

SECTION 02920**EARTH TUNNELING****02920.01 GENERAL****A. Description**

Earth tunneling shall include, but not necessarily be limited to, constructing earth tunnels, and furnishing and installing tunnel liners to the limits shown on the Plans and in accordance with the Contract Documents.

B. Related Work Included Elsewhere

1. Structure excavation; Section 02220.
2. Trench excavation, backfill, and compaction; Section 02250.
3. Excavation support; Section 02400.
4. Dewatering; Section 02512.
5. Storm drain installation; Section 02520.
6. Water main installation; Section 02551.
7. Sanitary sewer installation; Section 02561.
8. Sanitary sewer force main installation; Section 02563.

C. Quality Assurance

1. Qualifications
 - a. Use personnel thoroughly trained and experienced in skills required. Field supervisor of tunneling operations and tunneling machine operator to have not less than 12 months experience in operation of specific equipment to be used.
 - b. Make welds only by welders, tackers and welding operators previously qualified by tests as prescribed in Structural Welding Code AWS D1.1 to perform type of work required. Show proof of certification when requested by Engineer.
 - c. Where fabricated segments for tunnel lining are to be used, the segments shall be fabricated by a qualified firm with a minimum of 5 years' experience of similar type manufacturing and which has manufactured segments for at least three representative jobs of comparable type of

service and size to the Project, which have been in satisfactory service for at least 3 years.

2. Materials

- a. The Engineer will inspect all materials before and/or after installation to ensure compliance with the Contract Documents. When specific materials tests are required by the referenced standards and specifications, the Engineer will have the option of requiring that any or all of these tests be performed for materials furnished for a specific project. When testing is required, it will be specified in the "Special Provisions".

3. Field Tests

a. General

No testing will be conducted on tunnels installed in accordance with this Section, however the work will be visually inspected.

b. Tunnels

- 1) For segmented tunnel linings, inside dimensions of the ring measured along any diameter shall not vary by more than 3% of the lining diameter.
- 2) Where concrete invert is specified in the Contract Documents, tunnels shall be constructed to the line or grade indicated on the Plans so as to allow a minimum carrier pipe concrete cradle thickness of 4 inches.

- c. Vertical deflection of the tunnel lining shall be limited to 3% of the diameter. If the vertical diameter of the tunnel is reduced by more than 3%, all further operations shall be carried out with a heavier liner section.

d. Carrier Pipe

- 1) Carrier pipe will be inspected and/or tested in accordance with the applicable section or sections under which the remainder of the pipeline was installed.

4. Detection of Movement

- a. The Contractor shall install, maintain, make observations, and maintain a permanent record of his observations on a regular pattern of surface settlement markers as shown on the Plans or as directed by the Engineer. Settlement marker elevations shall be tied to benchmarks sufficiently remote as not to be affected by the construction operations.

- b. Subsurface Indicators
 - 1) Subsurface settlement indicators shall be installed at locations shown or directed by the Engineer prior to start of dewatering or tunneling.
 - 2) The tip of the indicator rod shall be installed to within 1 foot above the crown of the tunnel or as directed by the Engineer.
- c. The Contractor shall take at least 3 reading for each marker on three separate day prior to start of excavation to verify repeatability of readings. Pre-excavation readings shall be submitted and reviewed by the Engineer before start of excavation will be authorized.
- d. The Contractor shall monitor the movements of the indicators to an accuracy of +0.01 foot in accordance with readings taken on an approved schedule.
- e. Prepare a plan showing locations of monitoring indicators and their designations. Maintain an electronic (spreadsheet) log of all readings, including the pre-excavation readings, The Contractor shall submit copies of the records to the Engineer as the Project progresses and logs shall be available to the Engineer for review at all times.
- f. Whenever tunneling occurs within 50 feet of an indicator, the movements of the indicator shall be monitored before and after each advance of tunnel face within 50 feet of the indicator.
- g. Unless established by the Contract Documents, Threshold displacement shall be 0.5” and Limit displacement shall be 1.0”, horizontally or vertically. If a Threshold displacement is reached, Contractor shall immediately notify the Engineer to determine if any action is required. If a Limit displacement occurs, cease operations and ensure stable ground conditions, and immediately notify the Engineer to assess the need for corrective action. When directed by the Engineer, the Contractor shall take immediate remedial action, at no cost to the County.
- h. When authorized by the Engineer and prior to final acceptance, remove subsurface monitoring equipment and casing to at least 2 feet below grade. Remove all surface monitoring stakes.

D. Submittals

1. Shop Drawings

a. Shop drawings shall be submitted as specified in the "General Provisions" for all liner plate materials. The shop drawings shall include liner shapes, sizes, load capacities, method of attachment and connection details, details of grout holes, and coatings.

b. Tunnel Work Plan

1) The Contractor shall submit a Tunnel Work Plan with Tunnel Working Drawings for approval at least 4 weeks ahead of construction. The Work Plan approval is for the general arrangement and location of facilities and to demonstrate that the proposed work addresses the critical areas of concern. The tunneling means and methods are the responsibility of the Contractor.

2) Work Plan shall include pertinent descriptions and technical data for tunneling equipment, a summary of the soils data, method of dewatering of shafts and tunnel, shaft excavation and support system, the proposed tunnel access shaft locations and dimensions, method of excavation and means for face stabilization, and method of soil support for launch and reception portals. Work Plan shall also include locations of surface and subsurface settlement markers and monitoring plan if not indicated elsewhere.

c. Tunneling Method

1) Bids shall be based on tunneling using tunnel shields.

2) Complete detailed drawings shall be submitted of the shield and an adequate description of the proposed method of erecting, placing, and operating the shield.

3) The Contractor may submit an alternate method for performing tunneling operations to the Engineer for approval.

4) At the request of the Engineer, complete details of alternate method and pertinent calculations shall be submitted. Should the Engineer approve an alternate method, submit shop and working drawings as previously specified and directed by the Engineer.

d. Access Shaft Design

- 1) When the Contract Documents do not include access shaft design, the Contractor shall be solely responsible for the preparation of access shaft design. Design details and calculations shall be signed and sealed by a Professional Engineer registered in Maryland and shall be submitted for review only.
- 2) When the Contract Documents include access shaft designs, the Contractor may submit alternate access shaft redesigns equal to or greater in size than those indicated. Shaft redesign and resultant additional construction costs shall be at no expense to the County.

2. Certificates of Compliance

Certificates of compliance shall be submitted in accordance with the "General Provisions" for tunnel liner plates stating that the plates have been manufactured in accordance with, and meet the requirements specified in Section 02920.02.

3. Certified Test Reports

The Contractor shall submit certified test reports before delivery of materials for the items listed below.

- a. Gravel packing
- b. Liner plate segments for tunnel lining
- c. Tunnel liner plate connectors
- d. Protective coatings

02920.02 MATERIALS

A. Materials Furnished by the County

The County will not furnish any materials for earth tunneling.

B. Contractor's Options

None.

C. Detailed Material Requirements

1. Portland Cement Concrete

Portland cement concrete for invert cradles shall be Mix No. 2 as specified in Section 03310.

2. Mortar for Grout

Mortar for grouting shall conform to the requirements of Section 04100 except as modified herein:

- a. For filling the annular spaces after the carrier pipe is installed, the grout shall consist of one part Portland cement and three parts sand. Mix shall be sufficiently fluid to be self-leveling. Where metallic carrier pipe is installed, grout shall have a pH of 11.0 or greater.
- b. For filling voids outside the liner plate (contact grout), the grout shall have a minimum compressive strength of 100 psi attained within 24 hours. The grout shall remain fluid long enough to be injected through the lining and to fill the voids and shall set promptly enough to avoid grout flowing into the new annular space after the next advance.

3. Liner Plate

- a. Steel liner plate shall conform to requirements of ASTM A 569. Liner plate steel shall have the minimum mechanical properties of flat plate before cold forming as follows:

Tensile strength	=	42,000 psi
Yield strength	=	28,000 psi
Elongation, 2 inches	=	30%

- b. Tolerances

- 1) Variation in thickness of liner plates shall be ± 0.01 inch maximum.
- 2) Similar segments shall be fabricated with such accuracy and uniformity in dimensions that segments will be entirely interchangeable not only in individual rings but with similar segments of other rings. Space holes accurately so that any two rings can be bolted up in any relative position with same size bolts in every bolt hole.
- 3) Bolt holes shall be provided with a diameter tolerance of ± 0.02 inches. Grout holes shall be located to a tolerance of ± 0.50 inch.
- 4) In making the taper offset, dimensions between the bolt pad and the flange face shall not increase by more than $9/16$ inch or decreased

by more than 1/16 inch from the dimensions indicated, provided bolt length is adjusted accordingly.

- 5) Any segment which does not comply with the tolerances indicated shall be replaced.
- c. At least 10% of the number of liner plates shall be supplied with a 2” diameter cast iron grout plugs. Grout plugs shall be fitted into cast iron threaded couplings welded in place or may be inserted into threaded holes for liner plate 12 gauge or heavier. The actual location and spacing of the plugs shall be in accordance with the Contract Documents or will be determined by the Engineer and Contractor according to field conditions.
- d. Bolts and nuts shall conform to requirements of ASTM A 307. The bolts shall have rolled threads.
- e. Coatings
 - 1) Liner plate shall be hot dipped galvanized to meet requirements of AREMA Chapter 1, Part 4, Section 4.13 Specification for Corrugated Structure Steel Plate Pipe, Pipe Arches and Arches. Bolts and nuts shall be galvanized to meet requirements of ASTM A 153.
 - 2) Liner plate shall be bituminous coated to meet requirements of AREMA Chapter 1, Part 4, Section 4.6.1 Specification for Bituminous Coated Galvanized Steel Pipe and Pipe Arches. Provide prime coat as required to assure compatibility with galvanized surface.
 - 3) Tunnels which are to be filled with concrete after carrier pipe is in place shall not be coated.
- 4. Gravel Packing

Gravel packing shall be rounded gravel, clean and free from objectionable material, and graded as follows:

Sieve Sizes <u>U.S. Standard</u>	Mass Percent <u>Passing</u>
3 inch	100
1/2 inch	85-100
3/8 inch	70-100
No. 4	0-55
No. 8	0-15
No. 16	0-8

5. Carrier Pipe

Carrier pipe shall be as specified in the Contract Documents and meet the requirements specified in Sections 02520.02, 02551.02, 02561.02, or 02563.02 as appropriate.

6. Manufactured Casing End Seals

a. Where manufactured End Seals are shown or approved, Approved Manufacturers:

- 1) Advance Products & Systems, Model AC or AM
- 2) Pipeline Seal & Insulator, Inc., Model S or C.
- 3) Maloney Technical Products, MULTIFLEX End Seal.
- 4) Or equal.

7. Surface Settlement Markers

- a. Surface settlement markers within pavement areas shall be P.K. nails.
- b. Surface settlement markers within non-paved areas shall be wooden hubs.

8. Subsurface Settlement Indicators

Subsurface settlement indicators shall be fabricated of 2-1/2 inch diameter steel pipe casing, an inner 1 inch diameter extra strong steel pipe with a pipe cap, and 1/4 inch diameter round head stainless steel bolt as directed by the Engineer. Fabricate in accordance with the Standard Details.

02920.03 EXECUTION

A. Construction Criteria

1. Tunnel construction shall be performed in a manner that will minimize movement of the ground in front of and surrounding the tunnel and prevent subsidence of the surface above and in the vicinity of the tunnel. During all stages of tunnel construction, the ground shall be continuously supported and controlled in a manner that will prevent loss of ground and keep the perimeters and face of the tunnel stable. The Contractor shall be responsible for all settlement resulting from tunnel operations and shall repair and restore surface subsidence and damaged property to its original condition at no cost to the County.
2. The Contractor shall comply with applicable ordinances, codes, statutes, rules, and regulations of the State of Maryland, SHA, applicable County building codes,

and/or affected Railroad Company and applicable regulations of the Federal Government (OSHA 29CFR 1926).

B. Job Conditions

1. Provide ventilation system to maintain the tunnel air in a condition suitable for the health of the workers at all times in accordance with OSHA requirements.
2. Maintain an adequate supply of straight and tapered liner segments at the site at all times.
3. Prevent damage to protective coatings during storage and delivery of liner plates. Keep wire ropes, chains, or hooks from direct contact with the coated surfaces.
4. Dewatering if required, shall be performed in accordance with Section 02512.03.

C. Reports and Records

1. Maintain and submit daily report of tunneling operations, observations, events, and progress, including:
 - a. Progress of excavation including location of tunnel face, number of liner rings installed, and quantity of material removed.
 - b. Notes of soil material encountered and any changes in soil type or conditions.
 - c. Hours of operation, crew, and equipment.
 - d. Volume of contact grout placed.
 - e. Cause and duration of any delays or equipment failures.
 - f. Settlement monitoring logs.

D. Equipment

1. Tunneling equipment shall be of U.S. Bureau of Mines approved types.
2. Tunnel shields shall have uniform exterior surface from leading edge of head or poling plates to the rear edge of the tail. A horseshoe-shape shield may have a closed or open bottom: a circular shield shall have closed bottom.
3. A substantially proportioned hood shall be provided that projects not less than 2 feet beyond the shield bottom with sufficient rear overhang or tail to provide at least 12 inches of overlap beyond the last element erected when the shield has been shoved forward to the fullest extent possible. The annular space between the tail and the lining shall be as small as current practice indicates, but in no case shall it be greater than 1 1/2 inches.

4. Provide each shield with suitably designed breast plates, face jacks, breast-tables or combination of equipment and such other bracing as is necessary to support the face of the tunnel excavation without loss of ground.
5. Provide on each shield a propulsion system capable of moving the shield in a forward direction while maintaining line, grade, and direction. The propulsion system shall be designed to prevent the shield from moving backward despite a failure of any element of the propulsion system and shall not overstress or distort the lining.
6. Prevent grout from leaking into the tunnel space between the shield and lining by incorporating a seal in the tail of each shield.
7. The shield shall be equipped with an erector arm or system capable of handling the largest sizes of liner plate sections and erecting the sections of the lining to the required tolerances without damage to the lining.

E. Power Supply

1. All power machinery and tools within the tunnel shall be operated by either electricity, compressed air, diesel with approved scrubber, or other approved power. All electrical tools and equipment shall be grounded in accordance with the latest requirements of the National Electrical Code.
2. Temporary electric lights shall be provided to properly and safely illuminate all parts of the tunnel construction area including special illumination at the working faces. Lighting circuits shall be thoroughly insulated and separated from power circuits; and all lights shall be enclosed in wire cages. The Contractor shall secure all electrical permits necessary for the installation and operation of this service.

F. Operation of Tunnel Shields and Machines

1. On initial set-up, the tunnel shields or tunneling machines shall be supported and properly set at lines and grades which will permit the correct installation of the tunnel lining. During forward movement of the shield provide sufficient support at the excavation face to prevent movement of any materials except such materials as are physically displaced by the elements of the shield itself.
2. The face shall be controlled using such support procedures as breasting, poling plates, face jacks, sliding tables, either singly or in combination, spaced as necessary.
3. Advance excavation for the tunnel liner in increments sufficient for the erection of one ring of liners and install liner plates immediately after each increment of excavation. Carry on excavation in such a manner that voids behind the liner plates

are held to a minimum. Completely fill such voids with grout or gravel followed immediately by grout placed under pressure.

4. Whenever tunnel excavation is suspended or shut down, the tunnel invert is below the level of groundwater, and/or there is danger of water infiltration from any source, maintain on duty qualified personnel to observe conditions that might threaten the stability of the heading. The Contractor may substitute acceptable observation devices such as closed circuit TV that enables continuous monitoring of conditions at the face by qualified observers from outside the tunnel.
5. During shut down periods, support the face of the excavation by positive means; no support shall rely solely on hydraulic pressure.

G. Control of Line and Grade

1. Unless otherwise directed in the Contract Documents, a laser guidance system shall be used for accurate guidance of tunneling operations. The system shall be capable of displaying the position and attitude of the tunnel shield and shall maintain continuous record of alignment. Install the tunnel lining in a manner that will not damage the lining or coating.
2. Laser shall be mounted on a stable surface independent from the thrust block and jacking frame in a location protected from inadvertent movement of the instrument.
3. Qualified personnel shall be employed to set the laser and to reset it in the event it is shifted or disturbed.
4. Monitor continuously and record location relative to design every 5 feet of excavation.
5. If alignment deviation from design exceeds specified tolerance, Contractor shall make necessary corrections, as approved by the Engineer.

H. Installation of Tunnel Linings

1. Install the tunnel lining in a manner that will not damage the lining or coating.
2. Ensure that the edges are clean and free from material that could interfere with proper bearing and water tightness.
3. Install bolts for liner plates in accordance with liner plate manufacturer's recommendations and replace necessary any bolt which does not meet the requirements.
4. Assemble liners to the lines and grades shown on the Plans or as directed by the Engineer.

5. Upon completion of liner plate installation and prior to installation of carrier pipe, the liner will be inspected for damage, leaks, coating damage, and proper bolting of connections.

I. Gravel Packing and Contact Grouting

1. Contact Grouting shall be performed after liner rings are installed to fill voids between liner sections and excavated soils. Where approved, gravel packing may be used to fill voids between the excavation and support system. For voids to be filled with gravel pack, place gravel in the voids behind liner plate by compressed air (minimum pressure 80 psi) through a 1-1/2 or 2-inch diameter hose. Voids in the gravel pack shall then be filled with grout.
2. Filling voids with grout shall generally proceed from the bottom grout hole of each ring to the top hole.
3. Vent air through one of the upper holes.
4. The grout pump and injection system shall be of a type that will deliver the grout in a smooth even flow without surge. The grouting circuit shall contain a return line to allow return of the grout from the nozzle to the supply tanks. Grout nozzle shall include a pressure gauge to ensure grout pressure does not exceed pressure established by the Engineer. The grouting equipment shall be capable of developing a maximum pressure of 20 psi at the grout hole connection and equipped with hoses with a minimum inside diameter of 1-1/2 inches. The grouting equipment shall have a minimum capacity of 1/2 cubic yards and shall be capable of monitoring volume of grout take.
5. Grout ports shall be fitted with stop valves to prevent loss of grout upon removal of grout nozzle and to maintain grout pressure until set.
6. Grouting between the liner plates and excavation shall follow progressively with each adjacent set of holes provided in the liner plates.
7. In general, grouting shall proceed from the lowest grout hole of each ring and proceed progressively upward. When going from lower to higher grout holes, do not make connection to the higher holes until grout has completely filled the space below and grout is evidenced at the next higher hole. Fill all voids completely at the close of each 8-hour work period. Leave no liner ring ungrouted when work is interrupted or shut-down.
8. Continue grouting until grout appears in the next set of grout holes, which shall be kept open during grouting to permit escape of air and water.

J. Installation of Carrier Pipe

1. Install pipe inside tunnel where indicated on the Plans.
2. Pipe and joint requirements are specified elsewhere in the Contract Documents.
3. Provide bedding and anchorage in accordance with the Plans.
4. Provide wooden skids or other approved devices as required to eliminate damage to pipe.
5. Where so indicated, fill annular space between pipe and tunnel with grout, with concrete having a maximum aggregate size of 3/8 inch, or with sand. Positive means shall be provided to hold the pipe in place and to prevent flotation.

K. Concrete Invert

Where required by Contract, place cast-in-place concrete invert to the limits shown on the Plans in accordance with Section 03300.

L. Casing End Seals

1. Install casing end seals as required by the Contract Documents. If casing is to be filled with grout after installation of carrier pipe, end seals shall be of brick and mortar, and shall include piping connections necessary to permit grout fill and air/water release.
2. If manufactured end seal products are used, install in accordance with manufacturer's requirements.

02920.04 METHOD OF MEASUREMENT**A. Tunnel and Liner**

Measurement for earth tunneling and liners will be made horizontally along the centerline of the tunnel satisfactorily constructed between the interior faces of the access shafts. Measurement will not be made for the access shafts.

B. Carrier Pipe

Carrier pipe will be measured horizontally along the centerline of the tunnel for pipe installed to 1 foot outside of each end of the tunnel casing.

02920.05 BASIS OF PAYMENT**A. Tunnel and Liner**

1. Payment for tunnel construction and tunnel liner will be made at the unit prices bid per linear foot of the particular size of tunnel constructed, unless specified otherwise in the Contract Documents.
2. The prices bid shall include the installation and removal of tunneling equipment, installation and removal of equipment support materials, removing and disposing excess excavated material; dewatering; settlement monitoring; furnishing and installing tunnel liner, furnishing and placing gravel fill, contact grout, Portland cement concrete for invert fill if required; and the furnishing of all engineering, labor, equipment, tools, and incidentals necessary to complete the installation as shown and as specified in strict accordance with the Contract Documents and accepted by the Engineer.

B. Tunnel Shafts

1. Payment for Tunnel Shafts shall be at the Lump Sum price bid for the launch and receiving shafts associated with each tunnel installation.
2. The price shall include the excavation, support, backfill, compaction, and restoration of the access shafts; removing and disposing excess excavated material; dewatering; and the furnishing of all engineering, labor, equipment, tools, and incidentals necessary to complete the installation as shown and as specified in strict accordance with the Contract Documents, and accepted by the Engineer.
3. Price bid for shafts shall also include furnishing and installing casing end seals.

C. Carrier Pipe

1. Payment for carrier pipe installed within the tunnel will be made per linear foot of the particular size of pipe installed, unless specified otherwise in the Contract Documents.
2. The prices shall include furnishing and installing the carrier pipe including all supports, skids, casing spacers, restraints, testing as required in Sections 02520.02, 02551.02, 02561.02, or 02563.02 as appropriate, and furnishing of all engineering, labor, equipment, tools, and incidentals necessary to complete the carrier pipe installation as shown and as specified in strict accordance with the Contract Documents, and accepted by the Engineer. If required by the contract documents, the price shall include furnishing and installing the annular grout.

END OF SECTION