Section 02425

TUNNEL EXCAVATION AND PRIMARY LINER

PART 1 G E N E R A L

1.01 SECTION INCLUDES

A. Tunnel construction by placement of primary liner for installation of sewer pipe using 2-pass method. Placement of sewer pipe inside tunnel constructed with primary liner shall be in accordance with Section 02426 - 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. Install liner types as shown on Drawings. Use techniques and liner methods appropriate for prevailing ground conditions, unless otherwise indicated.

1.02 MEASUREMENT AND PAYMENT

A. Unit Prices.

1. Work performed under this Section such as excavation, primary liner, and grouting will not be paid directly. Include cost of this work in unit prices for installation of sewer line in tunnel, in accordance with Section 02426 - Sanitary Sewer Line in Tunnels.

2. Monitoring will be paid for at lump sum price for installation, observation, and reporting.

3. Refer to Section 01270 - Measurement and Payment for unit price procedures.

B. Stipulated Price (Lump Sum). If Contract is Stipulated Price Contract, payment for work in this Section is included in Total Stipulated Price.

1.03 REFERENCE STANDARDS

A. American Association of State Highway and Transportation Officials (AASHTO).

B. American Railway Engineering and Maintenance-of-Way Association (AREMA) Manual for Railway Engineering.

C. American Society for Testing and Materials (ASTM).

1. ASTM A 36 - Standard Specifications for Carbon Structural Steel.

2. ASTM A 283 - Standard Specifications for Low and Intermediate Tensile Strength Carbon Steel Plates.

3. ASTM A 307 - Standard Specifications for Carbon Steel Bolts and Studs, 60,000 PSI Tensile Strength.

D. Occupational Safety and Health Administration (OSHA).

1.04 DEFINITION

A. Primary liner: First tunnel support installed by Contractor in 2-pass method.

B. Carrier pipe: Sewer line as specified in Section 02426 - Sewer Line in Tunnels.

C. Zone of Active Excavation. Area located within radial distance about surface point immediately above face of excavation equal to depth to bottom of excavation.

D. Critical Structure: Building, structure, bridge, pier, or similar construction partially or entirely located within 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: Written description, together with supporting documentation that defines Contractor's plans and procedures for tunneling operations.

G. Shield: Fabricated ground support, circular in section, providing 360-degree protection to those working in it. Shield will have cutting edge, and be equipped with independently operated hydraulic propulsion rams, allowing it to be steered. Liner is erected within tail attached to shield.

H. Open Face: Face of heading or tunnel, which is unsupported during excavation (e.g., in hand mining or shield excavation).

I. Closed Face: Face of heading or tunnel which is supported during excavation process from TBM, where cutter head allows both partial exposure of face and full closure, by means of hydraulically operated gates.

1.05 SUBMITTALS

A. Conform to requirements of Section 01330 - Submittal Procedures.

B. The following submittals are required:

1. Tunneling Methodology. Brief description of proposed tunnel methodology for review. Description should be sufficient to convey 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 face, surface storage, and disposal location.

   g. Method of installing pipe.

   h. Identification of critical utility crossings and special precautions proposed.

   i. Manufacturer and type of chemical grout proposed.

2. Drawings and Calculations. Submit for record purposes, drawings and calculations for tunnel support system designed by Contractor. Drawings shall be adequate for construction, and include installation details. Documents must be signed and sealed by Professional Engineer registered in State of Texas. Include calculations with clear statement of criteria used for design, as described in Paragraph 1.06, Design Criteria.

3. Quality Control. Submit for review 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 zone of active excavation.

   d. Settlement survey plan (may be included in instrumentation plan).

4. Geotechnical Investigation. When geotechnical investigations are conducted by Contractor, submit results to City Engineer for record purposes.

5. Monitoring Plans:

a. Instrumentation Monitoring Plan. Submit for review, prior to construction, monitoring plan that includes 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 settlement monitoring plan for review prior to construction. Identify location of settlement monitoring points, reference benchmarks, survey frequency and procedures, and reporting formats on plan.

6. Structures Assessment. Submit preconstruction and post-construction assessment reports for critical structures, namely those located within zone of active excavation from proposed tunnel centerline. Include photographs or video of existing damage to structures in vicinity of sewer alignment in assessment reports.

7. Submit monitor readings to City Engineer.

8. Daily Reports. Maintain shift log as defined in Paragraph 3.04, Tunneling Data, and make available to City Engineer on request.

1.06 DESIGN CRITERIA

A. Provide primary liner designed by Contractor’s Professional Engineer for appropriate loading conditions and deflection criteria, including but not limited to: overburden and lateral earth pressures; handling and installation stresses; loads imposed by tunnel shield or tunnel boring machine thrust jacks; subsurface soil and water loads; grouting; and other conditions of service. Assume responsibility for design of primary liner to carry construction loads in combination with overburden, earth and hydrostatic loads.

B. At railroad crossings conform to Cooper E-80 locomotive loading distributions in accordance with AREMA specifications for culverts. In design, account for additive loadings due to multiple tracks. Provide liner type for railroad crossings as specified or as shown on Drawings.

C. For truck loading use HS-20 vehicle loading distributions in accordance with AASHTO.

D. Use liner system compatible with special requirements shown on Drawings.

PART 2 P R O D U C T S

2.01 STEEL LINER PLATES

A. In locations shown on Drawings, manufacture liner plate (2-flange or 4-flange) certified by manufacturer for compliance with Specifications.

B. Provide bolts and nuts conforming to ASTM A 307, Grade A.

C. Punch plates for bolting on both longitudinal and circumferential seams and fabricate to permit complete erection from inside tunnel. Provide plates of uniform fabrication. Plates intended for one size tunnel shall be interchangeable.

D. Material used for construction of liner plates shall be in good condition.

E. Provide sufficient number of bolted steel liner plates with approximately 2-inch diameter grout holes furnished with plugs. Locate holes near plate center.

PART 3 E X E C U T I O N

3.01 PREPARATION

A. Use methods for tunneling operations that will minimize ground settlement. Select method, which will control flow of water, prevent loss of soil into tunnel, and provide stability of 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 public.

C. Maintain clean working conditions inside tunnel and shafts.

D. For tunneling under railroad embankments, highways, or streets, perform installation so as to avoid interference with operation of railroads, highways, or streets, except as approved by owner of facility.

E. Support ground continuously in manner to prevent loss of ground and keep perimeters and faces of tunnel stable.

F. Completed primary tunnel lining shall have full bearing against ground. Grout peripheral space between support elements and excavated surface or close by expanding support elements against ground to achieve full bearing as tunnel advances.

G. Ground Conditions. Perform additional exploration by geotechnical borings in advance of construction to define necessary parameters for design of primary tunnel liner, planning and designing ground water control system, and for selection of tunneling method and equipment to successfully complete each tunnel reach.

H. Be aware that various existing soil borings, piezometers, or instrument wells, where indicated on Drawings, may coincide with 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 effect these boreholes, piezometers, or instrument wells may have on tunneling operations.

3.02 GROUND WATER CONTROL

A. Provide necessary ground water control measures to perform work and to provide safe working conditions. Comply with provisions of Section 01578 - Control of Ground Water and Surface Water.

B. Anticipate that portions of tunnel excavation may be below ground water table and in cohesionless soils, even when not indicated on soil borings, and in conditions, which may require ground water control system for tunneling operations. Install filter fabrics, backer rods and other means as necessary to prevent piping of fines into tunnel.

C. When Contractor chooses pumping installations to control ground water level or installs pervious liner through water bearing layers, install and maintain instrumentation system to monitor water level and to detect movement in adjacent structures and property.

D. Operate dewatering system for tunnels until carrier pipe has been installed and annular space is fully grouted, or until watertight liner designed for hydrostatic pressures is installed.

E. Do not proceed with tunneling for which ground water control is necessary until monitoring data indicates that ground water control system is operating in accordance with Contractor's plan.

3.03 EQUIPMENT

A. Assume responsibility for selection of tunneling equipment which, based on past experience, has proven to be satisfactory for excavation of soils to be encountered.

B. Employ tunneling equipment that will be capable of handling various anticipated ground conditions and which minimizes loss of soil ahead of face and allows satisfactory support of excavated face.

C. TBM or shield shall conform to shape of tunnel with 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 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 light fixtures in watertight enclosures with suitable guards. Provide separate circuits for lighting and other equipment.

F. Conform to requirements of National Electrical Code - NFPA70 for Electrical systems.

3.04 TUNNELING DATA

A. Maintain shift logs of construction events and observations. City Engineer shall have access to 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 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 lost ground or other ground movement.

7. Unusual conditions or events.

8. Reasons for operational shutdown in event drive is halted.

B. Clearly mark primary liner with paint every 20 feet along tunnel with distance in feet from centerline of 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 public.

2. Maintain tunnel excavation within easements and rights-of-way indicated on Drawings, to lines and grades shown on Drawings. Excavation shall be of sufficient size to allow installation of sewer pipe to lines and grades indicated on Drawings.

3. Open-face excavations:

   a. Keep face breasted or otherwise supported and prevent falls, excessive raveling, or erosion. Maintain standby face supports for immediate use when needed.

   b. During shut-down periods, support face of excavation by positive means; do not rely solely on hydraulic pressure for support.

4. Closed-face excavation:

   a. Control volume of spoil removed. Determine that advance rate and excavation rate are compatible to avoid over excavation or loss of ground.

   b. When cutting head is withdrawn, keep excavated face supported and stabilized.

   c. When face of machine is open for maintenance, monitor conditions that might threaten stability of heading. Take appropriate action to prevent or limit influx of soils and water, which would threaten stability of heading.

5. Whenever condition is identified which could endanger tunnel excavation or adjacent structures, operate continually for 24 hours day, including weekends and holidays, without intermission until condition no longer exists.

B. Determination of primary liner size and section shall be sole responsibility of Contractor, to match construction methods and equipment described in tunneling methodology submittal. Provide tunnels of sufficient size to permit efficient excavation operations, sufficient working space for placing primary tunnel liner, and to allow for installation of sewer pipe.

C. Primary Liner Installation:

1. Provide method to ensure full bearing of soil against primary liner without significant settlement or movement of surrounding soil. To fill void behind primary liner, either expandable liner (e.g., ring beams and timber lagging) or non-expandable liner (e.g., bolted steel liner plates) may be used provided grout is placed behind non-expandable liner. Box tunnel where ground is excavated to true shape may be ungrouted.

2. When using TBM or tunnel shield, advance equipment only far enough to permit construction of one primary liner set, entirely within equipment shield.

3. Install filter fabric around exterior of primary liner when using steel ribs and lagging. Install backer rods at ribs as required to control migration of fines. Close windows in lagging.

4. After grouting, ensure deflection of liner is no more than allowable, nor liner is distorted by excessive pressure.

D. Seal blind headings with temporary bulkhead.

E. Grouting: Requirements pertaining to grout mix design and tunnel grouting are provided in Section 02431 - Tunnel Grout.

3.06 CONTROL OF TUNNEL LINE AND GRADE

A. Construction Control.

1. City Engineer will establish baselines and benchmarks indicated on Drawings. Check baselines and benchmarks at beginning of Work and report errors or discrepancies to City Engineer.

2. Use baselines and benchmarks established by City Engineer to establish and maintain construction control points, reference lines, and grades for locating tunnel.

3. Establish control points sufficiently far from face so as not to be affected by tunneling operations.

B. Benchmark Movement. Ensure that when settlement of ground surface occurs during construction, which affects accuracy of temporary benchmarks, detect and report such movement and reestablish temporary benchmarks. Locations of permanent City of Tomball monumentation benchmarks are indicated on Drawings. Advise City Engineer of settlement affecting permanent monumentation benchmarks. Upon completion, submit field books pertaining to monitoring of permanent monumentation benchmarks to City Engineer.

C. Line and Grade.

1. Maintain means sufficient to check alignment and grade continuously.

2. Check survey control for tunneling against 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 installation of sewer pipe to be completed to tolerances given in Section 02426 - Sanitary Sewer Line in Tunnels.

D. Earth Movement. Assume responsibility for damages due to settlement from construction-induced activities or occurrences.

1. Survey crown, invert, and springline on each side of primary liner at 50-foot intervals, or minimum of once per shift, or more frequently when line and grade tolerances have been exceeded, to ensure alignment is within tolerances specified. Conduct survey immediately behind tunnel excavation to allow immediate correction of misalignment.

3.07 MONITORING

A. Instrumentation Monitoring. Instrumentation requirements are shown on Drawings. Ensure instrumentation specified is accessible to City Engineer. Submit readings promptly to City Engineer.

1. Install and maintain instrumentation system to monitor and detect movement of ground surface and adjacent structures. Establish vertical control points at distance from construction areas that avoids disturbance due to ground settlement.

2. Installation of instrumentation shall not preclude City Engineer, through independent contractor or consultant, from installing instrumentation in, on, near, or adjacent to construction work. Provide access to work for such independent installations.

3. Install instruments in accordance with Drawings and 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 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 centerline ahead of tunneling operations at 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 centerline. Clearly mark settlement monitoring points 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 utility or pipeline intersection.

C. Reading Frequency and Reporting. Submit to City Engineer, records of readings from various instruments and survey points.

1. Instrumentation monitoring results to be read at frequency specified, unless otherwise specified. Start monitoring before zone of active excavation is passed and until no further detectable movement occurs.

2. Record surface settlement monitoring readings:

   a. Prior to zone of active excavation reaching that point,

   b. When tunnel face reaches monitoring point (in plan), and

   c. When zone of active excavation has passed and no further movement is detected.

3. Submit monitoring readings promptly to City Engineer.

4. Immediately report to City Engineer movement, cracking, or settlement, which is detected.

5. Following substantial completion, but prior to final completion, perform final survey of monitoring points.

3.08 DISPOSAL OF EXCESS MATERIAL

A. Remove spoil from job site and dispose in accordance with Section 01576 - Waste Material Disposal.

END OF SECTION