

SECTION 02310

TUNNEL EXCAVATION AND PRIMARY LINER

NOTE TO SPECIFIER: THIS SPECIFICATION IS INCLUDED FOR REFERENCE BUT SHALL BE THOROUGHLY REVIEWED FOR APPLICABILITY AND REVISED AS NECESSARY FOR PROJECT SPECIFIC REQUIREMENTS.

PART 1 GENERAL

1.01 SECTION INCLUDES

- A. Tunnel construction by placement of a primary liner for installation of sewer pipe using a 2-pass method. Placement of the sewer pipe inside the tunnel constructed with a primary liner shall be in accordance with Section 02725 - Sewer Line in Tunnels.
- B. Various construction methods for tunneling, including tunnel boring machine (TBM), hand tunneling or shield. Liners include rib and lagging, steel liner plate, bolted steel liner, box tunnels, and segmented concrete. Liners may be expanded or grouted.
- C. Contractor shall install liner types as shown on the Drawings. Where not otherwise indicated, Contractor shall use techniques and liner methods appropriate for the prevailing ground conditions.

1.02 UNIT PRICES

- A. Work performed under this Section such as excavation, primary liner and grouting will not be paid directly. Include the cost of this work in unit prices for installation of sewer line in tunnel, in accordance with Section 02725 - Sewer Line in Tunnels.
- B. Monitoring will be paid for at the lump sum price for installation, observation and reporting.

1.03 DEFINITION

- A. Primary liner is the first tunnel support installed by the Contractor in a 2-pass method.
- B. Carrier pipe is the sewer line as specified in Section 02725 - Sewer Line in Tunnels.
- C. Zone of Active Excavation. Area located within a radial distance about a surface point immediately above the face of excavation equal to the depth to the bottom of excavation.

- D. Critical Structure. Any building, structure, bridge, pier, or similar construction partially or entirely located within a zone of active excavation.
- E. Tunnel Boring Machine (TBM). Mechanized and fully shielded excavating equipment that is steerable, guided and articulated, with man entry.
- F. Tunneling Methodology. A written description, together with supporting documentation that defines Contractor's plans and procedures for the tunneling operations.
- G. Shield. Fabricated ground support, circular in section, providing a 360-degree protection to those working in it. Shield will have a cutting edge, and be equipped with independently operated hydraulic propulsion rams, allowing it to be steered. Liner is erected within a tail attached to the shield.
- H. Open Face. The face of a heading or tunnel which is unsupported during excavation (e.g., in hand mining or shield excavation).
- I. Closed Face. The face of a heading or tunnel which is provided support during the excavation process from a TBM, where the cutter head allows both partial exposure of the face and full closure, by means of hydraulically operated gates.

1.04 SUBMITTALS

- A. Make submittals in accordance with all sections and provisions of these specifications.
- B. The following submittals are required:
 - 1. Tunneling Methodology. A brief description of proposed tunnel methodology for review. The description should be sufficient to convey the following:
 - a. Proposed method of tunnel construction and type of face support and lining system.
 - b. Manufacturer and type of tunneling equipment proposed; type of lighting and ventilation systems.
 - c. Number and duration of shifts planned to be worked each day.
 - d. Sequence of operations.
 - e. Location of access shafts and work sites.
 - f. Method of spoil transportation from the face, surface storage and disposal location.

- g. Method of installing pipe.
 - h. Identify critical utility crossings and special precautions proposed.
 - i. Manufacturer and type of any chemical grout proposed.
- 2. Drawings and Calculations. Submit for record purposes, drawings and calculations for any tunnel support system designed by the Contractor. Drawings shall be adequate for construction, and include installation details. Documents must be signed and sealed by a Professional Engineer registered in the State of Texas. Calculations shall include clear statement of criteria used for the design, as described in paragraph 1.06, Design Criteria.
- 3. Quality Control. Submit for review a brief description of quality control methods including:
 - a. Method and frequency of survey control.
 - b. Example of tunnel daily log.
 - c. Instrumentation plan showing location, and frequency of monitoring relative to critical structures within the zone of active excavation.
 - d. Settlement survey plan (may be included in instrumentation plan).
- 4. Geotechnical Investigation. When geotechnical investigations are conducted by the Contractor, submit results to the Owner's Representative for record purposes.
- 5. Monitoring Plans:
 - a. Instrumentation Monitoring Plan. Submit for review, prior to construction, a monitoring plan that includes a schedule of instrumentation design, layout of instrumentation points, equipment installation details, manufacturer's catalog literature, and monitoring report forms.
 - b. Surface Settlement Monitoring Plan. Submit a settlement monitoring plan for review prior to construction. The plan shall identify the location of settlement monitoring points, reference benchmarks, survey frequency and procedures, and reporting formats.
- 6. Structures Assessment. Preconstruction and post-construction assessment reports shall be provided for critical structures, namely those located within the zone of active excavation from the proposed tunnel centerline.

Photographs or a video of any existing damage to structures in the vicinity of the sewer alignment shall be included in the assessment reports.

7. The readings of all monitoring shall be submitted to the Owner's Representative.
8. Daily Reports. The shift log as defined in paragraph 3.04, Pipe-jacked Tunneling Data, shall be maintained by the Contractor and must be made available to the Owner's Representative on request.

1.05 DESIGN CRITERIA

- A. The primary liner shall be designed by the Contractor's Professional Engineer for appropriate loading conditions and deflection criteria, including but not limited to: the overburden and lateral earth pressures, handling and installation stresses, loads imposed by the tunnel shield or tunnel boring machine thrust jacks, subsurface soil and water loads, grouting, and other conditions of service. Contractor shall be responsible for the design of the primary liner to carry construction loads in combination with overburden, earth and hydrostatic loads.
- B. The criteria to be used at railroad crossings shall be Cooper E-80 locomotive loading distributions in accordance with AREA specifications for culverts. In the design, account for additive loadings due to multiple tracks. Liner type for railroad crossings shall be as specified or as indicated on the Drawings.
- C. The criteria for truck loading shall be HS-20 vehicle loading distributions in accordance with AASHTO.
- D. The liner system shall be compatible with any special requirements shown on the Drawings.

PART 2 PRODUCTS

2.01 STEEL LINER PLATES

- A. In locations shown on the Drawings, liner plate shall be manufactured from steel conforming to ASTM A36 and ASTM A283, as manufactured by Armco Steel Corporation (4-flange), Commercial Intertech, Inc. (4-flange), or equal, and certified by manufacturer for compliance with the Specifications.
- B. Bolts and nuts shall conform to ASTM A307, Grade A.
- C. Plates shall be punched for bolting on both longitudinal and circumferential seams and shall be fabricated to permit complete erection from inside the tunnel. Plates shall be of uniform fabrication and those intended for one size tunnel shall be interchangeable.

- D. Material used for construction of liner plates shall be in good condition.
- E. A sufficient number of bolted steel liner plates shall be equipped with approximately 2-inch diameter grout holes furnished with plugs. Holes shall be located near plate center.

PART 3 EXECUTION

3.01 PREPARATION

- A. Use methods for tunneling operations that will minimize ground settlement. Select a method which will control flow of water, prevent loss of soil into the tunnel, and provide stability of the face under anticipated conditions.
- B. Conduct tunneling operations in accordance with applicable safety rules and regulations, OSHA standards and Contractor's safety plan. Use methods which include due regard for safety of workmen, adjacent structures, utilities, and the public.
- C. Maintain clean working conditions inside the tunnel and shafts.
- D. For tunneling under railroad embankments, highways, or streets, perform the installation so as to avoid interference with the operation of the railroads, highways, or streets, except as approved by the owner of the facility.
- E. Support the ground continuously in a manner to prevent loss of ground and keep the perimeters and faces of the tunnel stable.
- F. The completed primary tunnel lining shall have full bearing against the ground. The peripheral space between the support elements and the excavated surface shall be grouted or shall be closed by expanding the support elements against the ground to achieve full bearing as the tunnel advances.
- G. Ground Conditions. The Contractor may perform additional exploration by geotechnical borings in advance of construction to define necessary parameters for design of the primary tunnel liner, planning and designing the ground water control system, and for selection of tunneling method and equipment to successfully complete each tunnel reach.
- H. The Contractor shall be aware that various existing soil borings, piezometers, or instrument wells, where indicated on the Drawings, may coincide with the proposed tunnel alignment. These may or may not have been backfilled with grout and, therefore, caution should be used in tunneling through these locations. Contractor shall take mitigating measures to counter any effect these boreholes, piezometers, or instrument wells may have on tunneling operations.

3.02 GROUND WATER CONTROL

- A. Contractor shall provide the necessary ground water control measures to perform the work and to provide safe working conditions. Contractor shall comply with the provisions of Section 01563 - Control of Ground Water and Surface Water.
- B. Contractor shall anticipate that portions of the tunnel excavation may be below the ground water table and in cohesionless soils, even if not indicated on the soil borings, and in conditions which may require a ground water control system for the tunneling operations. Contractor shall install filter fabrics, backer rods and other means as necessary to prevent piping of fines into tunnel.
- C. If the Contractor chooses pumping installations to control the ground water level or installs a pervious liner through water bearing layers, the Contractor shall install and maintain an instrumentation system to monitor the water level and to detect any movement in adjacent structures and property.
- D. The dewatering system for tunnels shall remain in operation until the carrier pipe has been installed and the annular space is fully grouted, or until a watertight liner designed for hydrostatic pressures is installed.
- E. Tunneling for which ground water control is necessary shall not proceed until monitoring data indicate that the ground water control system is operating in accordance with the Contractor's plan.

3.03 EQUIPMENT

- A. The Contractor shall be responsible for selection of tunneling equipment which, based on past experience, has proven to be satisfactory for excavation of the soils to be encountered.
- B. The Contractor shall employ tunneling equipment that will be capable of handling the various anticipated ground conditions and which minimizes loss of soil ahead of the face and allows satisfactory support of the excavated face.
- C. A TBM or shield shall conform to the shape of the tunnel with a uniform perimeter that is free of projections that could produce over excavation or voids. An appropriately sized over cutting bead may be provided to facilitate steering. In addition it shall:
 - 1. Be capable of full directional guidance.
 - 2. Be capable of full-face closure, or permit ready installation of breasting boards.
 - 3. Be equipped with appropriate tail in which liner is erected.
 - 4. Be capable of correcting roll.

5. Be designed to handle adverse ground conditions including ground water ingress.
 6. Be equipped with visual display to show the operator actual position of TBM or shield relative to design reference.
- D. Air Quality. Provide equipment to maintain proper air quality of tunnel operations during construction in accordance with OSHA requirements.
- E. Enclose lighting fixtures in watertight enclosures with suitable guards. Provide separate circuits for lighting, and other equipment.
- F. Electrical systems shall conform to requirements of National Electrical Code - NFPA70.

3.04 TUNNELING DATA

- A. Maintain shift logs of construction events and observations. The Owner's Representative shall have access to the Contractor's logs with regard to the following information:
1. Location of face by station and progress of tunnel drive during shift.
 2. Hours worked per shift on tunneling operations.
 3. Completed field forms for checking line and grade of the tunneling operation, showing achieved tolerance relative to design alignment. Steering control logs will generally be acceptable for shield or TBM driven tunnels.
 4. Location, elevation and brief soil descriptions of soil strata and strata boundaries.
 5. Ground water control operations and piezometric levels, ground water inflow location and rates.
 6. Observation of any lost ground or other ground movement.
 7. Any unusual conditions or events.
 8. Reasons for operational shutdown in the event a drive is halted.
- B. Primary liner shall be clearly marked with paint every 20 feet along the tunnel with distance in feet from centerline of the preceding shaft.

3.05 TUNNEL EXCAVATION AND PRIMARY LINER INSTALLATION

- A. Tunnel Excavation.

1. Conduct tunneling operations in accordance with applicable safety rules and regulations, and Contractor's safety plan. Use methods which include due regard for safety of workmen, adjacent structures, utilities, and the public.
 2. Tunnel excavation shall remain within the easements and rights-of-way indicated on the Drawings, to the lines and grades designated on the Drawings. The excavation shall be of sufficient size to allow the installation of the sewer pipe to the lines and grades indicated on the Drawings.
 3. Open-face excavations:
 - a. Keep the face breasted or otherwise supported and prevent falls, excessive raveling, or erosion. Maintain standby face supports for immediate use when needed.
 - b. During shutdown periods, support the face of the excavation by positive means; no support shall rely solely on hydraulic pressure.
 4. Closed-face excavation:
 - a. Control volume of spoil removed. Determine that the advance rate and the excavation rate are compatible to avoid over excavation or loss of ground.
 - b. When cutting head is withdrawn for any purpose, keep excavated face supported and stabilized.
 - c. When the face of the machine is open for maintenance, monitor conditions that might threaten the stability of the heading. Take appropriate action to prevent or limit influx of soils and water which would threaten the stability of the heading.
 5. Whenever there is an identified condition which could endanger the tunnel excavation or adjacent structures, operate continually for 24 hours a day, including weekends and holidays, without intermission until the condition no longer exists.
- B. Determination of primary liner size and section shall be the sole responsibility of the Contractor, to match the construction methods and equipment described in the tunneling methodology submittal. Tunnels shall be of sufficient size to permit efficient excavation operations, to provide sufficient working space for placing the primary tunnel liner, and to allow for installation of the sewer pipe.
- C. Primary Liner Installation:

1. Contractor's method shall ensure full bearing of the soil against the primary liner without significant settlement or movement of the surrounding soil. To fill the void behind the primary liner, either an expandable liner (e.g., ring beams and timber lagging) or a nonexpandable liner (e.g., bolted steel liner plates) may be used provided grout is placed behind the nonexpandable liner. Box tunnel where the ground is excavated to a true shape may be ungrouted.
 2. When using a TBM or tunnel shield, advance the equipment only far enough to permit construction of one primary liner set, entirely within the equipment shield.
 3. Filter fabric shall be installed around the exterior of the primary liner when using steel ribs and lagging. Backer rods shall be installed at ribs as required to control migration of fines. Windows in lagging shall be closed.
 4. After grouting, deflection of liner shall be no more than allowable, nor shall the liner be distorted by excessive pressure.
- D. Seal blind headings with a temporary bulkhead.
- E. Grouting: Requirements pertaining to grout mix design and tunnel grouting are provided in Section 02330 - Tunnel Grout.

3.06 CONTROL OF TUNNEL LINE AND GRADE

- A. Construction Control.
1. The Owner's Representative will establish the baselines and benchmarks indicated on the Drawings. Contractor shall check baselines and benchmarks at the beginning of the Work and report any errors or discrepancies to the Owner's Representative.
 2. Use the baselines and benchmarks established by the Owner's Representative to establish and maintain construction control points, reference lines, and grades for locating tunnel.
 3. Establish control points sufficiently far from the face so as not to be affected by tunneling operations.
- B. Benchmark Movement. The Contractor shall ensure that if settlement of the ground surface occurs during construction which affects the accuracy of the temporary benchmarks, the Contractor shall detect and report such movement and reestablish temporary bench marks. The locations of the permanent monumentation benchmarks are indicated on the Drawings. Advise the Owner's Representative of any settlement affecting the permanent monumentation benchmarks.

- C. Line and Grade.
1. Maintain a means sufficient to check alignment and grade continuously.
 2. Check the survey control for tunneling against an aboveground undisturbed reference at least once each week and once for each 250 feet of tunnel constructed.
 3. When excavation is off line or grade, make alignment corrections to avoid reverse grades in gravity sewers.
 4. Construct primary liner to such tolerances that permit the installation of sewer pipe to be completed to the tolerances given in Section 02725 - Sewer Line in Tunnels.
- D. Earth Movement. The Contractor shall be responsible for damages due to settlement from any construction-induced activities or occurrences.
1. The Contractor shall survey the crown, invert, and springline on each side of the primary liner at 50-foot intervals, or a minimum of once per shift, or more frequently if line and grade tolerances have been exceeded, to ensure the alignment is within the tolerances specified. The survey shall be conducted immediately behind the tunnel excavation to allow immediate correction of misalignment.
 2. The Contractor should be aware that if settlement of the ground surface should occur during construction of the tunnel which will affect the accuracy of the temporary benchmarks established by the Owner's Representative, it shall be the Contractor's responsibility to detect and report such movement. The locations of the permanent monumentation benchmarks are indicated on the Drawings; the Contractor may use these to verify temporary benchmark accuracy. Advise the Owner's Representative of any settlement affecting the permanent monumentation benchmarks. Upon completion, the field books pertaining to monitoring of the permanent monumentation benchmarks shall be submitted to the Owner's Representative.

3.07 MONITORING

- A. Instrumentation Monitoring. Instrumentation requirements are shown on the Drawings. Instrumentation specified shall be accessible at all times to the Owner's Representative. Readings shall be submitted promptly to the Owner's Representative
1. Install and maintain an instrumentation system to monitor and detect movement of the ground surface and adjacent structures. Establish vertical control points at a distance from the construction areas that avoids disturbance due to ground settlement.

2. Installation of the instrumentation shall not preclude the Owner's Representative, through an independent contractor or consultant, from installing instrumentation in, on, near, or adjacent to the construction work. Access shall be provided to the work for such independent installations.
 3. Instruments shall be installed in accordance with the Drawings and the manufacturer's recommendations.
- B. Surface Settlement Monitoring
1. Establish monitoring points on all critical structures.
 2. Record location of settlement monitoring points with respect to construction baselines and elevations. Record elevations to an accuracy of 0.01 feet for each monitoring point location. Monitoring points should be established at locations and by methods that protect them from damage by construction operations, tampering, or other external influences.
 3. Ground surface elevations must be recorded on the centerline ahead of the tunneling operations at a minimum of 100-foot intervals or at least three locations per tunnel drive. For primary lined tunnels greater than 60 inches cut diameter also record similar data at approximately 20 feet each side of the centerline. Settlement monitoring points must be clearly marked by studs or paint for ease of locating.
 4. Railroads. Monitor ground settlement of track subbase at centerline of each track.
 5. Utilities and Pipelines. Monitor ground settlement directly above and 10 feet before and after the utility or pipeline intersection.
- C. Reading Frequency and Reporting. The Contractor shall submit to the Owner's Representative, records of readings from the various instruments and survey points.
1. Instrumentation monitoring results to be read at the frequency specified and unless otherwise specified, shall be started prior to the zone of active excavation has passed and until no further detectable movement occurs.
 2. Surface settlement monitoring readings shall be taken:
 - a. Prior to the zone of active excavation reaching that point,
 - b. When the tunnel face reaches the monitoring point (in plan), and
 - c. When the zone of active excavation has passed and no further movement is detected.

3. All monitoring readings shall be submitted promptly to the Owner's Representative.
4. Immediately report to the Owner's Representative any movement, cracking, or settlement which is detected.
5. Following substantial completion but prior to final completion, make a final survey of all monitoring points.

3.08 DISPOSAL OF EXCESS MATERIAL

- A. Remove spoil from the job site and dispose in accordance with Section 01564 - Waste Material Disposal.

END OF SECTION