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ASCE/CI 36–15

Standard Design and Construction Guidelines for Microtunneling

This document uses both the International System of Units (SI) and customary units

ASCE

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ASCE STANDARDS

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PREFACE

These design and construction guidelines for microtunneling have been created by a group of engineers, owners, contractors, suppliers, and manufacturers working over the past several years. The changes to these microtunneling guidelines take into account many of the advances that have occurred since their original publication in 2001. A number of new sections have been added. Many of the existing sections have been updated because of changes in technology as well as changes in construction that make microtunneling a more acceptable means of construction.

Sections have also been expanded and modified so that those reviewing the guidelines can best understand what is needed in detail in order to undertake a microtunneling project. In addition, the methods for preparing construction contract documents, including drawings, technical specifications, and contractual specifications, have been updated. The qualifications of contractors who construct a microtunneling project as well as those of the engineers who design them have been updated.

The committee that worked on these guidelines acknowledges that there have been significant improvements in best practices and technology since 2001. No document, including this one, can encompass all of the issues on a particular microtunneling project. In addition, improvements in best practices and technology continue to evolve so quickly that consideration of these guidelines in connection with any project must take into account not only the specific characteristics of the particular project but also further improvements in best practices and technology.

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PART I
GENERAL

CHAPTER 1
SCOPE

1.1 This standard guideline covers planning, design, pipe materials, and construction of microtunneling. The term *microtunneling* is defined as a trenchless construction method for installing pipelines. The North American definition of microtunneling describes a method but does not impose size limitations on that method; therefore, a tunnel may be considered a microtunnel if all of the following are used during construction:

- *Remote control:* The microtunneling boring machine (MTBM) is operated from a control panel, normally located on the surface. The system simultaneously installs pipe as the ground is excavated and removed. Personnel entry is not required for routine operation.
- *Guidance:* The guidance system usually consists of a laser beam projected onto a target in the MTBM. With this system, the MTBM is capable of installing gravity sewers or other types of pipelines to the required tolerance for line and grade.
- *Pipe jacking:* A pipeline is constructed by consecutively pushing pipes and the MTBM through the ground, using a jacking system for thrust.
- *Continuous support:* Continuous pressure is provided to the face of the excavation to balance groundwater and earth pressures.

1.2 Part II of this standard guideline presents planning aspects of microtunneling.

1.3 Part III of this standard guideline presents design aspects of microtunneling.

1.4 Part IV of this standard guideline presents pipe material aspects of microtunneling.

1.5 Part V of this standard guideline presents construction aspects of microtunneling.

1.6 This standard guideline may be used as a reference by owners, engineers, contractors, and construction managers. This document is to be used as a guideline only for development of the trenchless project, including engineering, drawings, specifications, submittal requirements, and work plans. Each project has its own set of unique challenges and conditions. All sections of this guideline may not be applicable to all projects. The engineer should use a standard of care and good judgment in selecting which items are appropriate and relevant to the specific project after a thorough review of the project site conditions. In no case should this document be used as the project specification.

1.7 The guidelines in this document are intended for use by owners, engineers, and contractors familiar with the installation and pipe characteristics that affect the structural behavior of pipe for jacking installations and the significance of the installation requirements associated with the construction method. Before applying the guidelines given in Parts II, III, IV, and V, the user should review the guidance and requirements given in this standard practice and the commentary.

1.8 The values of dimensions and quantities are expressed in SI (metric) units, which are to be regarded as standard. SI unit values are converted to English unit values, which are presented in parentheses following the SI units. The use of SI units is in accordance with ASTM Practice E380. English units expressed in parentheses are supplied for information only and are not a part of this standard practice.

Some of the applicable standards referenced may have a double designation (Axxx/AxxxM) or separate inch-pound (English) and SI (metric) units.

1.9 The commentary in the applicable sections of this guideline is provided for background and clarification.

1.10 Microtunneling is a highly specialized and technical form of construction. The engineer and the contractor should have experience that covers the size, length, ground conditions, complexities, and risks of a particular project. Qualifications of the engineer designing the microtunnel, the engineering firm responsible for the design, and key personnel should be checked and verified before the design and implementation of the project to ensure a proper microtunnel design and to ensure that performance and project goals are met. Engineering firms without the requisite microtunneling qualifications should hire qualified staff or a microtunneling subconsultant knowledgeable in the field. The contractor and its key personnel should be prequalified before bidding or before award of the microtunneling project. More details on suggested contractor qualifications are discussed in Sections 15.4 and 21.2.

CHAPTER 2
REFERENCE DOCUMENTS

2.1 AMERICAN SOCIETY OF CIVIL ENGINEERS (ASCE)

ASCE 27-00: *Standard Practice for Direct Design of Precast Concrete Pipe for Jacking in Trenchless Construction*
ASCE/CI 38-02: *Standard Guidelines for the Collection and Depiction of Existing Subsurface Utility Data*
ASCE/AIME: *Geotechnical Baseline Reports for Construction: Suggested Guidelines*, 2007
Manual of Practice No. 46: *Pipeline Route Selection for Rural and Cross-Country Pipelines* (Out of print)
Manual of Practice No. 60/WEF FD-5: *Gravity Sanitary Sewer Design and Construction, Second Edition*
Manual of Practice No. 77: *Design and Construction of Urban Stormwater Management Systems* (Out of print)
Manual of Practice No. 89: *Pipeline Crossings* (Out of print)
Manual of Practice No. 106: *Horizontal Auger Boring Projects*
Manual of Practice No. 108: *Pipeline Design for Installation by Horizontal Directional Drilling*
Manual of Practice No. 112: *Pipe Bursting Projects*
Manual of Practice No. 115: *Pipe Ramming Projects*
Manual of Practice No. 120: *Trenchless Renewal of Culverts and Storm Sewers*
Manual of Practice No. 125: *Pipelines for Water Conveyance and Drainage*

Commentary. The manuals are available for purchase through the ASCE website. Check the website at www.asce.org/bookstore for the latest versions and editions.

2.2 AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

2.2.1 Standards for Soil, Rock, and Groundwater Sampling and Testing

C295: *Standard Guide for Petrographic Examination of Aggregates for Concrete*
D421: *Standard Practice for Dry Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants*
D422: *Standard Test Method for Particle-Size Analysis of Soils*
D653: *Standard Terminology Relating to Soil, Rock, and Contained Fluids*
D698: *Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft^3 (600 kN-m/m^3))*
D854: *Standard Test Methods for Specific Gravity of Soil Solids by Water Pycnometer*
D1140: *Standard Test Methods for Amount of Material in Soils Finer Than No. 200 (75-μm) Sieve*
D1556: *Standard Test Method for Density and Unit Weight of Soil in Place by the Sand-Cone Method*
D1557: *Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft^3 (2,700 kN-m/m^3))*
D1587: *Standard Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes*
D2216: *Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass*
D2217: *Standard Practice for Wet Preparation of Soil Samples for Particle Size Analysis and Determination of Soil Constants*
D2435: *Standard Test Methods for One-Dimensional Consolidation Properties of Soils Using Incremental Loading*
D2487: *Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)*
D2488: *Standard Practice for Description and Identification of Soils (Visual Manual Procedure)*
D2850: *Standard Test Method for Unconsolidated-Undrained Triaxial Compression Test on Cohesive Soils*
D3080: *Standard Test Method for Direct Shear Test of Soils under Consolidated Drained Conditions*
D3550: *Standard Practice for Thick Wall, Ring-Lined, Split Barrel, Drive Sampling of Soils*
D3967: *Standard Test Method for Splitting Tensile Strength of Intact Rock Core Specimens*
D4221: *Standard Test Method for Dispersive Characteristics of Clay Soil by Double Hydrometer*
D4318: *Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils*
D4546: *Standard Test Methods for One-Dimensional Swell or Collapse of Soils*
D4643: *Standard Test Method for Determination of Water (Moisture) Content of Soil by Microwave Oven Heating*
D4767: *Standard Test Method for Consolidated Undrained Triaxial Compression Test for Cohesive Soils*
D5434: *Standard Guide for Field Logging of Subsurface Exploration of Soil and Rock*
D5873: *Standard Test Method for Determination of Rock Hardness by Rebound Hammer Method*
D6032: *Standard Test Method for Determining Rock Quality Designation (RQD) of Rock Core*
D6938: *Standard Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)*
D7012: *Standard Test Methods for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens under Varying States of Stress and Temperatures*

D7625: *Standard Test Method for Laboratory Determination of Abrasiveness of Rock Using the CERCHAR Method*

2.2.2 Standards for Concrete Pipes

C76: *Standard Specification for Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe*
C361: *Standard Specification for Reinforced Concrete Low-Head Pressure Pipe*
C506: *Standard Specification for Reinforced Concrete Arch Culvert, Storm Drain, and Sewer Pipe*
C507: *Standard Specification for Reinforced Concrete Elliptical Culvert, Storm Drain, and Sewer Pipe*
C655: *Standard Specification for Reinforced Concrete D-Load Culvert, Storm Drain, and Sewer Pipe*
C822: *Standard Terminology Relating to Concrete Pipe and Related Products*
C1417: *Standard Specification for Manufacture of Reinforced Concrete Sewer, Storm Drain, and Culvert Pipe for Direct Design*

2.2.3 Standards for Ductile Iron Pipes

A377: *Standard Index of Specifications for Ductile-Iron Pressure Pipe*
A674: *Standard Practice for Polyethylene Encasement for Ductile Iron Pipe for Water or Other Liquids*
A716: *Standard Specification for Ductile Iron Culvert Pipe*
A746: *Standard Specification for Ductile Iron Gravity Sewer Pipe*

2.2.4 Standards for Fiberglass Pipes

D3262: *Standard Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Sewer Pipe*
D3517: *Standard Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pressure Pipe*
D3567: *Standard Practice for Determining Dimensions of Fiberglass (Glass-Fiber-Reinforced Thermosetting Resin) Pipe and Fittings*
D3681: *Standard Test Method for Chemical Resistance of Fiberglass (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe in a Deflected Condition*
D3754: *Standard Specification for Fiberglass (Glass-Fiber-Reinforced Thermosetting-Resin) Sewer and Industrial Pressure Pipe*
D5365: *Standard Test Method for Long-Term Ring-Bending Strain of Fiberglass (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe*

2.2.5 Standards for Polymer Concrete Pipes

D6783: *Standard Specification for Polymer Concrete Pipe*

2.2.6 Standards for Steel Pipes

A36: *Standard Specification for Carbon Structural Steel*
A139: *Standard Specification for Electric-Fusion (ARC): Welded Steel Pipe (NPS 4 and Over)*
A515: *Standard Specification for Pressure Vessel Plates Carbon Steel for Intermediate and Higher Temperature Service*
A572: *Standard Specification for High-Strength Low Alloy Columbium-Vanadium Structural Steel*
A999: *Standard Specification for General Requirements for Alloy and Stainless Steel Pipe*

2.2.7 Standards for Vitrified Clay Pipe

C12: *Standard Practice for Installing Vitrified Clay Pipe Lines*
C301: *Standard Test Methods for Vitrified Clay Pipe*
C700: *Standard Specification for Vitrified Clay Pipe, Extra Strength, Standard Strength, and Perforated*
C828: *Standard Test Method for Low-Pressure Air Test of Vitrified Clay Pipe Lines*
C1091: *Standard Test Method for Hydrostatic Infiltration Testing of Vitrified Clay Pipe Lines*
C1208: *Standard Specification for Vitrified Clay Pipe and Joints for Use in Microtunneling, Sliplining, Pipe Bursting, and Tunnels*

2.2.8 Standards for Slurries, Lubricants, and Other Additives

D3910: *Standard Practices for Design, Testing, and Construction of Slurry Seal*
D4380: *Standard Test Method for Density of Bentonitic Slurries*
D4381: *Standard Test Method for Sand Content by Volume of Bentonitic Slurries*
D6910: *Standard Test Method for Marsh Funnel Viscosity of Clay Construction Slurries*

2.2.9 Other Standards

IEEE/ASTM SI 10: *American National Standard for Metric Practice*

Commentary. The ASTM standards are available for purchase through the ASTM website. Check the website at www.astm.org for the latest versions and editions.

2.3 AMERICAN WATER WORKS ASSOCIATION (AWWA)

C150/A21.50: *Thickness Design of Ductile-Iron Pipe*
C151/A21.51: *Ductile Iron Pipe, Centrifugally Cast, for Water or Other Liquids*
C200: *Steel Water Pipe, 6 Inch (150 mm) and Larger*
C300: *Reinforced Concrete Pressure Pipe, Steel-Cylinder Type*
C302: *Reinforced Concrete Pressure Pipe, Noncylinder Type*
C950: *Fiberglass Pressure Pipe*
M11: *Steel Pipe: Guide for Design and Installation*

Commentary. The AWWA standards are available for purchase through the AWWA website. Check the website at www.awwa.org for the latest versions and editions.

2.4 AMERICAN PETROLEUM INSTITUTE (API)

API 2B: *Specification for the Fabrication of Structural Steel Pipe*
API 5L: *Specification for Line Pipe*
API 13A: *Specification for Drilling Fluid Materials*
API 13G: *Recommended Practice Standard Procedure for Drilling Mud Report Form*
API 29: *Suggested Procedures for Laboratory Evaluation Drilling Mud Materials*
API 1102: *Steel Pipelines Crossing Railroads and Highways*
API 1104: *Welding of Pipelines and Related Facilities*

Commentary. The API standards are available for purchase through the API website. Check the website at www.api.org for the latest versions and editions.

Note that standards developed by the American Petroleum Institute for drilling slurries allow the use of petroleum

by-products, which may not be appropriate for microtunneling applications because the fluids may contaminate the ground.

2.5 EUROPEAN STANDARDS

ATV-A 125: *Pipe Jacking*
ATV-A 127: *Static Calculation of Drains and Sewers*
ATV-A 161: *Structural Calculation of Driven Pipes*
BS 5911-1: *Concrete Pipes and Ancillary Concrete Products*
DIN EN 12889: *Trenchless Construction and Testing of Drains and Sewers*
DIN EN 14636-1: *Plastics Piping Systems for Non-Pressure Drainage and Sewerage: Polyester Resin Concrete (PRC); Part 1: Pipes and Fittings with Flexible Joints*
DIN 54815-1: *Pipe Made of Filled Polyester Resin Molding Materials; Part 1: Dimensions, Material, and Marking*
DIN 54815-2: *Pipe Made of Filled Polyester Resin Molding Materials; Part 2: Requirements, Testing*
DWA-A 125E: *Pipe Jacking and Related Techniques*
EN 295-7: *Requirements for Vitrified Clay Pipes and Joints for Pipe Jacking*

Commentary. The European standards are available for purchase through various websites. Check the Internet for the latest versions and editions. Note that the European standards are typically not used in North America but may be useful resources.

2.6 NORTH AMERICAN SOCIETY FOR TRENCHLESS TECHNOLOGY (NASTT)

Horizontal Directional Drilling (HDD) Good Practices Guidelines
Pipe Bursting Good Practices Guideline Manual

Commentary. The NASTT manuals are available for purchase through the NASTT website. Check the website at www.nastt.org for the latest versions and editions.

2.7 OTHER STANDARDS

ANSI/AWS D1.1/D1.1M: Structural Welding Code—Steel
Common Ground Alliance Best Practices
NSF/ANSI International 60: *Drinking Water Treatment Chemicals—Health Effects*
NSF/ANSI International 61: *Drinking Water System Components—Health Effects*
29CFR 1926: *Code of Federal Regulations, Title 29—Labor, Part 1926—Safety and Health Regulations for Construction*

Commentary. The standards are available through the associated websites. Check the Internet for the latest versions and editions.

Check the state website where the project is located to verify the enforcement agency for 29CFR 1926 because some states have more restrictive regulations.

CHAPTER 3
DEFINITIONS

adapter ring: In microtunneling, a fabricated ring, usually made from steel, that is mounted on the first pipe of the pipe string. This ring is intended to transfer the jacking force from the microtunnel boring machine's (MTBM's) bearing area to the jacking pipe and to create a waterproof seal between the machine and the spigot of the first joint.

advance rate: Forward progress over a given period of time; includes penetration rate, makeup time, downtime, and idle time; typically measured in feet or meters per shift.

annular space: The theoretical volume between the gauge cut and the outside radius of the jacking pipe times the length of the installation, equal to annulus × length of tunnel.

annular thickness: The radial distance between the excavated radius created by the gauge cutter and the outside radius of the jacking pipe. The radial distance is equal to the overcut (gauge cut) plus the shield cut.

annulus: The theoretical area between the gauge cut and the pipe outside diameter (OD) equal to ($\pi \times$ (gauge cut OD^2 – pipe OD^2)/4). It is the combined area created by the overcut and the shield cut.

auger boring: A technique for forming a bore from a jacking or drive shaft to a receiving shaft by means of a rotating auger with cutting tools. The casings are jacked forward sequentially in a cyclic process while the auger is turned. Spoils are removed back to the drive shaft by helically wound auger flights rotating in the steel casing. The equipment may have limited guidance and steering capability.

auger MTBM: A type of microtunnel boring machine that uses auger flights to remove the spoils through a separate, smaller casing placed through the jacking pipe.

backfill grouting: Grout injected into the void space between the carrier pipe and casing after the drive is completed.

belly pans: Shims or other steel plates added to the bottom of the MTBM to adjust the machine's location within the excavation. Also known as *belly plates*.

Berlin construction method: A sewer collection system developed in Berlin, Germany, whereby sewer laterals are brought to a manhole and then dropped into the sewer interceptor. This method of connecting laterals to sewer is more compatible with trenchless installations.

boulder: Per ASTM D653, a rock fragment, usually rounded by weathering or abrasion, with a dimension of 12 in. (305 mm) or more.

buried objects: Items in the ground that can affect MTBM advancement and line and grade control. Buried objects that prevent continued advancement along the design path, which includes tolerances, are called *obstructions*.

caisson: A watertight chamber used in shaft construction under water. The ground within the chamber is excavated, allowing the chamber to sink under its own weight into the ground.

carbon footprint: The amount of carbon dioxide generated and caused by a construction project, including any traffic effects.

carrier pipe: Pipe for conveyance of water, gas, sewage, or other products and services. Some carrier pipe can be installed by direct jacking (i.e., one-pass microtunneling).

cased bore: A bore in which a pipe, usually a steel casing, is inserted simultaneously with the boring operation.

casing: A jacked pipe in a two pass system that supports a bore. The casing is not a carrier pipe.

cemented soils: Soils in which the particles are held together by a naturally occurring or human-made chemical agent that changes the soils' physical and mechanical properties.

charge line: See **feed line**.

closed-face: Term referring to one mode of operation of a traditional tunnel boring machine (TBM).

cobble: Per ASTM D653, a rock fragment, usually rounded or semirounded, with dimensions between 3 and 12 in. (75 and 305 mm).

cohesionless soils (noncohesive soils): Earth materials containing less than 20 percent soil particles passing the No. 200 sieve. Any free-running soil, such as sand or gravel, whose strength depends on friction between particles.

cohesive soils: Earth materials containing 20 percent or more soil particles passing the No. 200 sieve.

compression ring: A ring fitted between the end-bearing area of the leading pipe bell and the trailing pipe spigot to help distribute jacking forces more uniformly. A compression ring is attached to the trailing end of each pipe and is compressed between the pipe sections during jacking. The compression ring compensates for steering corrections, pipe misalignment, and pipe dimensional tolerances. Also referred to as a *packer*.

contact grouting: Grout injected into the theoretical space between the jacking pipe and the ground after the drive is completed.

contaminated plume: The underground trace of an environmental pollutant.

contract documents: Documents prepared by the owner and project engineer for bidding and for awarding a project; they can include bid forms, general conditions, special conditions, technical specifications, drawings, geotechnical data reports, and geotechnical baseline reports.

control console: An electronic unit typically inside a container located on the ground surface that controls the operation of the microtunneling machine. As the machine operator drives the tunnel from the control console, electronic information is transmitted to the control console from the MTBM. This information includes head position, steering angle, jacking force, penetration rates, machine-face torque, slurry feed and return flow rates and pressures, and laser position. Some control consoles are equipped with a computer that tracks and

stores the data and allows real-time analysis of the tunnel drive.

controls: Part of the microtunneling system that allows synchronized excavation, removal of spoils, and jacking of pipe to balance forward movement with excavation so that ground settlement and heave are managed.

crossing: Pipeline installation in which the primary purpose is to provide one or more passages beneath a waterway, road, or other surface obstruction.

crown: The highest point of the pipe or tunnel.

cut and cover: See **open-cut**.

cutability: The capacity of rock to be spalled, ripped, chipped, and broken into smaller pieces to allow the advance of the MTBM. Key properties affecting cutability include the frequency of discontinuities, unconfined compressive strength, tensile strength, hardness, and abrasiveness of the rock.

cutter chamber access: See **face access**.

cutter wheel: Any rotating tool or system of tools on a common support that excavates at the face of a bore.

cuttings: See **spoils**.

delay time: Lost time associated with the owner's issues.

design specification: A document that establishes specific requirements the contractor must use, including means and methods. A design specification creates an implied warranty that if the contractor uses the specified means and methods along with industry-accepted good practices, the constructed product will meet the specification requirements.

desktop study: A compilation and review of available site, geotechnical, and other information pertinent to a project. Typically performed at the outset of a project, before field explorations and detailed design.

dewatering: The act of removing groundwater or lowering the groundwater elevation, using a system of wells and pumps.

differential cut: The spiral, screwlike pattern created on the excavated surface as the gauge cutter is advanced while being rotated around the bored periphery of the cutter wheel.

direct-jacked pipe: Pipe installed in the ground that serves as the casing and carrier pipe.

discharge line: See **return line**.

downtime: Time lost when the MTBM is unable to operate; generally associated with equipment failure.

drilling fluid: Water that may contain additives, including bentonite, polymers, soda ash, surfactants, or other materials, to enhance stability and excavatability. If the drilling fluid contains additives and is designed to have specific properties, it is considered to be an *engineered drilling fluid*, whether specified by the engineer or selected by the contractor. Some additives may increase the effectiveness of the drilling fluid and reduce adhesion of the spoils (cuttings). The drilling fluid is used in a closed-loop system for transporting spoils and for counterbalancing earth and groundwater pressures during microtunneling.

drive: Designation of the pipe installed from a jacking shaft to a reception shaft.

drive shaft: See **jacking shaft**.

earth piercing: The use of a tool that comprises a percussive hammer within a suitable, generally torpedo-shaped casing. The hammer may be pneumatic or hydraulic. The term is usually associated with nonsteered devices.

effective stresses: In a saturated mass of soil or rock, the total stress P minus pore water pressure, U_w.

emergency recovery shaft: See **rescue shaft**.

engineered drilling fluid: See **drilling fluid**.

entrance seal: See **launch seal**.

entry ring: See **launch seal**.

EPB machine: Earth pressure balance tunneling machine, by which mechanical pressure is applied to the material at the face and controlled to provide the correct counterbalance to earth and groundwater pressures in order to prevent heave or subsidence. The term is not applicable to microtunneling systems for which the primary counterbalance of earth and groundwater pressures is supplied by pressurized slurry.

exit seal: Same as a launch seal except for the retrieval of the machine at the reception shaft. Used in high groundwater and unstable soils to prevent loss of ground.

exit shaft: See **reception shaft**.

eye: The opening in the shaft wall through which the MTBM is launched.

face: The location where excavation is taking place.

face access: Access to the location where excavation is taking place, typically through the cutting chamber. MTBM configuration may only allow limited personnel access to the back of the cutter wheel from within the pipe string. An air lock may also be required in the rear of the MTBM to maintain air pressure for counterbalancing earth and groundwater pressures.

face pressure: Earth and groundwater pressures applied against the cross-sectional area of the microtunnel face.

factor of safety: The ratio of the structural capacity of a system to expected or actual loads on the system.

feed line: Pipeline that transports drilling fluid from the slurry separation plant to the face of the MTBM. Also known as a *charge line*.

filter cake: A thin layer of clay or polymer from the slurry at the face and perimeter of the formation being excavated. The filter cake is formed through filtrate loss.

filtrate: A liquid that has passed through a filter.

fines: Portion of a soil finer than a No. 200 (75 µm) U.S. standard sieve.

frac-out: See **inadvertent return** and **hydrofracture**.

gauge cut: The outermost projection of the excavation, measured as a diameter. The gauge cut is subject to cutter wear and to the differential cut.

gauge cutter: The cutter that creates the gauge cut and is subject to wear.

gel: Per ASTM D653, the condition of a liquid that has begun to exhibit measurable shear strength.

gel time: The measured time interval between the point when the slurry mix is in a fluid state and the point when it begins to form a gel.

gravel: Per ASTM D653, rounded or semirounded particles of rock that will pass a 3-in. (76.2-mm) sieve and be retained on a No. 4 (4.75-mm) U.S. standard sieve.

ground cover: Distance between the ground surface and the crown of the pipe.

groundwater: All subsurface water, as distinct from water on the surface.

grouting: The process of filling voids or of modifying or improving ground conditions. Grouting materials may be cementitious, chemical, or composed of other mixtures.

guidance system: System that locates the actual position of the MTBM relative to the laser or other device. The laser or other device should be referenced to the design line and grade.

guided boring method: Another term for the *pilot tube method*, in which an auger boring power unit is used with a pilot tube's guidance and steering system.

heave: Measurable upward movement of the ground or structure as the result of the excavation process.

horizontal directional drilling (HDD): A surface-launched trenchless technology for the installation of pipes, conduits,

and cables. HDD creates a pilot bore along the design pathway and reams the pilot bore in one or more passes to a diameter suitable for the product, which is pulled into the prepared bore in the final step of the process.

HQ: A diamond core wire line tube drill bit size where the hole diameter is 96 mm and the core diameter is 63.5 mm.

hydrofracture: A special form of inadvertent return in which drilling fluid reaches the surface or waterway. Also called a *frac-out*.

idle time: Lost time when the MTBM is not in operation; not including makeup time or downtime.

in-line microtunneling: A method of replacing an existing pipe by filling the pipe with flowable fill to prevent fluid loss and then excavating the entire pipe and surrounding ground with an MTBM for a new installation.

inadvertent return: The loss of drilling fluid, including slurry and lubrication, from the slurry or lubrication system. A special form of inadvertent return, where the fluid exceeds the strength and confining pressure of the ground and reaches the surface or waterway, is called a *hydrofracture* or *frac-out*.

inclinometer: (1) A geotechnical instrument used to measure horizontal deflection transverse to an installed vertical pipe casing by passing a probe through a casing (via two sets of grooves in the casing). (2) An instrument used within the MTBM to measure pitch and roll.

inlet line: See **feed line**.

interjack pipes: Pipes specially designed for use with an intermediate jacking station.

intermediate jacking station (IJS): A fabricated steel cylinder fitted with hydraulic jacks, which is incorporated into a pipeline between two specially fabricated pipe segments. Its function is to provide additional thrust in order to overcome skin friction and distribute the jacking forces over the pipe string on long drives.

invert: The lowest point of the pipe, tunnel, or shaft.

jacking force: The total force required to overcome the face pressure component and the frictional resistance component along the pipe to allow forward movement of the MTBM and the trailing pipe string.

jacking frame: A structural component that houses the hydraulic cylinders used to propel the microtunneling machine and pipeline. The jacking frame cradles the MTBM and jacking pipes, and serves to distribute the thrust load to the pipeline and the reaction load to the shaft wall or thrust block.

jacking loads: See **jacking force**.

jacking pipes: Pipes designed to be installed using pipe jacking techniques.

jacking shaft: Excavation from which trenchless technology equipment is launched for the installation of a pipeline. The jacking shaft may incorporate a thrust wall to spread reaction loads to the ground and an entry ring to control inflows of groundwater and soil at the portal.

jacking shield: A fabricated steel cylinder from within which the excavation is carried out either by hand or machine. An articulated steering section and steering jacks are incorporated into the shield to allow it to be adjusted to control line and grade. The term is associated with traditional tunneling.

Jersey barrier: See **K-rail**.

K-rail: A modular concrete or plastic barrier used to separate lanes of traffic. Also known as *Jersey barrier*.

laser: A device commonly incorporated into the guidance system and used to track alignment and grade during the tunneling or jacking operation.

launch seal: A mechanical seal, usually consisting of a rubber flange that is mounted to the wall of the jacking shaft. The flange seal is distended by the MTBM as the machine passes through the shaft. The seal is intended to prevent the flow of groundwater, soils, slurry, and lubrication into the shaft during tunneling operations.

lubrication: The act of injecting a fluid, normally bentonite and/or polymers, to reduce the skin friction and jacking forces on the jacking pipe during installation. The fluid fills the annular space.

makeup time: The time spent to add a pipe segment and make connections.

Marsh funnel viscosity: A measure of the flow rate of a fluid through a calibrated funnel. A Marsh funnel is typically used to measure drilling fluid and slurry viscosity, in seconds per quart (sec/qt) of fluid. The Marsh funnel viscosity of water is 26 sec/qt.

maximum allowable jacking force: The largest jacking force that can be applied to the jacked pipe, allowing for an appropriate factor of safety.

maximum anticipated jacking force: The largest anticipated jacking force required to advance jacking pipe and machine along a drive.

microtunneling: See Section 1.1.

mixed face: An interface within the excavated tunnel zone between two geological units that have a significant contrast in engineering properties (e.g., rock overlain by soft ground, or very soft, low-strength soil overlain or underlain by a very stiff, high-strength soil).

mixed ground: The excavated tunnel zone, without a defined interface, that contains soil and coarse fractions of gravels, cobbles, and boulders (i.e., silt with boulders). This term is not currently defined by ASTM or USCS.

mixed reach: A significant change in ground type, characteristics, or behavior along the excavated tunnel between the jacking and receiving shafts. This term is not currently defined by ASTM or USCS.

muck: Spoils or removal of same.

***N*-value:** The number of blows per foot required to drive a standard penetration test (SPT) soil sampler into the ground during geotechnical exploration. The *N*-value is often used to estimate in situ consistency of clays and silts and relative density of sands.

noncohesive soils: See **cohesionless soils**.

NQ: A diamond core wire line tube drill bit size where the hole diameter is 75.7 mm and the core diameter is 47.6 mm.

obstruction: Any buried object that lies completely or partially within the cross section of the microtunnel and that impedes continued forward progress along the design path and within allowable tolerances.

one-pass: A procedure by which the carrier pipe is directly jacked into the ground without a casing.

open-cut: A method by which access is gained to the required underground level for installation, maintenance, or inspection of a pipe, conduit, or cable. The excavation is then backfilled, and the surface is reinstated.

open-face: Term referring to one mode of operation of a traditional TBM.

overcut: The theoretical difference between the radial measurement of the gauge cut and the MTBM shield; equal to (gauge cut OD − MTBM OD)/2. Actual overcut is reduced as the gauge cutter is worn and because of the differential cut.

over excavation: A process of excavating more material than the theoretical volume of the tunnel based on diameter and

advanced distance. Over excavation can lead to ground settlement and the formation of voids.

packer: See **compression ring**.

penetration rate: Instantaneous excavation distance per time while the MTBM is operating, typically measured in inches per minute or millimeters per minute.

perched water: An accumulation of groundwater that is above the regional groundwater table in an unsaturated zone.

performance specification: A document that establishes the performance criteria the constructed product must meet. A performance specification leaves the selection of means and methods to the contractor.

piercing tools: See **earth piercing**.

piezometer: A specialized monitoring well that provides discrete screens and underground seals to produce a measurement of the groundwater pressure at specific intervals below ground. The groundwater pressure may be measured using open standpipes or vibrating wire transducers.

pilot tube method: A multistage method of accurately installing a product pipe to line and grade by use of a guided pilot tube followed by upsizing to install the product pipe. The pilot tube method does not fit within the definition of microtunneling.

pipe brake: A mechanical device designed to prevent the MTBM and pipe string from moving back into the shaft.

pipe eating: See **in-line microtunneling**.

pipe jacking: A system of using hydraulic jacking from a drive shaft to directly install pipes behind a shield machine so that they form a continuous string in the ground.

pipe lubricant: See **lubrication**.

pipe ramming: A trenchless installation method whereby a percussive hammer is attached, via an adapter, to an open-end casing, which is then driven through the ground. To create an open casing, the spoils within the casing are removed after the drive is completed, or periodically during the drive.

pipe string: The succession of joined individual pipes being used to advance and support the excavation.

pitch: The upward or downward angle of the MTBM, measured from a theoretical horizontal plane passing through the longitudinal axis of the MTBM.

plastic viscosity: A measure of the internal resistance to fluid flow, expressed as the tangential shear stress in excess of the yield stress divided by the resulting rate of shear.

plowing: A condition where the MTBM is being steered in one direction yet continues along an undesired direction.

pore water pressure: The pressure of the groundwater held within a soil or rock: in gaps (pores) between particles.

potholing: Small, carefully dug, nonmechanized excavation, used to locate a utility or other subsurface feature.

product pipe: See **carrier pipe**.

push ring adapter: Mechanical component mounted on the thrust ring to prevent the thrust ring from coming into contact with and damaging the pipe collar.

receiving shaft: See **reception shaft**.

reception shaft: Excavation into which the microtunneling equipment is driven and recovered.

rescue shaft: An unplanned additional shaft required to remove obstacles/obstructions and/or retrieve or repair the MTBM. The rescue shaft may need to function as a jacking shaft to complete the drive.

return line: Pipeline that transports slurry from the face of the MTBM to the slurry separation plant. Also known as a *discharge line*.

rider: A shallow collection line that runs along the microtunneled trunk sewer to a drop manhole.

rock: Per ASTM D653 and ISRM, any naturally formed aggregate of mineral matter occurring in large masses or fragments.

roll: The angle of rotation about the theoretical longitudinal centerline of the MTBM, measured from the 12 o'clock position.

settlement: Measurable downward movement of the ground or of an overlying utility or other structure as the result of excavation or dewatering.

settlement point or marker: An instrument installed at ground surface or driven into the ground to monitor vertical ground deformations before, during, and after construction.

shield cut: The theoretical difference between the radial measurement of the MTBM shield and the jacking pipe equal to (MTBM OD − pipe OD)/2.

skinning: The act of fitting a steel cylinder over the MTBM shield body to increase the diameter of an existing MTBM with the use of an appropriately upsized cutter wheel. Also referred to as *upsizing*.

slurry: A mixture of drilling fluid and spoils.

slurry chamber: A chamber in which excavated material is mixed with slurry for transport through the return line to the separation plant at the surface. The slurry chamber is located behind the cutter wheel of a slurry microtunneling machine.

slurry lines: Parallel hoses or pipes that transport spoils and slurry from the face of a slurry microtunneling machine through the return line to the ground surface for separation, and then return the slurry to the face for reuse through the feed line (the *feed line* is also known as a *charge line*).

slurry separation: A process in which excavated material is separated from the circulation slurry. Mechanical separation is typical, although gravity separation in pits or tanks is possible with coarse-grained soils.

spacers: Mechanical structures used to transfer the jacking force from the jacking thrust ring to the pipe and to accommodate lengths of pipe that are longer than the stroke length of the jacks.

specials: Pipe sections immediately ahead of and behind the IJS. Specials have ends that are specifically manufactured to physically accommodate the IJS.

spoils: Earth, rock, and other materials excavated during the installation process. Also referred to as *cuttings*.

sump pump: A device placed at the base of a shaft or in an MTBM to collect and remove fluids incidental to the construction process and resulting from shaft leakage and to prevent the excavation equipment from flooding.

surface water: Any water encountered or collected at ground level.

thrust block: An engineered structure, located between the jacking frame and the shaft wall, that distributes the jacking force developed by the hydraulic jacking frame over a large surface area to the ground behind the back wall of the shaft.

thrust ring: A fabricated ring that is mounted on the face of the jacking frame. It is intended to transfer the jacking force from the jacking frame to the thrust-bearing area of the pipe section being jacked.

tooling: Ground-engaging elements of the cutter wheel designed to excavate and penetrate the ground.

top hat: A steel can with a faceplate bolted to a reception shaft wall to receive the arriving MTBM.

trailing can: A principal module that is part of a shield machine such as an MTBM or tunnel boring machine (TBM); its use depends on the installation dimensions required and the presence of an articulated joint to facilitate steering.

trenching: See **open-cut**.

trenchless technology: A family of construction techniques for installing or rehabilitating underground infrastructure with minimal disruption to surface traffic, businesses, and residents. Also includes technologies for inspection, leak location, and leak detection with minimal disruption and minimal excavation from the ground surface.

tunnel horizon: The vertical band within the ground where the tunnel is excavated. Includes one tunnel diameter above the crown and one tunnel diameter below the invert.

two-pass: A procedure by which the carrier pipe is installed within a jacked casing.

unanticipated return: See **inadvertent return**.

upsizing: Process of creating a larger diameter MTBM than a machine with the original factory configuration. Also referred to as *skinning*. Also, any method that increases the cross-sectional area of an existing pipeline, replacing it with a larger cross-sectional area pipe.

utility monitoring point (UMP): An instrument designed to measure movement of an individual utility when exposed to construction activities.

utility tunneling: A construction method for excavating an opening beneath the ground without continuous disturbance of the ground surface. The excavation is of sufficient diameter to permit personnel access and to allow excavation, transport of spoils, and erection of a ground support system.

waler: Beam used within a braced excavation as support to control wall deflections.

water jetting: Process of using the internal cleansing mechanism of the cutter head, by which high-pressure water is sprayed from nozzles to help remove cohesive soils.

yaw: The angle of the MTBM to the left or right of a theoretical vertical plane passing through the MTBM's longitudinal axis.

zone of influence: Volume of ground that could possibly be affected by settlement or heave from tunnel mining, shaft excavation, pile driving, or other construction activities.