AKKTOBERFEST
TRENCHLESS TECHNICAL SEMINAR

ASCE-36, Standard Guidelines for Microtunneling

PRESENTED BY: Glenn Boyce

McMILLEN JACOBS ASSOCIATES

GLENN BOYCE, PhD, PE

PRINCIPAL

BIOGRAPHY

Glenn is a Principal with McMillen Jacobs Associates in the Walnut Creek, California.

Licensed professional engineer in six states and Hong Kong and have been involved in the trenchless industry for over 25 years.

Past Chairman of NASTT 2001-02, Trenchless Person of the Year in 2009, Bechtel Pipeline Award Recipient in 2017, and Chair of the Microtunneling Standard Committee **forever**!

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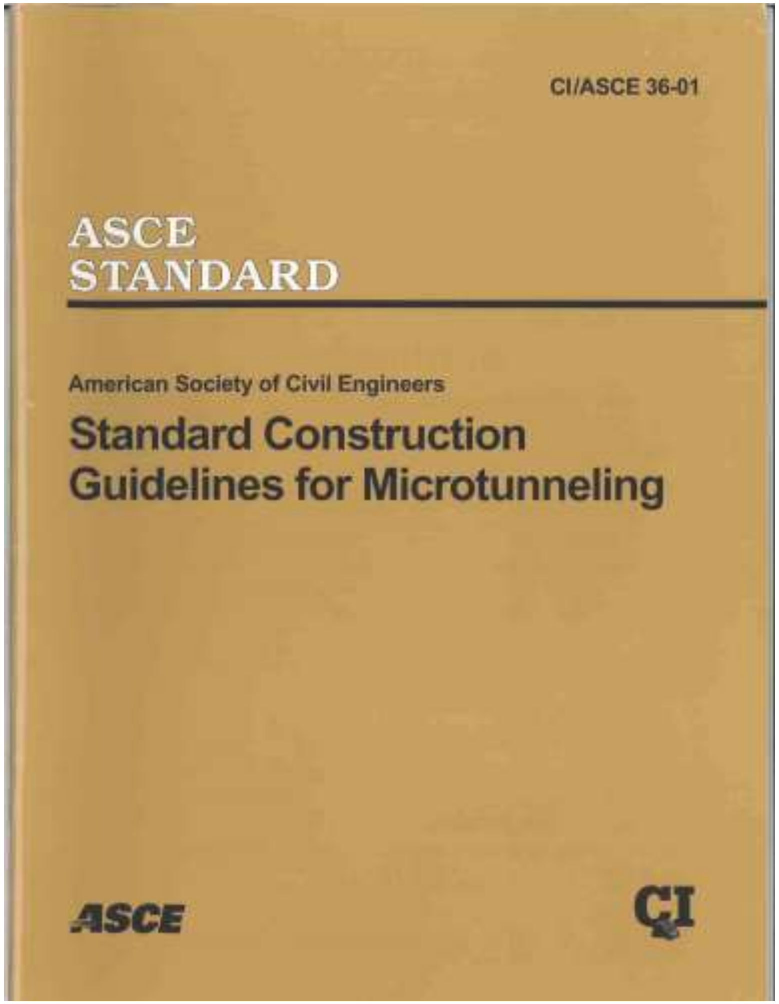
History of the Standard ASCE 36

- Started work on the document in 1995
- Originally published in December 2001
- 6-year process to write
- 40 pages in length
- 52 committee members
- 10 committee ballots
- 1 public ballot



The update included a dedicated group of engineers, owners, contractors, suppliers, and manufacturers working over the past five years to renew the ASCE Microtunneling Standard Guidelines

Updated ASCE 36 Standard

- Started update in 2010
- 5-year process to update
- Published in March 2015
- 122 pages in length
- Committee reduced to 26 voting members
- Added the North American Microtunneling Association
- Added a lot of detail and new information

Microtunneling Definition

- Four keys elements define microtunneling
  - Remote control
  - Guidance (not just laser beams)
  - Pipe jacking
  - Continuous support

- Different from other methods
  - Pilot tube method
  - Pilot tube guidance (similar to the auger microtunneling
  - Guided auger boring
  - Direct pipe

Qualifications

- Highly specialized and technical form of construction
- Engineers and contractors need to have experience
- Qualifications of the engineer designing the microtunnel should be checked and verified
- Engineering firm without the requisite qualifications should hire a qualified subconsultant and/or peer reviewer
- Contractors should meet qualifications to bid

Definition Changes

- 58 terms defined in the original standard
- 161 terms defined in the revised standard
- Key additions and changes
  - Advance rate, delay time, downtime, make-up time, penetration rate, idle time
  - Annular space, annular thickness, and annulus
  - Boulders, cobbles, gravel, cemented soils, cohesive soils, cohesiveless soils, rock
  - Buried objects
  - Drilling fluid and slurry
  - Face, face access, and face pressure
  - Mixed face, mixed ground, and mixed reach

Other Key Definitions

- Buried objects = items in the ground that can affect MTBM advancement and line and grade control
- Obstructions = 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

Buried Objects

- Expanded definition on what a “buried object” is
- Added a list of man-made (remnants of past construction) and natural buried objects
- Should be identified and planned for during the planning phase of the project

Summary of Practice

- Updated the history of microtunneling
- Mentioned deeper installations with pressures of 3 bar (100 feet depth)
- Mentioned the use of pilot tubes
- Increased use of curved alignments
- Focused on larger diameters with the ability to mine through more difficult ground (like, cobbles/boulders, wood, rock, mixed face, and mixed ground)

Key Elements for Success

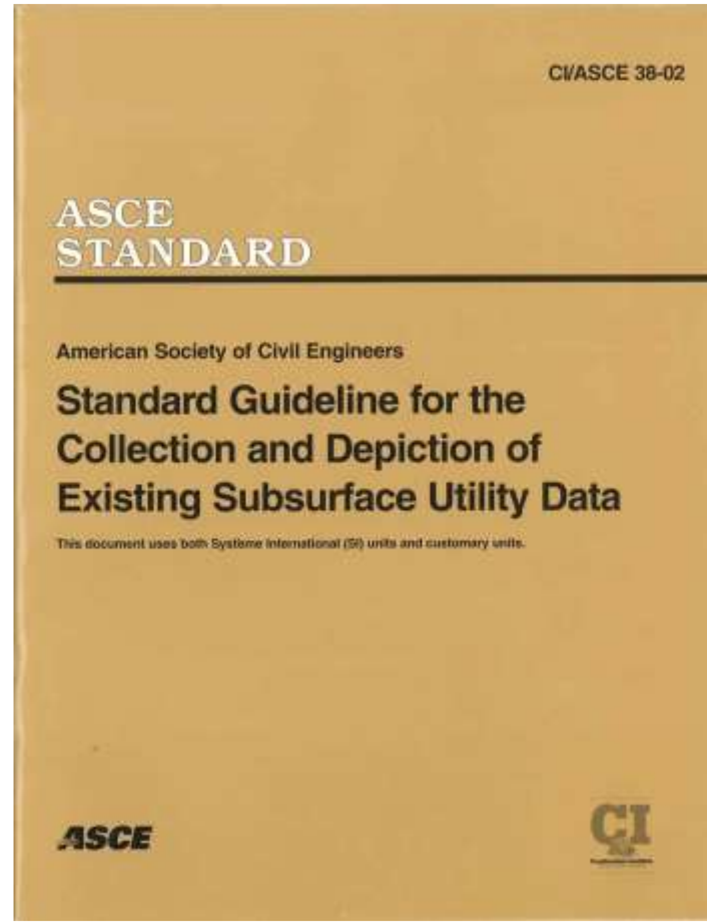
- Proper characterization of the subsurface conditions
- Detailed planning
- Proper design
- Development of fair contract procedures
- Selection of appropriate equipment
- Selection of appropriate pipe materials
- Use of skilled operators and crews

Subsurface Conditions

- Site investigation involves more than geotechnical investigation
- Site history
- Geotechnical investigation
- Utility survey
- Traffic flow and pedestrian access
- Environmental investigation
- Flood zone investigation
- Seismic investigation

Utility Surveys

- Survey subsurface and overhead utilities
- ASCE/CI 38, “Standard Guidelines for the Collection and Depiction of Subsurface Utility Data”
- Show utilities on drawings
- Contractor confirms locations before excavation
- One Call System-locates
- Potholing-confirmation

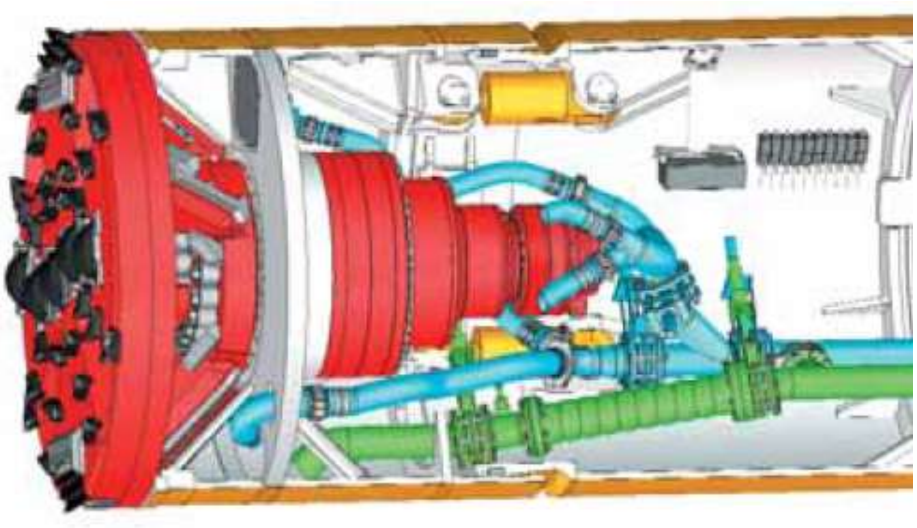


Line and Grade

- Add 0.1 foot drop at each manhole to assist in grade adjustments
- Use a two-pass system when grade is relatively flat, but critical to maintain
- Grades and tolerances are less critical for pressure pipelines and dry conduits
- For flat or critical grades or unfavorable ground conditions exist, use a two-pass approach
- Larger diameter may be more cost effective than smaller diameter

New Tolerances

- Alignment – Old tolerances +/- 1 inch
- New tolerance is +/- 3% of the outside diameter of the MTBM, or 1 inch, whichever is greater up to 600 feet
- For drives >600 feet consider:

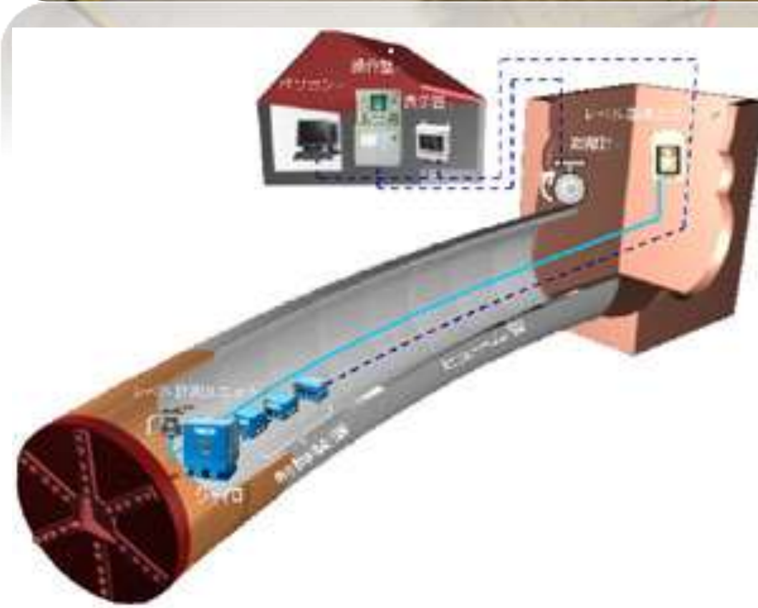


For drives greater than 600 feet follow one of these measures:

- Careful use of the laser
- Additional physical survey checks
- Use of advanced guidance systems
- Relaxation of the specified line and grade tolerances

Guidance Systems

- Laser Systems
- Gyroscope
- Water level
- Theodolite
- Set up
- Calibration
- Survey Checks



MTBM Requirements

- Designer must set forth in the contract documents the minimum capabilities and performance of the equipment
- Actual selection of the equipment is the responsibility of the contractor
- The selection of equipment is reviewed by the submittal process

MTBM Minimum Capabilities

- Provide continuous support to face to balance earth and groundwater pressures and prevent settlement
- Articulated Shield to allow steering in horizontal and vertical directions
- Remotely controlled; routine personnel entry not required
- Guided (laser or water level/theodolite)
- Bi-directional rotation
- Capable of lubrication injection around annulus
- Certification by manufacturer not practical

Added New Table 12-1

Ground Conditions	**Slurry**	**Auger**
Soft to very soft clays, silts, and organic deposits	Yes	Marginal
Medium to very stiff clays and silts	Yes	Yes
Hard clays and highly weathered shales	Yes	Yes
Very loose to loose sands **below water table**	Yes	No
Very loose to loose sands **above water table**	Yes	Yes
Medium to dense sands **below water table**	Yes	No
Medium to dense sands **above water table**	Yes	Yes
Gravels and cobbles less than 50-100 mm diameter	Yes	Yes
Soils with significant cobbles, boulders, and objects larger than 100-150 mm diameter	Marginal	Marginal
Weathered rocks, marls, chalks, and firmly cemented soils	Yes	Yes
Slightly weathered to unweathered rocks	Marginal	No

Drilling Fluid Design

- Definition – Water which may contain bentonite or other additives to enhance performance
- Slurry is drilling fluid mixed with cuttings
- Drilling fluid needed for microtunneling to transport cuttings to separation plant, counterbalance earth and groundwater pressures
- Drilling fluid characterized by:
  - Viscosity
  - Weight
  - Sand Content
  - Gel Strength
  - Yield Strength
  - Filtrate Loss

Evaluation of Settlement Risks

- Large settlements usually caused by face losses due to improper operation, set up of MTBM, and/or adverse ground conditions
- Necessary to protect existing utilities, roadways, other facilities
- Empirical approaches typically used
- Systematic settlements related to annular volume and face losses

Evaluation of Settlement Risks

- Identify facilities at risk
- Coordinate with owners of at risk facilities
- Establish allowable settlement limits
- Evaluate potential settlements
- Compare allowable and calculated values
- Develop and implement instrumentation and monitoring plan, including baseline survey of existing conditions

Evaluation of Jacking Forces

- Important for evaluating required capacity of pipe, thrust block, jacking system, and IJSs
- Jacking force components are face resistance and frictional resistance (JF = Fp + Fr)
- Empirical approaches used; good practices assumed
- Fp usually small compared to Fr
- Variety of factors can impact jacking forces; some are not accounted for in calculations
- Operational factors can exert large influences

Pipe Lubrication System

- Not the same as the slurry system
- Lubrication can be very effective in reducing frictional jacking forces
- Lubrication also effective in reducing systematic settlements
- Pretreatment of the excavated hole is important
- Pump sufficient volume to completely fill annular space

Considerations for Curved Drives

- Drives designed with curves increase risks
- Weigh benefits against risks
- Judgment and experience needed
    - Straight initial tangent
    - Increase number of IJSs
    - Diameters necessary to allow personnel entry for surveys; laser not appropriate
    - Evaluate allowable pipe joint deflection
    - May not be feasible in hard rock
    - Close monitoring needed

Risk Analysis

- Highlights the need for risk analysis
- Perform a risk analysis
- Reduce red risks to the yellow or green zones
- Reduce yellow risks to green if possible

Impact \ Probability	Rare (1)	Unlikely (2)	Possible (3)	Likely (4)	Most likely (5)
Very high (5)	5	10	15	20	25
High (4)	4	8	12	16	20
Moderate (3)	3	6	9	12	15
Low (2)	2	4	6	8	10
Very low (1)	1	2	3	4	5

Shafts and Working Space

- Discussed locating shafts to minimize impacts on other utilities (including overhead), traffic, and sensitive building structures
- Added recommendations of shaft spacing
- Discussed work zone size and equipment
- Minimum jacking and receiving staging areas of 7,000 ft^2 and 4,000 ft^2
- Recommendations on sizing shafts

Shaft Design Considerations

- Watertight vs non-watertight – should specify allowable options
- Anticipated earth and groundwater pressures
- Work space adequate for required sizes- may limit pipe lengths
- Settlement risks may preclude certain shaft types, sizes
- Dewatering issues and groundwater discharge permit constraints (volume and duration)
- Portal stabilization and entry/exit seals

Shaft Types

Speed

Slide Rail

Soldier Pile and

Caisson

Secant Pile

Sheetpile

Auger-Drilled

Launch Control

- Design and construction of shafts, including types of shafts, expanded
- Design of entry and exit seals for shafts and portal stabilization

General Pipe Requirements

- Microtunneling pipe should meet the following requirements:
  - Circular shape with a flush outside surface
  - Strength to withstand installation and in-place service loads
  - Dimensional tolerances on length, straightness, roundness, end squareness, and angular deflection
  - Durability for the service exposure
  - Joints capable of watertight performance and load transfer from jacking frame to MTBM face

Dimensional Criteria

- Table 17-1 cites the following:

- Circumference (< 0.5%)
- Exterior roundness (< 0.5%)
- End squareness (+/- 1.5 mm)
- Straightness (< 3 mm)
- Pipe length (+/- 6 mm)

Lubrication Ports

- Added commentary on ports
- Added sketches/drawings of
  - Typical flapper check valve
  - Witch’s hat check valve
- As cast-in-place or grouted-in-place
- Included photograph of both types

Joints

- Added commentary on intermediate jacking station joint configuration
- Provided new Figure 17-5 with the open and closed position of the IJS
- Added photograph of an IJS

Use of Engineered Drilling Fluid

- Mix with and transport the excavated material to the surface for separation
- In combination with mechanical pressure counterbalance the earth and groundwater pressures at the face of the MTBM
- In certain ground conditions accommodate the addition of additives to enhance performance of the excavation process

Use of Engineered Drilling Fluid

- Ground type considerations
- MBTM Operational parameters
- Percent Fines < 15% – 20%
- Can be water only or an engineered drilling fluid of water with bentonite and/or polymer additives
- Repetitive testing of the engineered drilling fluid is necessary

Guidance System

- Guidance system should be calibrated
- Set up checked by a second person
- Positioned and isolated in a safe location
- Checked Daily
- Watch for deflection and/or distortion
- Utilize an experienced underground surveyor
- Closed loop surveying requiring tunnel entry necessary to check projected laser control to MTBM
- Operator must log all laser adjustments

Lubricant System

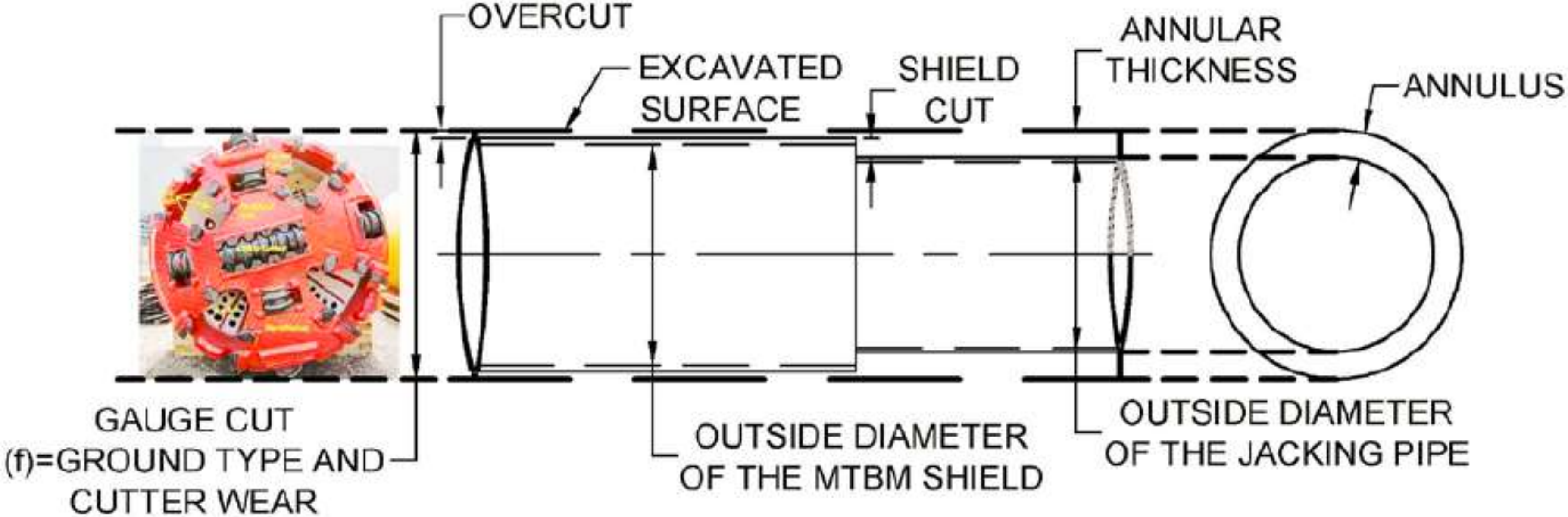
- Purpose is to reduce friction on the pipe
  - Formulated for ground conditions
  - Thin enough to flow around pipe
  - Thick enough not to be lost into soil
  - Track volume of lubricant pumped
  - Automatic injection systems are recommended
  - Avoid HDD style high gel strength fluid use
  - ANSI 060 Clean Water Approved additives only with potable water

Annular Thickness

- The radial distance between the outside diameter of the jacking pipe and the outside diameter of the tunnel excavation
- The annular thickness is normally:
  - 3/8 to 1 inch for soil conditions
  - 3/4 to 1-3/8 inch for rock condition
- See commentary for possible problems associated with too large or too small an annular thickness

Better Definition of Bored Hole

- Related to lubrication, excavation, operations, and settlement



Cutter Wheel Design

- Contractor should be responsible for selecting a cutter wheel suitable for the ground conditions ANTICIPATED along each drive
- The ANTICIPATED ground conditions should be documented in a geotechnical baseline report (GBR) prepared by the Engineer

Cutter Wheel Configurations

- Soft ground = drag teeth
- Mixed face = drag teeth and disc cutters
- Rock = disc cutters
- Some MTBM manufacturers use cutter wheel openings in conjunction with slurry pressure to control excavation
- Rock cutter wheel often require access to replace worn tools during a drive
- Cutter wheel upsizing is possible with care and recognition of production impacts

Cutter Wheel Design

Steering

- A good guidance system gives accurate real time information of the MTBM’s current positioning based on a projected control
- Excessive steering will cause increased jacking loads
- At a minimum a 1 to 300 ratio should be used to steer back to line or grade (1” in 25 feet)
- The owner should consider requiring a fully automatic or gyroscope system on drives over 1200 feet and curved drives

Inspection of the Work

- Owner should furnish or hire a full-time inspector
- Inspector to be knowledgeable with microtunneling, shaft construction, and pipe materials
- Monitor and document all activities, including:
  - Photographic documentation
  - Manpower and equipment log
  - Microtunnel activity log
  - Mining/advance log

Proposed Changes for 2020

- Define cohesive soils and 20% fines content – i.e., plasticity and silt content
- Add reference to ASTM A-1097 for steel casing
- Present pipe tolerances
- Include special pipe requirements
- Add a discussion on the Direct Pipe system since it meets the definition of microtunneling. The only different is “jacked pipe” versus ”thrusted pipe.”

Proposed Changes in 2020

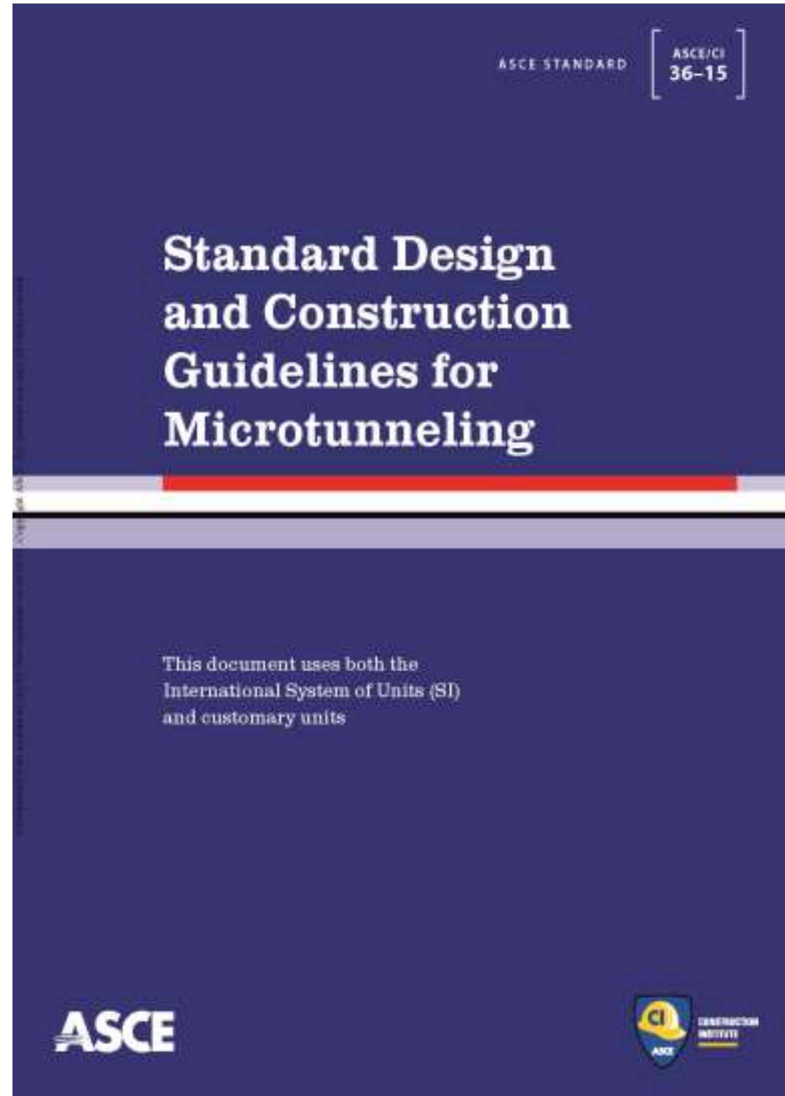
- Other methods: Front steer, guided boring, E-power pipe
- Discuss long drives over 1,500 feet and the extra considerations needed
- Add new discussions on intended curved microtunneling drives
- Add what happens when only water is used as an engineered drilling fluid

Proposed Change in 2020

- Add information on the flushing ring that prevents rock fines from traveling past the cutter wheel and along the outside of the jacking pipe
- Add emerging technology
  - Gyros
  - Auto lubrication system
  - Cameras and other sensors inside of the cutter head
- Discuss abrasivity from soil and rock
- Add to Chapter 2 – AREMA document

Closing Thoughts

- Available from ASCE.org
- Available as an e-Book and paper back
- It is a document for everyone to use
- Guideline – not a specification
- Thanks my MT colleagues for all the long hours in making this document happen



GLENN BOYCE
(925) 705.4114 | (510) 459.2995
boyce@mcmjac.com

McMILLEN JACOBS ASSOCIATES