

SECTION 02312

MICROTUNNELING AND PIPE JACKED TUNNELS

PART 1 GENERAL

1.01 SECTION INCLUDES

- A. Tunnel construction of sewers by one-pass methods with or without man entry. The construction methods involve jacking pipe following a hand-shield excavation or a tunnel boring machine (TBM) or micro-tunnel boring machine (MTBM), with the pipe serving as both the tunnel liner during construction and the sewer pipe after completion of construction.
- B. Pipe utilized shall be as specified on the project plans.

1.02 UNIT PRICE

- A. The length of the sewer installed will be measured by linear foot along the center line of the completed sewer from center line to center line of manholes, as designated on the Drawings; and to the end of stubs or the termination of the pipe; and to the inside face of lift station and treatment plant works. The installation of the sewer within the limits of a structure other than manholes will not be considered for measurement and payment at the unit price bid.
- B. Payment will include and be full compensation for labor, equipment, materials, and supervision for construction of the sewer and excavation, complete in place including disposal of excess materials, sheeting, shoring or bracing, dewatering, utility adjustments, connections to existing sewers, grouting (if required), tests, backfilling, clean-up, and other related work necessary for construction as specified or as shown on the Drawings.
- C. Monitoring (if required) will be paid for at the lump sum price for installations, observations, and reporting.

1.03 DEFINITIONS

- A. Jacked Pipe. A method for installing sewer pipe that serves as initial construction lining and tunnel support, installed for stability and safety during construction, and as the sewer pipe. The pipe is shoved forward, or jacked, as the tunnel is advanced.
- B. Microtunneling. A method of installing pipe by jacking the pipe behind a microtunnel boring machine which is connected to and shoved forward by the pipe being installed, generally precluding man-entry.

- C. Tunnel Boring Machine (TBM). Mechanized excavating equipment that is a steerable, guided and articulated, connected to and shoved forward by the pipe being installed, with man entry.
- D. Microtunnel Boring Machine (MTBM). Mechanized excavating equipment that is remotely-controlled, steerable, guided and articulated, connected to and shoved forward by the pipe being installed, usually precluding man entry.
- E. Tunneling Methodology. A written description, together with supporting documentation that defines Contractor's plans and procedures for the microtunneling or pipe jacking operations.
- F. 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 the excavation.
- G. Critical Structure. Any building, structure, bridge, pier, or similar construction partially or entirely located within a zone of active excavation.

1.04 TUNNEL SUBMITTALS

- A. Submittals shall be made 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.
 - 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. Locations of access shafts and work sites.
 - f. Method of spoil transportation from the face, surface storage and disposal location.
 - g. Capacity of jacking equipment and type of cushioning.
 - h. Identify critical utility crossings and special precautions 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. For pipe jacking and microtunneling, show pipe and pipe joint detail. 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.
4. Geotechnical Investigation: When geotechnical investigations are conducted by the Contractor, submit results to the Owner's Representative for record purposes.
5. Monitoring Plans (if required):
 - 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 postconstruction 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, subparagraph 3.04A, shall be maintained by the Contractor, and must be made available to the Owner's Representative on request.

1.05 DESIGN CRITERIA

- A. Contractor is responsible for selection of the appropriate pipe and pipe joints to carry the thrust of any jacking forces or other construction loads in combination with overburden, earth and hydrostatic loads. Design of any pipe indicated on the Drawings considers in-place loads only and does not take into account any construction loads. The criteria for longitudinal loading (jacking forces) on the pipe and joints shall be determined by the Contractor, based on the selected method of construction.
- B. The jacked pipe shall be designed to withstand the thrust from the MTBM, TBM or shield and pipe advance without damage or distortion. The propulsion jacks shall be configured so that the thrust is uniformly distributed and will not damage or distort the pipe.
- C. Take into account loads from handling and storing.
- D. 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.
- E. The criteria to be used for truck loading shall be HS-20 vehicle loading distributions in accordance with AASHTO.
- F. Provide pipes of diameter shown on the Drawings. Substitution of pipe with larger diameter to suit MTBM or TBM equipment availability will only be permitted if the Contractor can demonstrate to the Owner's Representative's satisfaction that design flows and velocities can be achieved.

PART 2 PRODUCTS

2.01 SEWER PIPE

- A. Contractor shall be responsible for selecting appropriate pipes and pipe joints to safely carry the loads imposed during construction, including jacking forces. Pipe joints shall be flush with the outside pipe face when the pipes are assembled. Pipe materials shall be selected by Contractor from the following:
- B. Centrifugally-cast fiberglass pipe, joints, and fittings to be in accordance with Section 02618 - Centrifugally-Cast Fiberglass Pipe.
- C. Vitrified clay pipe, joints and fittings to be in accordance with Section 02621 - Extra Strength Clay Pipe.
- D. Plastic-lined reinforced concrete pipe with joints and fittings to be in accordance with Section 02615 - Reinforced Concrete Pipe. Plastic liner to be omitted for storm sewers.

- E. Use pipe that is round with a smooth, even outer surface, and has joints that allow for easy connections between pipes. Pipe ends shall be designed so that jacking loads are evenly distributed around the entire pipe joint and such that point loads will not occur when the pipe is installed. Pipe used for pipe jacking shall be capable of withstanding all forces that will be imposed by the process of installation, as well as the final in-place loading conditions. Protect the driving ends of the pipe and joints against damage.

PART 3 EXECUTION

3.01 CONSTRUCTION OPERATIONS CRITERIA

- A. Use methods for microtunneling and pipe-jacked tunneling operations that will minimize ground settlement. Select a method which will control flow of water and 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 wherever there is man-access.
- 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.

3.02 GROUND WATER CONTROL

- A. Provide ground water control measures in conformance with Section 01563 - Control of Ground Water and Surface Water, when necessary to perform the Work.

3.03 EQUIPMENT

- A. Full directional guidance of a shield, TBM, or MTBM is a prerequisite of this method of construction.
- B. 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.
- C. The Contractor shall employ tunneling equipment that will be capable of handling the various anticipated ground conditions and is capable of minimizing loss of soil ahead of and around the machine and shall provide satisfactory support of the excavated face.

- D. Tunnel Boring Machine (TBM). A TBM used for pipe-jacking 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 overcutting bead may be provided to facilitate steering. In addition, it shall:
1. Be capable of full face closure.
 2. Be equipped with appropriate seals to prevent loss of bentonite lubricant.
 3. Be capable of correcting roll by reverse drive or fins.
 4. Be designed to handle adverse ground conditions including ground water ingress.
 5. Be equipped with visual display to show the operator actual position of TBM relative to design reference.
- E. Tunnel Shield. If a hand shield is used for pipe-jacked tunneling (with or without attached mechanized excavating equipment), the shield must be capable of handling the various anticipated ground conditions. In addition, the shield shall:
1. 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 overcutting bead may be provided to facilitate steering.
 2. Be designed to allow the face of the tunnel to be closed by use of gates or breasting boards without loss of ground.
- F. Microtunneling Equipment. In the case of MTBM, use a spoil transportation system which:
1. Either balances the soil and ground water pressures by the use of a slurry or earth pressure balance system; system shall be capable of adjustments required to maintain face stability for the particular soil condition and shall monitor and continuously balance the soil and ground water pressure to prevent loss of slurry or uncontrolled soil and ground water inflow, or, in the case of a slurry spoil transportation system:
 - a. Provides pressure at the excavation face by use of the slurry pumps, pressure control valves, and a flow meter.
 - b. Includes a slurry bypass unit in the system to allow the direction of flow to be changed and isolated, as necessary.
 - c. Includes a separation process. Provide adequate separation of the spoil from the slurry so that slurry with a sediment content within the limits

- required for successful tunneling can be returned to the cutting face for reuse. Appropriately contain spoil at the site prior to disposal.
- d. Uses the type of separation process suited to the size of tunnel being constructed, the soil type being excavated, and the work space available at each work area for operating the plant.
 - e. Allows the composition of the slurry to be monitored to maintain the slurry weight and viscosity limits required.
2. In the case of a cased auger earth pressure balance system, the system shall be capable of adjustments required to maintain face stability for the particular soil condition to be encountered. Monitor and continuously balance the soil and ground water pressure to prevent loss of soil or uncontrolled ground water inflow.
 - a. In a cased auger spoil transportation system, manage the pressure at the excavation face by controlling the volume of spoil removal with respect to the advance rate. Monitor the speed of rotation of the auger flight, and the addition of water.
 3. Remote Control System. Provide an MTBM which includes a remote control system with the following features:
 - a. Allows for operation of the system without the need for personnel to enter the tunnel. Has a display available to the operator, at a remote operation console, showing the position of the shield in relation to a design reference together with other information such as face pressure, roll, pitch, steering attitude, valve positions, thrust force, and cutter head torque; rate of advance and installed length.
 - b. Integrates the system of excavation and removal of spoil and its simultaneous replacement by pipe. As each pipe section is jacked forward, the control system shall synchronize all of the operational functions of the system.
 4. Active Direction Control. Provide an MTBM which includes an active direction control system with the following features:
 - a. Controls line and grade by a guidance system that relates the actual position of the MTBM to a design reference (e.g., by a laser beam transmitted from the jacking shaft along the pipe to a target mounted in the shield).
 - b. Provides active steering information which shall be monitored and transmitted to the operating console.

- c. Provides positioning and operation information to the operator on the control console.
 5. Use generator which is suitably insulated for noise ("hospital" type) in residential or commercial areas.
- G. Pipe Jacking Equipment. Provide a tunneling operation which includes a pipe jacking system with the following features:
1. Has the main jacks mounted in a jacking frame located in the starting shaft.
 2. Has a jacking frame which successively pushes a string of connected pipes following the tunneling excavation equipment towards a receiving shaft.
 3. Has sufficient jacking capacity to push the tunneling excavation equipment and the string of pipe through the ground. Incorporates intermediate jacking stations, if required.
 4. Has a capacity at least 20 percent greater than the calculated maximum jacking load.
 5. Develops a uniform distribution of jacking forces on the end of the pipe by use of spreader rings and packing, measured by operating gauges.
 6. Provides and maintains a pipe lubrication system at all times to lower the friction developed on the surface of the pipe during jacking.
 7. Jack Thrust Reactions. Use reactions for pipe jacking that are adequate to support the jacking pressure developed by the main jacking system. Special care shall be taken when setting the pipe guide rails in the jacking shaft to ensure correctness of the alignment, grade, and stability.
- H. Air Quality. Provide equipment to maintain proper air quality of manned tunnel operations during construction in accordance with OSHA requirements.
- I. Enclose lighting fixtures in watertight enclosures with suitable guards. Provide separate circuits for lighting, and other equipment.
- J. Electrical systems shall conform to requirements of National Electrical Code - NFPA70.

3.04 PIPE-JACKED 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 boring machine face or shield 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.
4. Maximum pipe jacking pressures per drive.
5. Location, elevation and brief soil descriptions of soil strata.
6. Ground water control operations and piezometric levels.
7. Observation of any lost ground or other ground movement.
8. Any unusual conditions or events.
9. Reasons for operational shutdown in the event a drive is halted.

3.05 EXCAVATION AND JACKING OF PIPE

A. Tunnel Excavation.

1. Keep tunnel excavation within the easements and rights-of-way indicated on the Drawings and to the lines and grades designated on the Drawings.
2. Perform tunneling operations in a manner that will minimize the movement of the ground in front of and surrounding the tunnel. Prevent damage to structures and utilities above and in the vicinity of the tunneling operations.
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. Carefully control volume of spoil removed. Advance rate and excavation rate to be compatible to avoid over excavation or loss of ground.

- b. When cutting head is withdrawn or is open for any purpose, keep excavated face supported and stabilized.
5. Excavated diameter should be a minimum size to permit pipe installation by jacking with allowance for bentonite injection into the annular space.
6. Whenever there is a condition encountered which could endanger the tunnel excavation or adjacent structures, operate without intermission including 24-hour working, weekends and holidays, until the condition no longer exists.
7. The Contractor shall be responsible for damage due to settlement from any construction-induced activities.

B. Pipe Jacking

1. Cushion pipe joints as necessary to transmit the jacking forces without damage to the pipe or pipe joints.
2. Maintain an envelope of bentonite slurry around the exterior of the pipe during the jacking and excavation operation to reduce the exterior friction and possibility of the pipe seizing in place.
3. If the pipe “freezes” in place and the Contractor elects to construct a recovery access shaft, obtain approval from the Owner’s Representative, then coordinate traffic control measures and utility adjustments as necessary prior to commencing work.
4. In the event a section of pipe is damaged during the jacking operation, or joint failure occurs, as evidenced by inspection, visible ground water inflow or other observations, the Contractor shall submit for approval his methods for repair or replacement of the pipe.

C. Grouting. Grouting requirements are defined in Section 02330 - Tunnel Grout.

3.06 CONTROL OF 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, sewer pipe, and structures.

3. Establish construction control points sufficiently far from the work so as not to be affected by ground movement caused by pipe-jacked tunneling operations.
- B. Bench Mark 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. Check and record the survey control for the tunnel against an above-ground undisturbed reference at least once for each 250 feet of tunnel constructed.
 2. Record the exact position of the MTBM or TBM or shield after each shove to ensure the alignment is within specified tolerances. Make immediate correction to alignment before allowable tolerances are exceeded.
 3. When excavation is off line or grade, make alignment corrections to avoid reverse grades in gravity sewers.
 4. Acceptance criteria for the sewer pipe shall be plus or minus 6 inches in horizontal alignment from the theoretical at any point between manholes, including the receiving end, slope shall meet design grade or greater.
 5. Pipe installed outside tolerances and subsequently abandoned shall first be fully grouted.

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 sewers greater than 60-inch 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 reaching that point, and shall be continued until 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 in accordance with Section 01564 - Waste Material Disposal.

3.09 ACCEPTANCE TESTING

- A. Acceptance testing is to be carried out by methods described in Section 02732 - Acceptance Testing for Sanitary Sewer.

END OF SECTION