fine aggregate and the surface left sound, smooth, even and uniform in color. Mortar used in pointing shall be not more than 30 minutes old. The mortar patches shall be cured as specified in Section 607.01 or other approved methods. All construction and expansion joints in the completed work shall be left carefully tooled and free of all mortar and concrete. The joint filler shall be left exposed for its full length with clean and true edges.
2. Class 2, Rubbed Finish. After completion of Class 1 Ordinary Surface Finish, the rubbing of concrete shall be started as soon as its condition will permit. Immediately before starting this work the concrete shall be moistened with water. Sufficient time shall have elapsed before the wetting down to all the mortar used in the pointing to thoroughly set. Surfaces to be finished shall be rubbed with a medium coarse carborundum stone, using a small amount of mortar on its face. The mortar shall be composed of cement and fine sand mixed in the same proportions as the concrete being finished. Rubbing shall be continued until all form marks, projections, and irregularities have been removed, all voids filled and a uniform surface has been obtained. The paste produced by this rubbing shall be left in place.

After all concrete above the surface being treated has been cast, the final finish shall be obtained by rubbing with a fine carborundum stone and water. This entire surface is of a smooth texture and uniform color.

After the final rubbing is completed and the surface has dried, it shall be wiped with burlap to remove loose powder and shall be left free from all unsound patches, paste, powder, and objectionable marks.

609.01 Filling and Repairing Bolt Holes

After forms are removed, bolt holes and tie rod holes shall be filled with mortar carefully packed into place in small amounts. The mortar should be mixed as dry as practicable, with only enough water so that it will be tightly compacted when forced into place.

White cement shall be mixed in patching mortar and concrete where appearance is important. Concrete in patches should be cured at least two (2) days and if non-shrink mortar is used. Curing is not required.

Bulges and projections shall be removed by chipping or tooling. The surface should then be rubbed or ground. Honeycombed and other defective areas shall be chipped out to solid concrete. The edges should be cut as straight as possible and at right angles to the surface or slightly undercut to provide a key at the edge of the patch. Shallow patches may be filled with stiff mortar similar to that used in the concrete. They shall be placed in layers not more than 1/2 inch thick and each layer given a scratch finish to improve bond with the subsequent layer. The final layer shall be finished to match the surrounding concrete by floating, rubbing, or tooling, or on formed surfaces by pressing the form material against the patch while still plastic.

Deep patches shall be filled with concrete held in place by forms. Such patches shall be reinforced and dowelled to the hardened concrete.

Defective concrete shall be cut out to expose solid concrete.

Before patching concrete is applied, the surrounding concrete shall be kept wet for several hours. A grout shall be brushed into the surfaces to which the new material is to be bonded. The area shall be damp when the grout is applied.

Curing shall be started as soon as possible to avoid early drying. Damp burlap, wet sand, or tarpaulins can be used. In locations where it is difficult to hold these materials in place, an application of two coats of membrane curing compound shall be used.

Wherever practicable, cavities that have a small area but are relatively deep shall be filled with dry-pack mortar. After the cavity has been cleaned of oil and loose material, the mortar should be tamped into place in layers of approximately 1/2 inch thick. Vigorous ramming and adequate curing will ensure good bond and minimum shrinkage of the patch.

610 ADMIXTURES

Calcium Chloride shall not be used as an antifreeze agent. Calcium Chloride as an accelerating agent in amounts not to exceed 1.5% by weight of cement may be used upon the approval of the Engineer.

611 SLUMP

The water-cement ratio shall be such as to produce the following slumps:

Type of Construction	Minimum	Maximum
Mass concrete	1"	3"
Reinforced slab, beams, girders and walls	1"	4"

612 DESIGN

Prior to the beginning of the concrete placement, the Contractor shall submit as required to the Engineer for approval a concrete mix design prepared at the Contractor's expense by a certified testing lab. The mix design shall include certified lab reports showing compliance of all materials to the specifications and test results of all required laboratory tests for concrete mixes. As a minimum, compressive strength values shall be 4000 psi at 28 days unless otherwise specified.

613 CONCRETE PROPORTIONING AND MIXING

613.01 Water-Cement Ratio

The maximum water-cement ratio for all concrete shall be 0.45.

613.02 Cement Content

The minimum cement content per cubic yard for all concrete shall be 6 sacks.

613.03 Air-Entraining Admixtures

All air-entraining admixtures shall contain an air-entraining agent conforming to ASTM C-260. The entrained air content of all concrete shall be controlled at 6% (-1+2).

614 INSPECTION

The Engineer shall be offered uninterrupted access to the batching plant at all times that the work is in progress.

615 AGGREGATE AND CEMENT STORAGE

Cement and aggregates shall be stored at the plant site in such a manner as to prevent deterioration or intrusion of foreign matter. Any material which has deteriorated or which has been damaged shall not be used.

616 MEASUREMENT AND PAYMENT

Measurement and payment shall be as outlined in the Bid Proposal and/or Special Provision sections.

SECTION 620 DRAINAGE CHANNELS

621 CHANNEL EXCAVATION

621.01 Description

This section covers channel excavation, excavation for structures, and work related to these items. Embankment materials shall be moisture conditioned at the site of excavation as necessary to comply with the requirements of these specifications.

The Contractor shall provide all temporary drainage facilities and dewatering necessary to prevent ponding of water in areas of excavation and washouts.

Existing topsoil shall be stripped, stockpiled, and placed on the compacted sideslopes as shown in the approved contract documents or as directed by the Engineer.

621.02 Sections and Slopes

Excavation sections, profiles, and slopes shall be cut true and straight in conformity with the lines and grades shown in the approved contract documents within the following tolerances, measured normal to the excavated surfaces:

Surfaces	Tolerance
Side Slopes	$\pm 10\%$
Profile of invert of ditches and channels	± 0.3 foot

The extreme of such tolerances shall not be continuous over a distance of 100-feet or more as measured at any place, in any direction, parallel to the excavated surface. No additional payment shall be made for over excavations.

621.03 Excavation Beyond Established Lines

Precautions shall be taken to preserve, in an undisturbed condition, material beyond the designated lines of the excavations except unsuitable material ordered removed by the Engineer. Material loosened beyond the excavation limits as a result of excavation operations shall be considered defective work and be compacted or removed and replaced with compacted embankment as directed by the Engineer at no cost to the owner.

621.04 Dewatering

The excavation shall be dewatered to the extent required for construction operations to proceed under dry conditions. Dikes, channels, flumes, drains, sumps, pumping equipment, and other temporary diversion and protective works shall be constructed, furnished, installed, operated, and maintained by the Contractor at no additional cost to the owner.

621.05 Bottom and Side Slopes

The bottom and side slopes of any excavation in soil against which concrete is to be placed shall be finished carefully to the elevations and dimensions shown on the approved contract documents. Prior to placement of the lining. The top one (1) foot of the foundation material shall be compacted to not less than

- A. For Cohesive Soils, 90% maximum Modified Proctor dry density at $\pm 2\%$ of optimum moisture content or 95% maximum Standard Proctor dry density at $\pm 2\%$ of optimum moisture content.
- B. For Cohesionless Soils, 92% maximum Modified Proctor dry density at $\pm 2\%$ of optimum moisture content or 97% maximum Standard Proctor dry density at $\pm 2\%$ of optimum moisture content.
- C. For Expansive Soils, 88% maximum Modified Proctor dry density at 3% or greater above optimum moisture content or 93% maximum Standard Proctor dry density at 1% or greater above optimum moisture content.

Material which will not provide a suitable foundation shall be removed and replaced with compacted backfill or concrete as directed by the Engineer.

621.06 Disposal of Excavated Materials

- A. General: The Engineer shall determine the suitability and placing of the materials in the various portions of the work in accordance with the requirements of these specifications. Oversize material or otherwise unsuitable material shall be broken down to acceptable sizes or shall be removed from the work. All areas receiving excavated material shall be cleared and grubbed removing all stumps, roots, logs, brush, grass, topsoil, and other debris. The cleared and grubbed area shall extend a minimum of ten (10) feet beyond the concrete or rip rap channel construction.

- B. **Compacted Embankment:** Material from the excavation which is suitable for compacted embankment shall be dense and homogeneous when compacted as specified in Section 621.05 above. The material within two (2) feet of the lining, measured horizontally, shall be free of all organic matter or other deleterious material and of all material larger than five (5) inches in maximum dimension.
- C. **Compacted Backfill:** Material from excavation which is suitable for compacted backfill shall be the same as that which is suitable for compacted embankment, except that it shall be free of all materials larger than three (3) inches in maximum dimensions.
- D. **Waste:** All excess and/or unsuitable material shall be hauled from the site at the Contractor's expense, unless otherwise specified in the approved contract documents.

621.07 Measurement and Payment

Measurement and payment for channel excavation shall be as set forth in the approved contract document. This payment shall be full compensation for all materials, tools, equipment, and labor necessary to complete the work under this section in accordance with the approved contract documents and these specifications.

622 CHANNEL EMBANKMENT AND BACKFILL

622.01 Description

This section covers the items Compacted Embankment and Compacted Backfill as defined under Section 621.06. Existing topsoil shall be stripped, stockpiled, and placed on the compacted embankment or backfill as shown in the approved contract documents or as directed by the Engineer.

622.02 Compaction and Watering Construction Equipment and Methods

The types of equipment and methods employed in moisture conditioning and compaction of embankments shall be at the option of the Contractor and as approved by the Engineer. The equipment and methods used must produce results in compliance with these specifications.

Construction equipment for the application of water shall be designed to apply water uniformly, under pressure, and in controlled quantities to variable widths of surface. Equipment shall have positive shutoff valves so that no leakage will result when not in operation.

622.03 **Compacted Embankment**

This section includes construction of all embankments designated on the drawings as compacted embankment and placing embankment material in over-excavated areas in the channel as directed by the Engineer.

- A. Foundation Preparation: Surfaces upon which the embankment is to be constructed shall be cleared and grubbed. The top two (2) feet of subgrade shall be compacted to not less than:
1. For Cohesive Soils, 90% maximum Modified Proctor dry density at $\pm 2\%$ of optimum moisture content or 95% maximum Standard Proctor dry density at $\pm 2\%$ of optimum moisture content.
 2. For Cohesionless Soils, 92% maximum Modified Proctor dry density at $\pm 2\%$ of optimum moisture content or 97% maximum Standard Proctor dry density at $\pm 2\%$ of optimum moisture content.
 3. For Expansive Soils, 88% maximum Modified Proctor dry density at 3% or greater above optimum moisture content or 93% maximum Standard Proctor dry density at 1% or greater above optimum moisture content.

Material unsuitable for embankment foundations shall be removed as directed by the Engineer and replaced with suitable material and compacted in accordance with the requirements of this section.

- B. Construction of Embankment: Material for embankment shall be as specified in Section 621.06. Material may be moisture conditioned at the site of excavation or at the embankment site at the Contractor's option. Material which contains excess moisture shall be dried until the required compaction can be obtained.

The embankment materials shall be conditioned to have a moisture content at the time of compaction such that the specified compaction may be obtained with the equipment being used. At all times it shall be the responsibility of the Contractor to employ such means as may be necessary to secure a uniform moisture content throughout the material being compacted.

The embankment shall be constructed in horizontal layers which extend the full width of the section. The fill shall be placed, unless otherwise authorized by the Engineer, in maximum of eight (8) inch horizontal layers (uncompacted thickness). When a layer of material is dissimilar from the preceding layer, the materials shall be blended by discing, mixing, scarifying, or as by methods approved by the Engineer. Compacted embankments shall be compacted to not less than:

1. For Cohesive Soils, 90% maximum Modified Proctor dry density at $\pm 2\%$ of optimum moisture content or 95% maximum Standard Proctor dry density at $\pm 2\%$ of optimum moisture content.
2. For Cohesionless Soils, 92% maximum Modified Proctor dry density at $\pm 2\%$ of optimum moisture content or 97% maximum Standard Proctor dry density at $\pm 2\%$ of optimum moisture content.
3. For Expansive Soils, 88% maximum Modified Proctor dry density at 3% or greater above optimum moisture content or 93% maximum Standard Proctor dry density at 1% or greater above optimum moisture content.

Temporary openings left in the embankment for structures or for other requirements shall be backfilled in layers with slopes no steeper than four (4) feet horizontal to one (1) foot vertical (4:1), except as otherwise designated by the Engineer.

During construction the Contractor shall keep the top of the embankments at such elevation and section to provide natural surface drainage at all times. If the Contractor stops work on any portion of the embankment on account of rain or impending rain, the surface shall be graded to facilitate drainage and the surfaces shall be sealed by passing rubber tired equipment or flat drum rollers over the surface. Before work is resumed in the area, the surface shall be scarified to a depth of not less than six (6) inches, re-leveled, moisture conditioned, and recompact to the specified density.

Should the Engineer determine that any portion of the surface of the embankment has become so dry or glazed during construction that bonding with the succeeding layer to be placed thereon cannot be obtained, or should ruts and roadways develop on the embankment, such surfaces shall be scarified to a minimum depth of six (6) inches, re-leveled, moisture conditioned, and recompact to the specified density prior to placing the succeeding layer of embankment.

All surfaces of completed embankment slope and profile surfaces shall be compacted to the lines shown in the approved contract documents with a tolerance of plus or minus 0.3 foot per 100-feet and shall be graded to a uniform surface.

622.04 Backfill

Backfill shall not be placed against concrete construction until the concrete has developed sufficient strength as determined by the Engineer to withstand, without injury, the pressures imposed upon the structure by the backfill and related operations.

622.05 Tests

Density testing of compacted embankment shall be ordered by the Engineer and performed at the owner's expense, on a first time basis only. All failing sections shall be retested and the expense thereof shall be borne by the Contractor. Testing will be performed in accordance with the following schedule unless authorized by the Engineer:

1. One test at each installation.
2. One test for each 300 cubic yards of material.
3. Minimum of one test for each soil type encountered.
4. Minimum of one test each 100 linear feet of ditch between expansion joints.

622.06 Measurement and Payment

Measurement and payment for compacted embankment shall be as set forth in the approved contract document. This payment shall be full compensation for all materials, tools, equipment and labor necessary to complete the work under this section in accordance with the approved contract documents and these specifications.

Measurement shall be made to the lines shown on the approved contract documents. Quantities shall be calculated by the average end area centerline distance method, using distances along the base line shown in the approved contract documents for quantities lying along the channel.

623 CONCRETE CHANNEL CONSTRUCTION

623.01 General

All concrete work shall conform to Section 613 of these specification except as follows:

- A. Maximum Slump
 1. Side Slopes 2 1/2 inches
 2. Channel Bottom 4 inches
- B. Weep Holes: Weep holes shall be constructed of minimum two (2) inch diameter plastic or galvanized steel pipe inserted to the thickness of the concrete lining and installed at maximum 25 foot intervals at all cutoff walls in accordance with details in Appendix B and shall be sloped to drain according to the details.
- C. Joints: Expansion and contraction joints shall be constructed as shown on the details.

1. Expansion joints shall be a maximum of 100-foot spacing unless specified otherwise by the Engineer.
2. Contraction joints shall be a maximum of 20-foot spacing unless specified otherwise by the Engineer.
3. Construction joints in accordance with details.

Waterstops, when specified, shall be furnished full length for each straight portion of the joint, without field splices.

- D. Placement and Finish: The concrete shall be placed in the forms and thoroughly spaded or tamped so that there will be no air spaces in the mass. The surface shall be floated with a wood float to draw the mortar to the surface. Just before the concrete takes its initial set, the surface shall be brushed with a soft bristle brush so as to remove all trowel marks and leave a uniform appearance.
- E. Testing: Concrete testing shall conform with Section 600 of these specifications. The owner shall provide for all testing laboratory services in accordance with Subsection 110.22 "Testing of Materials". Tests results shall be furnished verbally to the Engineer and the Contractor as soon as available, with a written, certified confirmation furnished to the Engineer, the Contractor, and the owner as soon as possible.
- F. Measurement and Payment: Measurement for concrete channel construction shall be by the units as set forth and to the dimensions shown in the approved contract documents. Payment shall be made at the unit price set forth in the approved contract documents and shall be full compensation for all materials, tools, equipment, and labor necessary to complete the work specified in this section in accordance with the approved contract documents and these specifications.

624 RIP RAP AND GROUTED RIP RAP CHANNEL CONSTRUCTION

624.01 Rip Rap Channel

Rip rap shall consist of hard, durable, angular stone of approximate cubical shape. The stone shall have a minimum specific gravity of 2.50, a sodium sulfate soundness value less than 10% (AASHTO T-104), and a Los Angeles abrasion value less than 35% (AASHTO T-96). The largest dimension of the stone shall not be greater than three (3) times the smallest dimension.

The size, gradation, and thickness of the rip rap shall be as shown in the approved contract documents and shall conform to the following requirements:

CLASSIFICATION AND GRADATION OF ORDINARY RIP RAP			
Rip Rap Designation by Weight	% Smaller Than Given Size (inches)	Intermediate Rock Dimension	d50* (inches)
Type VL	70 – 100	12	6**
	50 – 70	9	
	35 – 50	6	
	2 - 10	2	
Type L	70 – 100	15	9**
	50 – 70	12	
	35 – 50	9	
	2 - 10	3	
Type M	70 – 100	21	12
	50 – 70	18	
	35 – 50	12	
	2 - 10	4	
Type H	70 – 100	30	18
	50 – 70	24	
	35 – 50	18	
	2 - 10	6	
Type VH	70 – 100	42	24
	50 – 70	33	
	35 – 50	24	
	2 - 10	9	

* d50 = Mean particle size

** Bury types VL and L with native top soil and revegetate to protect from vandalism.

The Engineer shall approve the source and type of material used prior to its installation site. Acceptable material may be salvaged from clearing operations or excavation on the project. Rubble concrete may be used provided it has a density of at least 150 pounds per cubic foot and otherwise meets the applicable requirements of these specifications.

The type, gradation, and thickness of granular bedding material shall be as shown in the approved contract documents and shall conform to the following requirements:

GRADATION FOR GRANULAR BEDDING MATERIAL		
U.S. Standard Sieve Size	Percent Passing by Weight	
	Type I	Type II
3"	-	0 - 100
1-1/2"	-	-
3/4"	-	20 - 90
3/8"	100	-
# 4	95 - 100	0 - 20
# 16	45 - 80	-
# 50	10 - 30	-
#100	2 - 10	-
#200	0 - 2	0 - 3

Filter fabric shall be manufactured especially for erosion control applications and shall conform to the requirements of AASHTO M-288. The fabric shall be a woven or nonwoven fabric consisting of long chain polymeric filaments or yarns such as polyvinylidene chloride, nylon/polypropylene, polypropylene, polyethylene, polyester, or polyamide formed into a stable network such that the filaments or yarn retain their relative position to each other. The fabric shall be inert to commonly encountered chemicals and shall be resistant to insect, rodent, and moisture damage.

The filter fabric shall be placed as shown in the approved contract documents and secured in accordance with the manufacturer's recommendations. Securing pins shall be galvanized wire or as otherwise approved by the Engineer. Wire pins shall be made of wire 0.091-inches or larger in diameter and "U"-shaped with legs six (6) inches long and a one (1) inch crown.

Rip rap shall be placed to the thickness and limits as shown in the approved contract documents and plan details. Rip rap shall be placed in such a manner as to produce a well graded mass or of rock with a minimum of voids. The larger stones shall be well distributed and the finished surface shall be free from pockets of small stones and clusters of larger stones. Re-arranging of individual stones by equipment or by hand shall be required if necessary to maintain a well graded distribution of rock conforming to the contour specified.

Rip rap that is 12-inches in diameter or larger shall not be dumped directly onto filter fabric. A minimum of four (4") inches of Type 11 granular bedding material shall be placed over the filter fabric or the rip rap shall be placed onto the filter fabric by hand. Side slopes shall be graded to no steeper than two and one-half (2-1/2') feet horizontal to one (1') foot vertical (2.5:1) (unless otherwise approved by the Engineer) prior to placing filter fabric, granular bedding material, or rip rap.

Excavation for toe walls shall be made to the lines of the walls. Allowance will not be made for work outside the lines.

624.02 Grouted Rip Rap Channel

When grouted rip rap is required, the rip rap shall be grouted with concrete grout conforming to the requirements of Section 500 of these specifications except as follows:

Specified Compressive Strength at 28 Days 3000 PSI	Maximum Water/Cement Ratio by Weight 0.53
Minimum Cement Content per Cubic Yard of Concrete 517 lbs	

Slump	Minimum 5-inches	Maximum 8-inches
Entrained Air	6%	9%

The aggregate shall be comprised of 70% natural sand (fines) and 30% 3/8-inch rock (coarse).

The grout shall be mixed at the site of the work in stationary mixers, in a central-mix plant, in truck mixers, or in self-contained mobile mixers. The grout shall be used within 60 minutes after mixing.

The surfaces of the rock or stone to be grouted shall be cleaned of adhering dirt or other deleterious material and then moistened. Grout may be placed by pumping or any other method. In no case shall grout be permitted to flow a distance in excess of ten (10') feet. Immediately after depositing, the grout shall be spaded and rodded into place with suitable spades, trowels or other approved means until the openings are completely filled with grout. The grout shall fully penetrate all joints from bottom to top.

After the grout has been placed, the rocks or stones shall be thoroughly brushed with a wet broom so that the exterior surfaces are exposed. The outer rocks or stones shall project approximately two (2) to four (4) inches. The grout between the rocks shall be finished with a stiff broom.

Grouted rip rap shall be cured by water curing or membrane curing. Concrete shall be kept continuously wet for not less than seven (7) days when cured by water curing. Curing compound shall be as specified in Section 500 of these specifications.

Weep holes in accordance with Standard Specification 623.01 (B)

624.03 Measurement and Payment

Measurement and payment for rip rap and grouted rip rap shall be made by the cubic yard to the limits shown in the approved contract documents. Payments shall be made at the unit price set forth in the approved contract documents and shall be full compensation for all materials, tools, equipment and labor necessary to complete the work under this section in accordance with the approved contract documents and these specifications.

625 AIR PLACED CONCRETE LINED CHANNELS

625.01 Requirements

General. Only personnel skilled in the techniques of air placement of concrete shall be utilized for air placed concrete construction. Unless otherwise specified, air placed concrete shall be applied by one of the following methods:

Method A (Guniting). A proportional combination of Portland cement and aggregate pneumatically transported in a dry state through a pipe or hose to a nozzle where water is added immediately prior to discharge at the work site.

Method B (Shotcrete). A proportioned combination of Portland cement, aggregate, and water mixed by mechanical methods, pumped in a plastic state through a pipe or hose to the nozzle where, by the addition of air, the mixture is forcibly propelled to the work.

625.02 Equipment

- A. For Method A, the minimum air pressure shall be 45 psi on the gun tank when 100-feet or less of hose is used and the pressure shall be increased five (5) psi for each additional 50-feet of hose. The pressure shall also be increased five (5) psi for each 25-feet that the nozzle is located above the elevation of the gun tank. The maximum diameter of the nozzle shall be one and five-eighths (1-5/8") inches unless otherwise permitted by the Engineer. Water pressure at the nozzle shall be at least 15 psi above the air pressure at the nozzle.

- B. For Method B, the pump system utilized to convey premixed concrete shall deliver a uniform and uninterrupted flow of material, without segregation or loss of the ingredients. The main run from the pump to the work shall be at least three (3) inch diameter steel pipe or flexible hose reduced to two (2") inch diameter at the point of expulsion. Aluminum pipe will not be permitted. The air compressor shall have the capacity to deliver at least 100 cubic feet per minute for each operating nozzle.

625.03 Materials, Proportioning and Mixing

- A. Method A. Aggregate and Portland cement shall comply with Sections 402 and 500. Unless otherwise specified, the proportions by volume shall be one (1) part cement to four and one-half (4-1/2) parts sand. The sand shall contain not less than 3% not more than 6% moisture by weight. The cement and sand shall be mixed thoroughly in a power mixer for at least one and one-half (1-1/2) minutes. The dry-mixed material shall be used promptly after mixing and any material that has been mixed for more than 60 minutes shall be rejected and removed from the worksite.
- B. Method B. The concrete class shall comply with the requirements for Method A.

Where material is placed on overhead surfaces, the amount of water in the mix shall be controlled to permit placement of layers of material approximately 3/4 inch thick without sag or slough.

625.04 Preparation of Surface

Earth subgrade for air placed concrete shall be neatly trimmed to line and grade as shown on the plans and shall be free of all loose material. The subgrade shall be compacted as required by Sections 621 and 622 of these specifications.

Over-excavation shall be backfilled with earth compacted to the requirements of Sections 621 and 622 of these specifications, or air placed concrete at the contractor's expense.

Masonry, rock, asphalt and concrete surfaces to be covered by air placed concrete shall be free of loose material. Dust, dirt, grease, organic material or other deleterious substances shall be removed and the surface washed with water.

625.05 Forms and Reinforcement

The forms shall be built in accordance with the applicable requirements of Section 509.02 of these specifications. All forms shall be constructed so as to permit the escape of air and rebound.

Ground wires shall be installed in such a manner that they accurately outline the finished surface as indicated on the plans. They shall be located at intervals sufficient to insure proper thickness throughout. Wires shall be stretched tight and shall not be removed prior to application of the finish coat. Reinforcing steel shall be ASTM A-615 Grade 60 and Grade 40 unless otherwise specified, and shall comply with Section 603 of these specifications. Where steel fibers are used for reinforcement, they shall be thoroughly and evenly interspersed throughout the concrete mix. All steel fibers shall be barbed to insure sufficient flexural and shear strength.

Headers will/shall be required where the plans approved contract documents indicate a formed edge or joint.

625.06 Joints

Construction joints shall be sloped off at an angle of approximately 45-degrees to the surface to which air placed material is being applied. Before applying air placed material in the adjacent sections, the sloped portion shall be thoroughly cleaned and wetted by means of air and water blasting.

Control joints shall be formed at the locations designated in the approved contract documents.

625.07 Placement

All surfaces shall be dampened before application and material shall not be applied to a surface on which free water exists.

The velocity of the material as it leaves the nozzle shall be maintained uniformly at a rate satisfactory for the job conditions. Material that rebounds and does not fall clear of the work, or which collects on the surfaces, shall be removed. Rebound shall not be used in any portion of the work.

The nozzle shall be held at such distance and position that the stream of flowing material will impinge approximately at right angles to the surface being covered. Any portion of the in-place material which sags, is soft, contains sand pockets, or shows other evidence of being defective, shall be removed and replaced with new material. Reinforcement damaged or destroyed by such repairs shall be replaced by properly lapped additional steel.

Mortar blocks, metal chairs, clips, or spacers with wire ties, or other acceptable means shall be used to secure the reinforcement firmly in the position shown on the plans.

625.08 Finish

Upon reaching the thickness and shape outlined by forms and ground wires, the surface shall be rodded off to true line and grade. Low spots or depressions shall be brought up to proper grade by placing additional air placed material. Ground wires shall then be removed and, unless otherwise specified, the surface shall then be broom finished to secure a uniform surface texture. Rodding and working with a wood float shall be held to a minimum.

Rebound or accumulated loose sand shall be removed and disposed of by the Contractor.

When a nozzle finish is specified in the approved contract documents, the surface upon which the finish is to be applied shall be at the proper grade and prepared by sand and water blasting to remove all laitance prior to application of the concrete.

625.09 Curing

Air placed concrete shall be cured in accordance with the requirements of Section 508 of these specifications. The Contractor shall at all times protect the finished work from being scarred or damaged.

625.10 Tests

The Contractor shall make the work accessible to facilitate the preparation of test specimens. Unless otherwise specified, the owner shall provide for all testing laboratory services in accordance with Subsection 110.22 "Testing of Materials". Tests results shall be furnished verbally to the Engineer and the Contractor as soon as available, with a written, certified confirmation furnished to the Engineer, the Contractor, and the owner as soon as possible.

The strength of air placed concrete shall be determined from cores cut from the completed work, cores cut from test panels, compression test cylinders, or a combination of these methods as directed by the Engineer.

Compression test cylinders shall be prepared by the testing laboratory in the presence of the Engineer in six (6) inch diameter by 12-inch long containers of 3/4 inch square hardware cloth, utilizing the same mix, air pressure, water pressure and nozzle tip as

for the material placed in the structure. Cylinders shall be cured in accordance with ASTM C-39.

A compressive strength test of air placed concrete shall consist of three specimens. If the test specimens are six (6) inch diameter by 12-inch cylinders, one (1) shall be tested at seven (7) days. The remaining two (2) specimens shall be tested at 28 days. At least one (1) set of test specimens shall be obtained for each appurtenance.

When a test specimen shows deficient strength, two cores taken from adjacent areas at the Contractor's expense may be required for each deficient specimen. Should either core prove deficient, the entire area of noncomplying material shall be removed and replaced with material in compliance with these specifications.

625.11 Measurement and Payment

Quantities of air placed concrete shall be computed from measurements of actual areas in the plane of the work and the dimensions shown on the plans. No compensation shall be allowed for material placed in excess of the dimensions shown on the plans.

The bid item price for air placed concrete shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals involved in the performance of the work. Such work shall include, but not be limited to, preparing the foundation, setting all formwork and ground wires, furnishing and placing reinforcement, furnishing and placing the concrete, finishing surfaces, curing, and structural backfill as shown on the plans or contract documents.

SECTION 630 STORM DRAINS AND CULVERTS

631 SCOPE OF WORK

The work covered by this specification consists of furnishing all materials, labor, tools and equipment necessary to install storm drain pipe, culvert and appurtenances as shown on the plans and as herein specified. The work covered by this section will be considered as Standard Construction. Work not covered by this section will be considered as special construction and will require additional specifications and prior approval of the City Engineer.

632 GENERAL

Storm drain pipe, culvert and appurtenances shall conform with all additional standard specifications references and applicable documents as noted herein unless otherwise superseded by the exceptions noted. All reference specifications shall be the current revision. Standard manufactured pipe or culvert materials acceptable for installation as public storm drains are:

- A. Reinforced Concrete Pipe (RCP)
- B. Reinforced Concrete Box (RCB)
- C. Corrugated steel pipe is not to be installed unless the location and specific design considerations have been approved by the City Engineer. Acceptable corrugated steel pipe materials are:
 - 1. Corrugated Steel Pipe - Galvanized (CSP)
 - 2. Aluminized Corrugated Steel Pipe - Type 2 (ACSP)
- D. Thermoplastic pipe material is not to be installed unless specific written approval is granted by the City Engineer. Thermoplastic plastic pipe material will be considered for public storm drains in drainage easements and non-traffic areas only. Thermoplastic pipe material is not to be installed within any public roadway section. Acceptable plastic pipe materials are:
 - 1. Ribbed Polyvinyl Chloride Pipe (RPVC)
 - 2. Smooth Wall Polyvinyl Chloride (SPVC)
 - 3. Profile Wall Polyethylene Pipe (PWPE)
 - 4. Corrugated Polyethylene Pipe (CPE)

632.01 Standard Specification References

AASHTO	-	American Association of State Highway and Transportation Officials
ACI	-	American Concrete Institute
ASTM	-	American Society for Testing and Materials
CDOT	-	Colorado Department of Transportation
SS-S	-	Federal Specification
OSHA	-	Occupational Safety and Health Administration

633 DESIGN CRITERIA FOR PIPE

See Drainage Criteria Manual, Appendix 6A

634 REQUIREMENTS FOR PIPE DESIGN

See Drainage Criteria Manual, Appendix 6A.

635 MATERIALS

635.01 Precast Concrete Pipe

- A. ASTM C-76 "Reinforced Concrete Culvert, Storm Drain and Sewer Pipe". Class II shall be the minimum allowed for storm drain systems. Minimum acceptable size is 15 inch diameter.
- B. ASTM C-507 "Reinforced Concrete Elliptical Culvert, Storm Drain and Sewer Pipe". Class HE-II or VE-II pipe shall be the minimum allowed for Storm Drain Systems. Minimum acceptable size is 11 x 18 inch.
- C. ASTM C-14 "Concrete Sewer, Storm Drain and Culvert Pipe". Class III non-reinforced pipe will be allowed only up to a maximum of 24 inch diameter.

Joints for all pipe may be bell and spigot or tongue and groove according to the supplier's preference unless specifically noted on the plans

635.02 Precast Reinforced Concrete Box Sections

- A. ASTM C-789 "Precast Reinforced Concrete Box Sections for Culverts, Storm Drains and Sewers".

- B. ASTM C-850 "Precast Reinforced Concrete Box Sections for Culverts, Storm Drains and Sewers with less than 2 feet of cover subjected to Highway Loadings".

635.03 Corrugated Steel Pipe and Sections

- A. AASHTO M-218 "Steel Sheet, Zinc-Coated (Galvanized) for Corrugated Steel Pipe" and meeting all the fabrication requirements of AASHTO M-36 "Corrugated Steel Pipe, Metallic Coated, for Sewers and Drains".

The acceptable shapes for storm drain installation are Type I (full circular cross-section with single thickness of corrugated sheet with annular or Helical corrugations) and Type II (Type I pipe reformed into pipe-arch). Minimum acceptable size is 15 inch diameter or equivalent.

Acceptable nominal corrugations are 2 2/3 x 1/2, 3 x 1 and 5 x 1.

The seams for corrugated pipe and pipe arch shall be Helical lock seams or Helical continuous welded seams in conformance with AASHTO M-36. Spot welded or riveted seams will not be allowed.

For field assembled shapes, AASHTO M-167 "Structural Plate for Pipe, Pipe-Arches, and arches". Only sections shown on CDOT M-510-1 will be allowed unless otherwise approved by the City Engineer. Nominal corrugations to be 6 x 2. All joints to be bolted.

- B. AASHTO M-274 "Steel Sheet, Aluminum-Coated (Type 2) for Corrugated Steel Pipe" and meeting all the fabrication requirements of AASHTO M-36.

635.04 Thermoplastic Pipe

The following types of thermoplastic pipes shall conform to AASHTO Interim Specifications Bridges Section 18, soil - thermoplastic pipe interaction systems.

- A. ASTM F-794 "Polyvinyl Chloride Large Diameter Ribbed Gravity Sewer Pipe and Fittings based on controlled inside diameter". The minimum allowable pipe wall thickness shall be pipe series 46 with allowable pipe sizes 18 through 36 inch diameter.
- B. AASHTO M-278 "Class PS 50 Polyvinyl Chloride Pipe" smooth wall pipe. Also, ASTM D-3034 "Type PSM Polyvinyl Chloride (PVC) Sewer Pipe and Fittings", SDR-35. Allowable pipe size to be 15 inch diameter only.
- C. ASTM F-894 "Polyethylene Large Diameter Profile Wall Sewer and Drain Pipe". The minimum allowable pipe wall thickness shall be ring stiffness

constant Class 100 for pipe sizes 18 through 30 inch diameter and Class 160 for pipe sizes 33 through 48 inch diameter. Maximum allowable size shall be 48 inch.

- D. AASHTO M-294 "Corrugated Polyethylene Pipe 12 to 36 inch Diameter" with allowable sizes of 15 through 36 inch diameter maximum. Allowable pipe classification shall be Type S - full circular cross-section with an outer corrugated pipe wall and a smooth inner liner. Corrugations may be annular or Helical.

Joints for ASTM F-794, ASTM F-894 and AASHTO M-278 pipe shall be gasketed type integral Bell and Spigot.

Joints for AASHTO M-294 pipe shall be a coupling type with gasketed joints. Coupling shall be bell and spigot. Split collar couplings to be used only if specifically approved in writing by the City Engineer.

635.05 Joint Materials - Concrete Pipe

- A. AASHTO M-198 "Joints for Circular Concrete Sewer and Culvert Pipe using Flexible Watertight Gaskets" for bell and spigot or tongue and groove pipe. Also, ASTM C-433 "Joints for circular concrete sewer and culvert pipe, using rubber gaskets".
- B. Mastic Sealants conforming to federal specification SS-S-210A "Sealing Compound, Preformed Plastic, for Expansion Joints and Pipe Joints for Shapes other than Circular".
- C. Cement mortar for joint repair or joint filler only.

635.06 Joint Material - Corrugated Metal Pipe and Pipe-Arch

- A. Coupling Bands. Coupling Bands shall be of the same base metal and coating as the pipe material and shall conform to AASHTO M-36 with the exception that the bands may be two gages thickness lighter than the pipe gage but not less than 18 gage.

Coupling bands shall have annular corrugations for pipe with annular corrugations or for Helical pipe in which the ends have been rerolled to form a minimum of two annular corrugations. The band corrugation shall have the same dimensions as the pipe or may be of a special design to engage only the second corrugation from the end of the pipe.

Where corrugations are not compatible with the pipe sections being joined, due to dissimilar ends caused by field cuts or modifications,

couplings may be flat band or bands with projection (dimpled) as approved by the Engineer.

Bands for pipe with 2-2/3 x 1/2 corrugations shall have a width of not less than 7 inches for diameters 15 to 36 inches and not less than 10-1/2 inches for diameters 42 to 96 inches.

Bands for pipe with 3 x 1 or 5 x 1 corrugations shall have a width of not less than 10.5 inches for diameters 36 to 144 inches.

- B. Special Design Bands. The following special design coupling bands are approved for installation:
 - 1. Hugger Band (Contech)
 - 2. (Reserved)
- C. Gaskets. All coupling bands shall be installed with standard O-ring gaskets, closed cell synthetic expanded rubber gaskets or mastic sealant conforming with ASTM D-1056 and shall have minimum dimensions conforming to AASHTO M-36.

635.07 Joint Material - Thermoplastic Pipe

- A. The following specifications apply to pipe provided under ASTM F-794, ASTM F-894 and AASHTO M-278; ASTM D-3212 "Specification for Drain and Sewer Plastic Pipes using Flexible Elastomeric Seals" and ASTM F-477 "Specifications for Elastomeric Seals (gaskets) for Joining Plastic Pipe".
- B. The following specification applies to pipe provided under AASHTO M-294; ASTM D-1056 "Flexible Cellular Material - Sponge or Expanded Rubber" closed cell sponge rubber or mastic sealants conforming to Federal Specifications SS-S-210A "Sealing Compound, Preformed Plastic, for Expansion Joints and Pipe Joints" when using Split Collar Joints. Also, ASTM F-477 "Specification for Elastomeric Seals (gaskets) for Joining Plastic Pipe when using Bell and Spigot Joints".

635.08 Manholes

ASTM C-478 "Precast Reinforced Concrete Manhole Sections" for precast reinforced concrete riser sections, eccentric cones or flat slab tops. Also, corrugated metal prefabricated manholes conforming to the requirements AASHTO M-36 "Corrugated Steel Pipe, Metallic Coated for Sewers and Drains". Shop drawings to be submitted for approval by the Engineer.

635.09 Frame, Cover, Grates and Accessories

ASTM A-48 "Gray Iron Castings for Frames, Covers and Grates". Class should be a minimum of No. 30B unless, malleable iron castings conforming to ASTM A-47 are specified for heavier loadings. Frame, cover and grate shall conform to the City Standard Detail for dimensions and minimum weight.

Cast iron manhole steps shall have a minimum tensile strength of 35,000 psi and shall be asphalt coated.

Extruded aluminum alloy steps shall conform with ASTM B-221 and be either 6005-T5 or 6005-T6 extrusions.

Polypropylene coated steel steps shall conform to ASTM 2146 Type II Grade 43758 with grade 60 steel conforming to ASTM A-615.

All steps and installation shall conform to OSHA Standard 29 CFR 1910.27 "Fixed Ladders".

635.10 Concrete

All cast in place Portland cement concrete for drainage structures shall have a minimum 28 day compressive strength of 4,000 psi, shall have Type II cement (unless otherwise specified) with air entraining admixtures and shall conform to all the requirements of Sections 500 and 600 of these Specifications.

635.11 Mortar

Cement mortar used for repair work shall be mixed in the proportions of one (1) part of air-entrained Type II cement conforming to ASTM C-150 to two and one half (2-1/2) parts of clean, well graded sand meeting this requirement of AASHTO M-45.

The grading for sand shall be as shown below:

Sieve Size	Percent Passing Each Sieve
No. 4	100
No. 8	95-100
No. 16	70-100
No. 30	40-70
No. 50	10-35
No. 100	2-15

635.12 Reinforcing Steel

- A. Reinforcing bars shall conform to ASTM A-615 "Specifications for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement" and shall be Grade 60 or Grade 40 as specified by design requirements. All bars shall be deformed unless otherwise specified.
- B. Smooth welded wire fabric shall conform to ASTM A-82 "Cold-Drawn Steel Wire for Concrete Reinforcement". Wire shall be galvanized where specified on the plans.

All reinforcing bars and wire fabric shall conform to the minimum design, placing and construction requirements for reinforced concrete ACI-318 and as otherwise noted on the plans.

635.13 Structural Steel

Structural carbon steel for bolted or welded construction shall conform to ASTM A-36 "Structural Steel". Where specified, structural steel shall be galvanized in conformance with ASTM A-123 "Zinc (Hot-Galvanized) Coatings on Products Fabricated from Rolled, Pressed and Forged Steel Shapes, Plates, Bars and Strip".

635.14 Bedding Material - Granular

Where called for on plans or otherwise specified by bedding class, bedding material for pipe and culvert shall consist of clean, granular material meeting the requirements for structural backfill. For thermoplastic plastic pipe materials only, see Section 637.06. For all other pipe materials use the following bedding materials unless otherwise specified by the Engineer.

For the AASHTO classification system, granular materials shall be defined as cohesionless sands and gravel of A-1, A-2 and A-3 group classification having 35% or less passing the No. 200 sieve. Maximum particle size shall not exceed 1-1/2 inches.

The material shall have a liquid limit not exceeding 35 and a plasticity index not over 6 when tested in accordance with AASHTO T-89 and T-90 respectively. Where corrosion parameters are established for metal pipe, the granular material shall be compatible with the service life requirements.

For the unified soil classification system, granular materials shall be defined as sands and gravels in soil groups GW, GP, GM, GC, SW, SP, SM and SC having more than 50% retained on the No. 200 sieve.

Granular bedding material for pipe installation may be native trench material or imported material providing the materials are in conformance with the above soil classifications.

636 CONSTRUCTION REQUIREMENTS FOR MANHOLES, JUNCTION BOXES, CAST IN PLACE REINFORCED CONCRETE BOX, INLETS, PIPE END FINISH AND FITTINGS

636.01 Manholes - Precast Concrete

Precast concrete manhole riser and eccentric cone sections shall be standard construction as indicated in the City Standard Detail for Type I, Type II and Type III unless otherwise specified. The minimum inside diameter of the riser shall be 48 inches. For Type II the base shall consist of monolithically placed concrete to the top of the storm drain unless otherwise indicated by the Engineer. The base invert shall be uniformly shaped to conform to the storm drain pipes.

The joints of the precast riser rings and cone shall be sealed with a mastic material conforming to Federal Specification SS-S210A.

The steps shall be securely set in the riser sections at 16 inches on center and shall extend from the spring line of the storm drain pipe to the cone section or flat top cover.

Precast concrete adjusting grade rings shall be provided as noted on the Standard Detail D-20D.

Precast concrete "Tee" manholes (Type III) may be installed on storm drain of 48 inches or larger. The construction must be capable of withstanding all dead loads and H-20 Highway Live Loads without damage to the storm drain. Otherwise, the Type III manhole will not be allowed in areas subject to live loads.

636.02 Manholes - Corrugated Metal

Where approved by the City Engineer, corrugated steel manholes risers may be installed on corrugated steel storm drains in areas where vehicular live loads are not anticipated.

The manhole riser shall consist of an integral tee type construction with the storm drain. Non-corrodible metal steps shall be installed at 16 inch on centers.

The riser shall be a minimum of 48 inch diameter and shall be the same gage as the storm drain for corrosion requirements. The connection of the riser shall be shop welded to the storm drain section or shop welded to a bolt-on saddle for field connections and zinc coated as specified. At the riser, the storm drain pipe section shall be a minimum of 10 gage and/or shall be reinforced with structural angles at the riser as recommended by the fabricator and approved by the Engineer.

The top of the manhole shall consist of a precast concrete eccentric cone or flat slab with an offset access opening located over the steps. The slab shall be reinforced to withstand dead loads and live loads and be a minimum of 9 inches thick. The cone or slab shall be set so as not to transmit live loads to the riser. The frame and cover shall be City Standard.

636.03 Junction Boxes - Cast in Place

Where large diameter pipes or multiple pipe join at a point where standard base or box base cannot be constructed, reinforced cast in place junction boxes shall be installed. The junction boxes shall be designed and constructed to withstand all dead loads and H-20 Highway live loads and shall be reinforced in accordance with ACI Standard 318. Design or shop drawings shall be submitted to the City Engineer for approval. Steps and the City Standard frame and cover shall be provided at the access opening.

636.04 Cast in Place Reinforced Concrete Box Culvert

Wall thickness and reinforcement for cast in place box sections shall conform to the Colorado Department of Transportation Standards M-601-1 "Single Concrete Box Culvert", M-601-2 "Double Concrete Box Culvert", M-601-2 "Double Concrete Box Culvert" and M-601-3 "Triple Concrete Box Culvert", exceptions noted.

Where cast in place box sections do not conform with the above referenced standards, the design engineer shall submit structural calculations to the City Engineer for the appropriate live load and dead load design requirements. Live load shall be AASHTO HS 20-44 and dead load shall be an earth load of 84 lbs/cu. feet with equivalent fluid pressure of 30 lbs/cu. feet.

636.05 Inlets

Cast in place inlets shall be constructed in conformance with City Standard Drawings D-9, D-10R, D-11 and special design D-19. The inlet opening height shall be 8 inches for Type 1 vertical gutters and 6 inches for Type 3 vertical gutters (median). For Type 2 ramp curb, the inlet opening height shall be 6 inches.

Where shown on the project plans, radial inlets shall be in conformance with City Standard Detail D-11 and grated inlets shall be in conformance with Standard Detail D-9.

636.06 End Finish

Concrete end sections, metal end sections or cast in place concrete headwalls shall be installed at the upstream and downstream ends of pipe and culvert and shall be anchored with the pipe as indicated on the plans. Adequate toe-down and scour protection shall be provided along the embankment slopes and at the end conditions.

- A. Concrete End Sections. Precast concrete end sections may be installed up to a maximum pipe diameter or equivalent pipe diameter of 54 inches. The construction shall be in conformance with CDOT Standard M-603-10 "Concrete and Metal End Sections". At a minimum, concrete joint fasteners shall be installed between the end section and the next two pipe sections for anchorage.
- B. Metal End Sections. Fabricated metal end sections shall match the base metal and coating of the pipe and shall have a minimum metal thickness, dimension and fabrication details as shown on CDOT Standard M-603-10 "Concrete and Metal End Sections".

Fabricated metal end sections may be used up to a maximum pipe diameter or equivalent pipe diameter of 54 inches. An additional toe plate (minimum 18 inches height) shall be installed on the downstream end section where called for on plan. Connection of the end section to the pipe shall be as indicated on CDOT Standard M-630-10.

- C. Full Concrete Headwalls. Full cast in place concrete headwalls may be used for precast concrete or metal pipe diameters or equivalent pipe diameters up to 54 inches and shall be used for all pipe dimensions larger than noted above. Concrete headwalls shall be installed for all thermoplastic pipe end conditions and used with reinforced concrete box sections and structural plate sections. The headwalls shall be in conformance CDOT Standard M-601-10 "Headwall for Pipe Culverts" with the exception that additional toe-down may be required depending on field conditions determined by the Engineer.

Where required, wing walls shall be in general conformance with CDOT Standard M-601-20 "Wing Walls for Pipe or Box Culvert".

636.07 Special Fittings and Connections.

All wyes, tees and mitered bends for concrete, metal and thermoplastic pipe shall be shop fabricated. Where field connections are required, the connection shall be designed and constructed so as to maintain the structural integrity and load carrying capability and to prevent leakage of the storm drain or culvert.

Concrete pipe field connections shall be made with reinforced concrete collars according to the details shown on the plan.

Metal pipe field connections at the barrel of the pipe shall be made with welded or bolted saddle plates.

Thermoplastic field connections shall not be constructed unless a site specific design is provided and prior approval is obtained from the City Engineer. Where recommended by the pipe manufacturer, pipe barrel shall be sealed using an elastomeric gasket or mastic sealant. Field connections should be made with prefabricated wyes, tees and mitered bends where possible.

637 ACCEPTANCE, HANDLING, INSTALLATION, EXCAVATION, BEDDING AND BACKFILL

637.01 Acceptance.

All precast or fabricated pipe and culvert materials and appurtenances shall be subject to inspection at the shop and at the job delivery point by the Engineer. Additional requirements shall be as noted in the General Provisions Section 110.06, "Inspection".

All site constructed work shall conform with the specified materials, workmanship and tolerance noted herein and the Standard Specification references or be subject to rejection by the Engineer and removal from the job site.

Where required, testing of all materials to determine compliance with the specifications shall be the responsibility of the Contractor. Shop, laboratory or field tests in addition to the normal production or construction requirement shall be performed where and when requested by the Engineer. Copies of all certified test results shall be provided to the Engineer at the time of shipment and prior to the installation of the materials. Materials failing to meet the minimum specifications will be sufficient cause for rejection of materials by the Engineer. Additional testing requirements shall be noted in the General Provisions Section 110.22 "Testing of Materials" and Section 700 "Control of Materials".

Upon request, the Contractor shall provide the Engineer with shipping or delivery slips of all materials indicating compliance with the Standard Specifications (or Supplemental Specifications). Materials found to be defective or damaged will be subject to rejection and are to be promptly removed from the project site.

All manufactured or prefabricated materials delivered to the site shall be properly identified by the manufacturer or the fabricator with legible stamping on the materials or containers.

Acceptance of the work by the City shall be subject to the requirements as noted in the General Provisions Sections 110.28 "Cleaning Up and Final Inspection" and Section 111.04 "Acceptance of Final Payment" unless otherwise superseded by the requirements of the Subdivision Ordinance for work not directly contracted by the City.

637.02 Handling.

The handling and shipping of all materials shall be performed in a manner so as to prevent damage and maintain suitability for installation within the limits of the Specifications. Material and accessories shall be loaded and unloaded by means of adequate lifting lugs, slings and equipment. Materials shall not be dropped or improperly stacked. All OSHA Safety Requirements shall be observed.

637.03 Storage

Pipe materials, accessories and construction materials shall be stored at the construction site in a manner that will protect the materials from damage, movement, or vandalism. Storage methods employed by the Contractor or the Contractor's agent shall assure that hazards to the general public, workmen, public and private property are eliminated. All OSHA Safety Requirements shall be observed. Approval of the City Engineer shall be obtained for storage on public property or in a public right-of-way. Written permission shall be obtained from the owner or lessee prior to storage on private property. All storage areas are to be restored to their original condition upon completion of the work. All additional requirements of the General Provisions, Section 107 shall apply.

637.04 Installation

- A. General. Pipe or culvert shall not be placed in the trench until excavation has proceeded well beyond the point of installation, proper line and grade has been established and all bedding preparation has been completed. The pipe shall be laid upgrade beginning at the lower end of the pipeline. The bell or groove shall point upslope in all cases. Where pipe with bells is installed, additional excavation shall be provided beneath the bell to properly bed the pipe. Proper facilities and equipment shall be provided for constructing the bedding and lowering the pipe sections into the trench.

Where groundwater exists, dewatering shall be maintained and the trench stabilized prior to placement of the bedding material. Pipe shall not be installed where frost, debris or other unsuitable materials are encountered in the trench foundation or bedding materials. All unsuitable materials shall be removed and replaced with acceptable bedding materials.

Any section of installed pipe which is found to be out of alignment, defective or damaged, shall be taken up and relayed, replaced or rejected as directed by the Engineer.

For multiple culvert installations, where two or more pipes are laid in parallel and at the same grade, adequate clearance shall be provided between pipes to allow for proper bedding and compaction. No less than 12 inch clearance shall be provided for pipe diameters up to 24 inches, a minimum of 1/2 pipe diameter for pipe between 24 to 72 inches and minimum of 36 inch clearance over 72 inch pipe diameter. Similar clearance shall be provided for pipe arch or elliptical pipe.

- B. Precast Concrete Pipe and Box Sections. Precast concrete pipe or box sections shall be installed with gaskets or sealants as specified in Section 635.05. Gaskets and sealants for bell and spigot or tongue and groove joints shall be installed according to the manufacturer's recommendations.

The gasket or sealant shall be properly installed with care taken in fitting the pipe sections together to avoid displacing or damaging the gasket or sealant. Gaskets shall be installed with the manufacturer's recommended lubricant. The joint shall be cleaned of any foreign material which would prevent proper sealing or closure of the joints. As necessary, the pipe or box sections shall be shoved home by mechanical means, such as jacks, wedge puller, and cable winch without disturbing previously placed pipe and without damaging joints.

For pipe, the maximum joint opening for straight alignment shall not exceed one (1) inch or one and one-half (1-1/2) inch on curved alignment. Where this maximum tolerance cannot be maintained for curved alignment, shop fabricated mitered bends or a special joint design shall be provided.

Where jacked or bored pipe installation is required, the proper equipment and methods shall be employed to maintain pipe alignment and to protect the pipe and pipe joints from damage. Where necessary, specially designed steel collar joints shall be provided to reinforce the joint. All jacked or bored concrete pipe material shall conform to the requirements of ASTM C-76. The pipe class shall be determined by the overburden, axial forces and the allowable D-load pipe strength.

Any void between the pipe outer wall and the surrounding earth shall be filled with sand, pressure grout, concrete or other suitable material as approved by the Engineer. Backstops and boring pits shall be properly braced to distribute the loads developed by the jacking equipment.

The boring Contractor shall certify to the Engineer that they are properly qualified and equipped to perform the work.

- C. Corrugated Steel Pipe. Corrugated metal pipe shall be installed with the lengths joined firmly together with the specified bands and gaskets or sealants as specified in Section 635.06. All pipe shall be installed with a straight horizontal and vertical alignment. Any pipe deflections greater than 2 degrees shall be constructed with shop fabricated bends. Gaskets or sealants shall be properly installed with the manufacturer's recommended lubricant. The band shall be cleaned of any foreign material which would prevent proper sealing or closure of the band.

The bands shall be connected with suitable galvanized metal devices such as: angles, integrally or separately formed and attached flanges, galvanized or cadmium plated bolts, bars and straps, or lugs. Coupling bands shall be fastened with the following size bolt:

Pipe Diameters 18 inch and less = 3/8 inch

Pipe Diameters 21 inch and larger = 1/2 inch

Dependent on the pipe diameter, the number of pieces of band per pipe joint may be one to three according to the pipe fabrication recommendation. The bands shall be centered on the pipe joints and the spacing between the pipe sections shall not exceed one (1) inch.

Where damaged, the metallic coatings for galvanized or aluminum clad pipe shall be repaired with materials and methods specified in AASHTO M-36 or as otherwise recommended by the manufacturer's of the plate steel.

The foundation, bedding and backfill for metal pipe are to be designed and constructed so as to provide the required support and passive soil resistance for flexible conduit to retain its shape and structural integrity. The pipe cross-section should not deviate from its nominal dimensions or shape by more than 5% deflection after installation. The Contractor shall provide temporary bracing as may be required to support the pipe during backfilling operations. Installation shall be in conformance with ASTM A-798 "Installing Factory-Made Corrugated Steel Sewer Pipe".

Where asphalt invert paving is required by design, paving shall conform to AASHTO M-190, Type B with the additional provision that the paving shall have a minimum thickness of 1/4 inch above the crest of the corrugations. Repairs to asphalt paving shall be in conformance with ASTM A-849.

For concrete invert paving the minimum thickness over the top of the corrugations (or top of reinforcement, whichever controls) at the invert shall be a minimum 1/30 of the pipe diameter (or equivalent pipe diameter) or a minimum of 3 inch thickness, whichever controls. The concrete paving shall have a minimum strength of 4,000 psi and prepared with a minimum of Type IIa cement according to ASTM C-150 with chemical and

abrasive resistant fine aggregate according to ASTM C-150 with chemical and abrasive resistant fine aggregate according to ASTM C-33. Where required, welded wire fabric reinforcement or deformed reinforcing bars shall be provided to maintain the integrity of the lining and shall be mechanically fastened to the pipe. The minimum area of steel for reinforcement shall not be less than 0.007 of concrete cross sectional area. Welded wire fabric shall be galvanized and conform to AASHTO M-55. Steel reinforcement bars may be used with a design approved by the Engineer.

- D. Thermoplastic Pipe. Thermoplastic Pipe shall be installed with gaskets (or seals) as specified in Section 635.07. The gaskets shall be properly installed with care taken in fitting the pipe length together to avoid displacing or damaging the gasket. The gasket shall be installed with the manufacturer's recommended lubricant. The joint shall be cleaned of any foreign material which would prevent proper sealing or closure of the joint. Where bands are provided, the bands shall be installed according to the manufacturer's recommendations.

All pipe shall be installed with a straight horizontal and vertical alignment. Any pipe deflections shall be constructed with shop fabricated bends.

The foundation, bedding and backfill for thermoplastic pipe are to be designed and constructed so as to provide the required support and passive soil resistance for flexible conduit to retain its shape and structural integrity. The bedding material classification and compaction requirements shall limit the long term deflection in any cross-sectional dimension to 5%. The initial deflection after installation shall not exceed 3-1/2%. The Contractor shall provide temporary bracing and be required to support the pipe during backfilling operations as recommended by the pipe manufacturer. Installation shall be in conformance with ASTM D-2321 "Underground Installation of Flexible Thermoplastic Sewer Pipe".

- E. Manholes, Junction Boxes and Inlets. The base for structures shall be constructed on undisturbed material or on fill material compacted to a minimum of 95% natural dry density by the Proctor method. The foundation shall be capable of supporting all dead and highway live loads transmitted by the structures. Manhole risers and box structures shall be set plumb.

Where precast structures are approved for construction, a minimum of 4 inch thick gravel bedding material shall be provided as a leveling course over the compacted subgrade.

Backfill and compaction around the structures shall be performed in uniform lifts not to exceed 12 inches uncompacted thickness. The

material shall be compacted a minimum of 95% natural dry density by the Proctor method.

Heavy mechanized equipment shall not be used for compaction within three feet of the structure unless otherwise allowed by the Engineer.

The pipe contractor shall construct the manhole frame and cover to finish grade as noted on the plans or, where street paving exists, shall adjust the frame and cover to match the elevations and slopes of the pavement, curb and gutter.

637.05 Trench Excavation - General

Trench excavation shall be open cut to the depth shown on the plans, unless over-excavation is required as determined by the Engineer. The length of trench to be opened at one time may be limited when, in the opinion of the Engineer, such limitation is necessary. The amount of open or unfilled trench shall not exceed 500 lineal feet, unless allowed by the Engineer.

Trenches shall be excavated only to a width sufficient to provide a free working space on each side of the pipe to adequately compact backfill. Maximum trench width shall not exceed the specified design width measured at top of pipe.

Where possible, the trench walls in the area of the pipe should be constructed vertical to a point 12 inches over the pipe. Above this point, the trench may be sloped to the safe angle of repose. Where this criteria cannot be maintained, the pipe will be installed under positive projecting embankment conditions instead of trench conditions, the pipe and bedding classifications may have to be redesigned as determined by the Engineer. The Contractor will provide the necessary shoring and/or trench side sloping to comply with the OSHA Safety Requirements.

Trenches shall be kept free from water by dewatering methods acceptable to the Engineer.

All excavations for drainage structures or pipe trenches which extend down to or below the water-table shall be dewatered by lowering and keeping the groundwater level 12 inches or more below the bottom of the excavation. Water shall not be allowed to rise until all cast in place concrete has set and the forms have been removed. The dewatering shall continue until such time as it is safe to allow the water table to rise in the excavations. Where bedrock prevents dewatering below the finished grade of the structure, the excavation shall be pumped dry immediately preceding the placement of concrete, and any concrete shall be placed in such a way so as to displace the water remaining in the excavation. Pipe trenches shall contain enough backfill to prevent pipe floatation.

All water shall be disposed of in a suitable manner without being a menace to public health or causing public inconvenience. No water shall drain into other work being completed or under construction. The Contractor will be held responsible for the condition of any pipe or conduit which may be used for drainage purposes, and all such pipes or conduits shall be kept clean and free of sediment. Prior to commencement of construction, the Contractor shall submit to the Engineer a plan for handling ground and surface waters during construction.

Trenches will be sheeted and braced as soil conditions indicate. Such sheeting shall not be removed until backfilling has progressed to a stage that no damage to pipe lines, utilities or structures will result from its removal.

The excavation material shall be maintained a sufficient distance back from the edge of the trench to avoid overloading and to prevent slides or caving. The excavated material shall be kept trimmed in such a manner as to minimize inconvenience to traffic, to pedestrians and to adjoining property owners. Barricades and/or fencing required to protect the public shall be installed and meet with the approval of the Engineer. At street crossings, sidewalks, and other points where the Engineer deems necessary, the trenches shall be bridged and shored in a secure manner so as to prevent serious interruption of travel and to provide access to fire hydrants, public land, and private premises. Such bridging or shoring shall be approved by the Engineer.

- A. UNCLASSIFIED EXCAVATION. Unclassified excavation shall comprise the removal and disposal of all materials including but not limited to clay, silt, sand, gravel, hard pan, loose shale, conglomerate and boulders measuring less than one-half cubic yard volume. Material removed in tunneling on jacking pipe shall be considered unclassified.
- B. CLASSIFIED EXCAVATION - ROCK. Rock excavation shall consist of igneous, metamorphic and sedimentary rock which cannot be excavated without blasting or the use of rippers (one cubic yard or larger backhoe) and all boulders or conglomerate having a volume of one-half cubic yard or larger as determined by physical or visual measurement.

Where blasting is required, the Contractor shall employ qualified personnel to conduct the blasting and shall meet with OSHA Safety Requirements. Adequate notice or warning shall be given to adjacent property owners and posting of signage to the public in advance of blasting operations. All ordinances and laws shall be complied with during blasting operations.

- C. CLASSIFIED EXCAVATION - OTHER. Other forms of classified excavation shall be as noted on the plans or called out in the Bid Proposal.

- D. PROTECTION OF EXISTING UTILITIES. It shall be the responsibility of the Contractor to verify the existence and location of all underground utilities along the route of the work. The omission of utility locations on the plans is not to be considered as the nonexistence of underground utilities.

The Contractor will take the necessary precautions to protect existing utilities from damage due to construction activities. Any damage to the utilities will be repaired at the Contractor's expense, and any service disruption will be scheduled and restored by the Contractor.

Additional requirements shall be as noted in the General Provisions Section 110.09 "Protection of Utilities".

637.06 Bedding

- A. FOUNDATION PREPARATIONS. The pipe and culvert installation shall be founded on suitable supporting material to assure that the conduit will maintain its alignment and integrity at the joints. For corrugated metal pipe and thermoplastic pipe, the foundation material should be somewhat yielding to be compatible with the characteristics of flexible conduits.

The conduit shall not be installed directly on muck, rock, large stones, uncontrolled fill, debris or other unsuitable materials as determined by the Engineer. Where these conditions exist the trench shall be over-excavated below and either side of the conduit to a dimension as directed by the Engineer and suitable granular backfill material shall be installed as specified. If over-excavation occurs below the established grade, the area so excavated shall be backfilled with granular material and compacted to a minimum of 90% modified Proctor (AASHTO T-180) or 95% standard Proctor (AASHTO T-99) at 2%± optimum moisture content. The minimum over-excavation below the conduit shall be 6 inches in rock and all other unsuitable materials.

All bedding or backfill against the pipe shall be free from stones with a dimension greater than 3 inches for rigid pipe and no greater than 1 1/2 inches for flexible pipe. Where select granular bedding material is required, the material shall conform to Section 635.14.

Where free flowing ground water is encountered in the trench, a subdrain may be required to prevent "piping" along the conduit. The subdrain requirements shall be as determined by the Engineer. For thermoplastic pipe, installation methods recommended by the pipe manufacturer shall be employed to prevent floatation of the pipe.

- B. BEDDING FOR CONCRETE PIPE. Bedding shall be Class C (ordinary), Class B (first class) or Class A (concrete cradle or arch) as determined by the existing trench and soil conditions, the anticipated trench loadings, load factors and the D-Load crack limits for the class for pipe selected including minimum cover requirements. Bedding in the pipe zone shall be granular as specified in Section 635.14. All bedding material shall be carefully tamped in the pipe zone to a 6 to 12 inches above the pipe as required by the bedding class.
- C. BEDDING FOR REINFORCED CONCRETE BOX. Bedding for precast concrete box sections shall consist of a minimum of 6 inches of granular material beneath the section and extend to a point 12 inches over the section. Where required, granular bedding material shall be provided as specified in Section 635.14. Bedding for cast in place box section shall be as determined by the Engineer based on existing foundation conditions.
- D. BEDDING FOR CORRUGATED METAL PIPE. The pipe shall be completely bedded in granular material as specified in Section 635.14 with cover over the pipe equal to $D/8$ or 12 inches, whichever is greater. "D" being the nominal diameter on span of the pipe section.

The bedding material shall be firmly tamped under the haunches of the pipe or the pipe foundation shall be shaped to the lower portion of the pipe. The remainder of the granular bedding shall be compacted in lifts of approximately 6 to 12 inches thick and brought up uniformly on both sides of the pipe to the cover noted above. Compaction of the material in the pipe zone shall be a minimum of 90% Standard Proctor. In all cases, the minimum cover for the pipe structural requirements as noted in the City Standard Details D-26 and D-27 shall be observed. Additional temporary cover shall be provided according to the pipe manufacturer recommendations where heavy construction equipment traffic (heavier than H-20) is encountered.

Where a high ground water table is encountered, a properly installed bedding filter material may be necessary to prevent loss of pipe support by the migration of fine materials.

- E. BEDDING FOR THERMOPLASTIC PIPE. The pipe shall be completely bedded in granular material with a minimum cover over the pipe of 12 inches. Where required for additional foundation support, granular bedding material shall be provided as specified in Section 635.14.

Allowable granular material for bedding of thermoplastic pipe and in direct contact with the pipe shall be as defined in ASTM D-2321:

CLASS I

Angular Graded Stone, 1/4" to 1-1/2"

CLASS II

Coarse sands and gravels with maximum particle size of 1-1/2", including variously graded sands and gravels containing small percentages of fines, generally granular and non-cohesive. Unified classification soil types GW, GP, SW, and SP.

CLASS III

Fine sand and clayey gravels, including fine sands, sand-clay mixtures and gravel-clay mixtures. Unified classification soil types GM, GC, SM and SC.

Class II material shall be compacted to a minimum of 85% Standard Proctor Density and Class III material shall be compacted to a minimum of 90% Standard Proctor Density.

In wet conditions, Class I material with a high void ratio should not be used if free flowing water may be present in the vicinity of the pipe zone causing the migration of the fine materials and loss of pipe support.

Where a high ground water table is encountered, a properly installed bedding filter material may be necessary to prevent loss of pipe support.

The bedding material shall be firmly tamped under the haunches of the pipe. The remainder of the granular bedding shall be compacted by hand or mechanical tamping equipment in lifts of approximately 6 to 12 inches thick and brought up uniformly on both sides of the pipe to the cover noted above. The placement and compaction of backfill should be continuously supervised to assure that the required conditions are maintained for pipe integrity, support and dimensional tolerance.

In all cases, the minimum cover of two feet to top of subgrade shall be observed. Additional temporary cover shall be provided according to the pipe manufacturer recommendations where heavy construction equipment traffic (heavier than H-20) is encountered.

637.07 Backfilling

Unless otherwise specified by the Engineer, trench backfill may consist of unclassified material extending from a point 6 to 12 inches above the pipe to the finish grade or roadway subgrade. Backfill material shall be placed in the trench in lifts of a maximum 8 inch uncompacted thickness within the right-of-way or under roadway surfaces. Each lift shall be compacted not less than:

- A. For cohesive soils, 90% Modified Proctor at +2% of optimum moisture content or 95% Standard Proctor at + 2% of optimum moisture content.

- B. For non-cohesive soils, 92% Modified Proctor at $\pm 2\%$ of optimum moisture content or 97% Standard Proctor at $\pm 2\%$ of optimum moisture content.
- C. For expansive soils, 88% Modified Proctor at 3% above optimum moisture content or 93% Standard Proctor at 1% above optimum moisture content. In areas other than roadway surfaces, areas unaffected by settlement, or as otherwise specified by the Engineer, the backfill shall be placed in lifts as required to achieve a minimum density of 85% Standard or 90% Modified Proctor.

Frequency of density testing for trenches shall be as established by Section 206 "Compaction of Utility Trenches."

Where a sheepsfoot or vibratory roller is employed, a minimum of 3 feet of material must be provided over the pipe. No stones larger than 6 inches shall be allowed within 2 feet of the pipe.

A hydro hammer shall not be utilized for trench compaction over flexible storm drain pipe.

The depth and location of compaction tests shall be as determined by the Engineer to assure conformance of these specifications throughout the work.

Jetting or ponding shall not be allowed for cohesive soils but may be allowed for non-cohesive soils if approved by the Engineer.

638 MEASUREMENT AND PAYMENT

Unless otherwise stated in the Specifications or Bid Proposal, the contract price for each item of work noted in the Bid Proposal shall be full compensation for furnishing all materials, tools, equipment, installation and labor necessary to construct the storm drain, culvert and appurtenances in accordance with the plans and the specifications.

The work will include but is not limited to testing of soils, materials, and in-place construction, dewatering, protection of utilities, bracing and shoring, traffic control, disposal of surplus excavated materials, storage, delivery, hauling, cleaning of the pipeline and construction site and all other requirements of the General Provisions of these Specifications or as otherwise noted in the Special Provisions. Where noted, surface restoration, pavement replacement, and utility relocation will be separate pay items.

The following pay units as noted in the Bid Proposal or As-Built field measurement shall include the method of measurement as described below and shall be U.S. Standard Measure unless otherwise noted:

- A. Storm Drain Pipe and Culvert Pipe. (Linear Foot) - shall be measured on the horizontal plain along the center line of the pipeline. Measurement of pipeline lengths shall be from the inside face of the junction box or inlet. Where the storm drains pass through manholes, measurement shall be from center to center of the manholes. Measurement of culverts shall be to the outside face of headwalls but shall not include end sections. Linear foot measurement shall include elbows, bends, tees and special fittings. Fabrication costs shall be a separate line item.

Measurement shall include gaskets, sealants, couplings, coatings and linings, bedding materials, excavation and trench backfill to finished surface or pavement subgrade. Special fittings, connectors or prefabricated bends, shall be as noted in the Bid Proposal.

Boring, jacking or tunneling of pipe along with boring pits and all associated work shall be measured separately as noted on the bid proposal.

- B. Manholes, Precast Concrete. (each) - Where vertical dimensions are noted on the Bid Proposal or where field measured, heights shall be from the lowest invert to the top of frame and cover. Measurement shall include the base, invert paving, eccentric cone or flat slab, adjusting rings, frame and cover, steps and sealants. Included is excavation and backfill.
- C. Box Manhole or Junction Box, Cast in Place. (each) - Measurement shall include all concrete, steel reinforcement, invert paving, precast risers and cone, adjusting rings, frame and cover, steps and sealants. Included is excavation and backfill and formwork.
- D. Manholes, Corrugated Metal. (each) - Where vertical dimensions are noted on the Bid Proposal or where field measured, heights shall be from the pipe invert to top of the frame and cover. Measurement shall include the fabricated storm drain pipe section and riser, steps, coating or lining, precast cone or flat slab, frame and cover. Included is excavation and backfill.
- E. Inlets. (each) - Measurement for cast in place construction shall include all materials indicated on the Standard Detail including the transition gutters and frame and cover. Included is any granular bedding material specified. Included is excavation, backfill and formwork.

Measurement for special precast construction shall be as noted on the Bid Proposal.

- F. Headwalls. (each) - Measurement for cast in place concrete headwalls shall include all materials indicated on the Standard Detail or as detailed on the plans and as otherwise specified. Measurement shall include wingwalls and slope treatment where indicated on the plans. Included is excavation, backfill and formwork.
- G. End Sections (Concrete and Metal), Elbows, Bends, Tees, and Special Fittings. (each) - Measurement shall include all materials, anchors, gaskets, couplings, toe plate and erosion protection such as rip-rap or concrete slope paving.
- H. Unclassified Excavation. No separate measurement for unclassified excavation will be made for work associated with pipeline and appurtenant structures. The cost of this item will be included with the Bid Proposal price of the work item unless otherwise noted.
- I. Classified Excavation, Rock. (cubic yards) - Measurement shall include, drilling, blasting, removal, hauling and disposal and all protective devices, permits and fees associated with the work.
- J. Classified Excavation, Other. (units as noted in the Bid Proposal). Measurement shall be as specified.