

Section 02441

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. Construction methods involve jacking pipe following hand-shield excavation or tunnel boring machine (TBM) or micro-tunnel boring machine (MTBM), with pipe serving as both tunnel liner during construction and sewer pipe after completion of construction.
- B. Select centrifugally cast fiberglass pipe (FRP), vitrified clay pipe (VCP), reinforced concrete pipe (RCP) for storm or sanitary sewers. Use plastic-lined RCP for sanitary sewers. Unlined RCP or RCP lined with liner other than that specified in Section 02427 - Plastic Liner for Large-diameter Concrete Sewers and Structures will not be allowed for sanitary sewers.

1.02 MEASUREMENT AND PAYMENT

- A. Unit Prices.
 - 1. Length of sewer installed will be measured by linear foot along center line of completed sewer from center line to center line of manholes, as designated on Drawings; and to end of stubs or termination of pipe; and to inside face of lift station and treatment plant works. Installation of sewer within limits of structure other than manholes will not be considered for measurement and payment at unit price bid.
 - 2. Payment will include and be full compensation for labor, equipment, materials, and supervision for construction of sewer and excavation, complete in place including disposal of excess materials, sheeting, shoring or bracing, dewatering, utility adjustments, connections to existing sewers, grouting when required, tests, backfilling, clean-up, and other related work necessary for construction as specified or as shown on Drawings.
 - 3. Payment for installation of sewer will be authorized by City Engineer in two parts. Pay estimates for partial payments will be made as measured above according to following schedule:
 - a. 95 percent payment will be made for jacked pipe installed but not yet grouted, in cases where grouting is specified.
 - b. 100 percent payment will be authorized on linear foot basis for amount of jacked sewer pipe installed, including grouting when specified.

4. Monitoring will be paid for at lump sum price for installations, observations, and reporting.

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

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

C. Occupational Safety and Health Administration (OSHA).

D. National Electrical Code - (NFPA 70).

1.04 DEFINITION

A. Jacked Pipe. Method for installing sewer pipe that serves as initial construction lining and tunnel support, installed for stability and safety during construction, and as sewer pipe. Pipe is shoved forward, or jacked, as tunnel is advanced.

B. Microtunneling. Method of installing pipe by jacking pipe behind microtunnel boring machine which is connected to and shoved forward by pipe being installed, generally precluding man entry.

C. Tunnel Boring Machine (TBM). Mechanized excavating equipment that is steerable, guided and articulated, connected to and shoved forward by 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 pipe being installed, usually precluding man entry.

E. Tunneling Methodology. Written description, together with supporting documentation that defines plans and procedures for microtunneling or pipe jacking operations.

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

G. Critical Structure. Building, structure, bridge, pier, or similar construction partially or entirely located within zone of active excavation.

1.05 SUBMITTALS

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

B. Following submittals are required:

1. Tunneling Methodology. Brief description of proposed tunnel methodology. Description should be sufficient to convey 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 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 tunnel support system. Provide adequate drawings and installation details for construction. For pipe jacking and microtunneling, show pipe and pipe joint detail. Documents must be signed and sealed by Professional Engineer registered in State of Texas. Calculations shall include 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.
4. Geotechnical Investigation: When geotechnical investigations are conducted, 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 on plan location of settlement monitoring points, reference benchmarks, survey frequency and procedures, and reporting formats.
6. Structures Assessment. Provide preconstruction and postconstruction 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. Readings of all monitoring shall be submitted to City Engineer.
8. Daily Reports: Maintain shift log as defined in Paragraph 3.04, Pipe-jacked Tunneling Data, and make available to City Engineer on request.

1.06 DESIGN CRITERIA

- A. Assume responsibility for selection of appropriate pipe and pipe joints to carry thrust of any jacking forces or other construction loads in combination with overburden, earth and hydrostatic loads. Design of any pipe indicated on Drawings considers in-place loads only and does not take into account any construction loads. Criteria for longitudinal loading (jacking forces) on pipe and joints shall be determined, based on selected method of construction.
- B. Jacked pipe shall be designed to withstand thrust from MTBM, TBM or shield and pipe advance without damage or distortion. Propulsion jacks shall be configured so that thrust is uniformly distributed and will not damage or distort pipe.
- C. Take into account loads from handling and storing.
- D. Criteria to be used at railroad crossings shall be Cooper E-80 locomotive loading distributions in accordance with AREMA specifications for culverts. In design, account for additive loadings due to multiple tracks.
- E. 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 Drawings. Substitution of pipe with larger diameter to suit MTBM or TBM equipment availability will only be permitted if demonstrated to satisfaction of City Engineer that design flows and velocities can be achieved.

PART 2 PRODUCTS

2.01 SEWER PIPE

- A. Assume responsibility for selecting appropriate pipes and pipe joints to safely carry loads imposed during construction, including jacking forces. Pipe joints shall be flush with outside pipe face when pipes are assembled. Pipe materials shall be selected from following:
- B. Centrifugally cast fiberglass pipe, joints, and fittings to be in accordance with Section 02504 – Centrifugally Cast Fiberglass Pipe.
- C. Vitrified clay pipe, joints and fittings to be in accordance with Section 02508 - Extra Strength Clay Pipe.
- D. Plastic-lined reinforced concrete pipe with joints and fittings to be in accordance with Section 02611 - Reinforced Concrete Pipe and Section 02427 - Plastic Liner for Large-Diameter Concrete Sewers and Structures. Plastic liner is not required for storm sewers.
- E. Use pipe that is round with smooth, even outer surface, and has joints that allow for easy connections between pipes. Design pipe ends so that jacking loads are evenly distributed around entire pipe joint and such that point loads will not occur when pipe is installed. Pipe used for pipe jacking shall be capable of withstanding all forces that will be imposed by process of installation, as well as final in-place loading conditions. Protect driving ends of 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 method, which will control flow of water and 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 wherever there is man access.
- 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.

3.02 GROUND WATER CONTROL

- A. Provide ground water control measures in conformance with Section 01578 - Control of Ground Water and Surface Water, when necessary to perform Work.

3.03 EQUIPMENT

- A. Full directional guidance of shield, TBM, or MTBM is prerequisite of this method of construction.
- B. Assume responsibility for selection of tunneling equipment which, based on past experience, has proven to be satisfactory for excavation of soils to be encountered.
- C. Employ tunneling equipment that will be capable of handling various anticipated ground conditions and is capable of minimizing loss of soil ahead of and around machine and shall provide satisfactory support of excavated face.
- D. Tunnel Boring Machine (TBM). A TBM used for pipe jacking shall conform to shape of tunnel with uniform perimeter that is free of projections that could produce over- excavation or voids. 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 operator actual position of TBM relative to design reference.
- E. Tunnel Shield. If hand shield is used for pipe-jacked tunneling (with or without attached mechanized excavating equipment), shield must be capable of handling various anticipated ground conditions. In addition, shield shall:
 - 1. Conform to shape of tunnel with uniform perimeter that is free of projections that could produce over-excavation or voids. Appropriately sized overcutting bead may be provided to facilitate steering.
 - 2. Be designed to allow face of tunnel to be closed by use of gates or breasting boards without loss of ground.
- F. Microtunneling Equipment. In case of MTBM, use spoil transportation system which:
 - 1. Balances soil and ground water pressures by use of slurry or earth pressure balance system; system shall be capable of adjustments required to maintain face stability for particular soil condition and shall monitor and continuously balance soil and ground

water pressure to prevent loss of slurry or uncontrolled soil and ground water inflow, or, in case of slurry spoil transportation system:

- a. Provides pressure at excavation face by use of slurry pumps, pressure control valves, and flow meter.
 - b. Includes slurry bypass unit in system to allow direction of flow to be changed and isolated, as necessary.
 - c. Includes separation process. Design it to provide adequate separation of spoil from slurry so that slurry with sediment content within limits required for successful tunneling can be returned to cutting face for reuse. Appropriately contain spoil at site prior to disposal.
 - d. Uses type of separation process suited to size of tunnel being constructed, soil type being excavated, and work space available at each work area for operating plant.
 - e. Allows composition of slurry to be monitored to maintain slurry weight and viscosity limits required.
2. In case of cased auger earth pressure balance system, system shall be capable of adjustments required to maintain face stability for particular soil condition to be encountered. Monitor and continuously balance soil and ground water pressure to prevent loss of soil or uncontrolled ground water inflow.
- a. In cased auger spoil transportation system; manage pressure at excavation face by controlling volume of spoil removal with respect to advance rate. Monitor speed of rotation of auger flight, and addition of water.
3. Remote Control System. Provide MTBM, which includes remote control system with following features:
- a. Allows for operation of system without need for personnel to enter tunnel. Has display available to operator, at remote operation console, showing position of shield in relation to 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 system of excavation and removal of spoil and its simultaneous replacement by pipe. As each pipe section is jacked forward, control system shall synchronize all of operational functions of system.
4. Active Direction Control. Provide MTBM, which includes active direction control system with following features:

- a. Controls line and grade by guidance system that relates actual position of MTBM to design reference (e.g., by laser beam transmitted from jacking shaft along pipe to target mounted in shield).
 - b. Provides active steering information, which shall be monitored and transmitted to operating console.
 - c. Provides positioning and operation information to operator on control console.
5. Use generator which is suitably insulated for noise ("hospital" type) in residential or commercial areas.

G. Pipe Jacking Equipment. Provide pipe-jacking system with following features:

1. Has main jacks mounted in jacking frame located in starting shaft.
2. Has jacking frame, which successively pushes string of connected pipes following tunneling excavation equipment towards receiving shaft.
3. Has sufficient jacking capacity to push tunneling excavation equipment and string of pipe through ground. Incorporates intermediate jacking stations, if required.
4. Has capacity at least 20 percent greater than calculated maximum jacking load.
5. Develops uniform distribution of jacking forces on end of pipe by use of spreader rings and packing, measured by operating gauges.
6. Provides and maintains pipe lubrication system at all times to lower friction developed on surface of pipe during jacking.
7. Jack Thrust Reactions. Use reactions for pipe jacking that are adequate to support jacking pressure developed by main jacking system. Special care shall be taken when setting pipe guide rails in jacking shaft to ensure correctness of 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. City Engineer shall have access to all logs with regard to 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, such as steering control logs, for checking line and grade of tunneling operation, showing achieved tolerance relative to design alignment.
 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 event drive is halted.

3.05 EXCAVATION AND JACKING OF PIPE

- A. Tunnel Excavation.
1. Keep tunnel excavation within easements and rights-of-way indicated on Drawings and to lines and grades designated on Drawings.
 2. Perform tunneling operations in manner that will minimize movement of ground in front of and surrounding tunnel. Prevent damage to structures and utilities above and in vicinity of tunneling operations.
 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; 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 minimum size to permit pipe installation by jacking with allowance for bentonite injection into annular space.
 6. Whenever there is condition encountered which could endanger tunnel excavation or adjacent structures, operate without intermission including 24-hour working, weekends and holidays, until condition no longer exists.
 7. Assume responsibility for damage due to settlement from any construction-induced activities.

B. Pipe Jacking

1. Cushion pipe joints as necessary to transmit jacking forces without damage to pipe or pipe joints.
2. Maintain envelope of bentonite slurry around exterior of pipe during jacking and excavation operation to reduce exterior friction and possibility of pipe seizing in place.
3. If pipe seizes up in place and elect to construct recovery access shaft, obtain approval from City Engineer. Coordinate traffic control measures and utility adjustments as necessary prior to commencing work.
4. In event section of pipe is damaged during jacking operation, or joint failure occurs, as evidenced by inspection, visible ground water inflow or other observations, submit for approval his methods for repair or replacement of pipe.

C. Grouting. Grouting requirements are defined in Section 02431 - Tunnel Grout.

3.06 CONTROL OF 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 any 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, sewer pipe, and structures.

3. Establish construction control points sufficiently far from work so as not to be affected by ground movement caused by pipe-jacked tunneling operations.
- B. Bench Mark Movement. Ensure that if 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 any settlement affecting permanent monumentation benchmarks.
- C. Line and Grade.
1. Check and record survey control for tunnel against above-ground undisturbed reference at least once for each 250 feet of tunnel constructed.
 2. Record exact position of MTBM or TBM or shield after each shove to ensure 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 sewer pipe shall be plus or minus 6 inches in horizontal alignment from theoretical at any point between manholes, including receiving end, and plus or minus 1-1/2 inches in elevation from theoretical.
 5. Pipe installed outside tolerances and subsequently abandoned shall first be fully grouted.

3.07 MONITORING

- A. Instrumentation Monitoring. Instrumentation requirements are shown on Drawings. Instrumentation specified shall be accessible at all times to City Engineer. Readings shall be submitted 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. Access shall be provided to work for such independent installations.
 3. Instruments shall be installed 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 shall be recorded on centerline ahead of tunneling operations at 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 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 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 and unless otherwise specified, shall be started prior to zone of active excavation reaching that point, and shall be continued until zone of active excavation has passed and until no further detectable movement occurs.
2. Surface settlement monitoring readings shall be taken:
 - 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. All monitoring readings shall be submitted promptly to City Engineer.
4. Immediately report to City Engineer any movement, cracking, or settlement which is detected.
5. Following substantial completion but prior to final completion, make final survey of all monitoring points.

3.08 DISPOSAL OF EXCESS MATERIAL

- A. Remove spoil in accordance with Section 01576 - Waste Material Disposal.

3.09 ACCEPTANCE TESTING

- A. Acceptance testing is to be carried out by methods described in Section 02533 - Acceptance Testing For Sanitary Sewer.

END OF SECTION