



CURVED MICROTUNNEL PROJECT

CASE STUDY



GROUNDING IN STRENGTH

Forterra Drainage Pipe & Products

Can we tunnel RCP on a radius?

Northeast Ohio
Regional Sewer District



DWIRS Project

Project Clean Lake

- Part of the NEORSD's Project Clean Lake Program to reduce Combined Sewer Overflows (CSO's) through a 25 year, 3 billion dollar program
- Project Clean Lake is designed to ensure that 98% of wet weather flows entering the CSO system receive treatment, therefore drastically reducing raw sewage discharges into Lake Erie and adjacent waterways

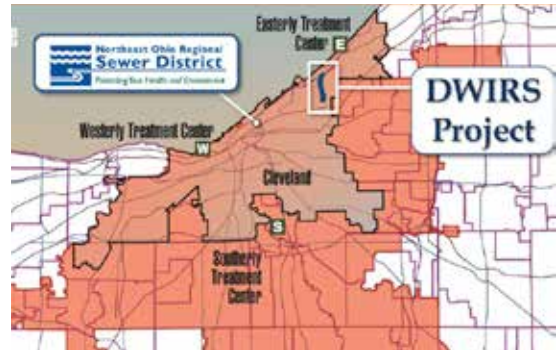
Microtunneling

- 6,631 LF of 72-inch RCP
- 3,069 LF of 48-inch RCP
- 2,889 LF of open-cut sewer installation (from 24-inch to 108-inch diameter)
- Multiple cast-in-place structures (flow structures, culvert connections, etc)
- Installation of 71 manholes 39 regulator modifications
- Contract awarded in October 2014 to Walsh/Super Excavators Joint Venture II (WSXJV) in the amount of \$57,479,355
- Construction commenced in December 2014
- Located in the Glenville neighborhood on Cleveland's east side

Microtunnel Run PM-13 to PM-16

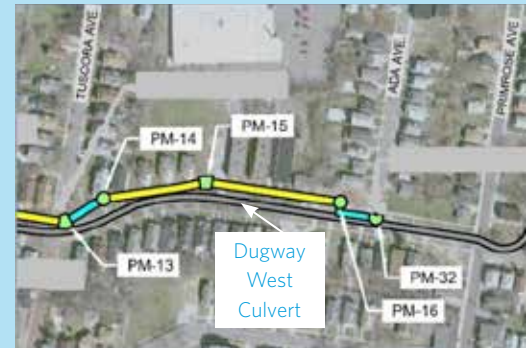
- 662 LF of 72-inch RCP installed to a gradient of 0.20%
- Four (4) shafts: PM-13 (CIP concrete lined), and PM-14, PM-15 & PM-16 (pre-cast manholes)
- Tight easement conditions due to clearance concerns to existing Dugway West Culvert





Project Location

- Located at the south end of the project
- Per specifications the tunnel alignment & gradient tolerances:
 - Horizontal Line = Not to exceed (NTE) 0.40 ft. than shown in contract drawings.
 - Elevation (grade) = NTE 0.20 feet than shown in contact drawings
 - Ground Settlement Control Requirement: "The average ground settlement over any distance of 100 ft. along tunnel centerline NTE 1.5 inches."
 - "Ground settlement at the structure nearest to any shaft excavation was not to exceed 2.5 inches."



Anticipated Ground Conditions

- Geological conditions expected were primarily of lacustrine silt and clay deposits
 - Medium to stiff to very stiff silty clay
 - Medium stiff to hard silty clay with traces of sand and gravel
 - Intermittent alluvial deposits (very loose to medium dense silty fine sand; with fresh wood)
- Water Table: 10 to 20 feet deep (several feet above the microtunnel)

Curve Proposal

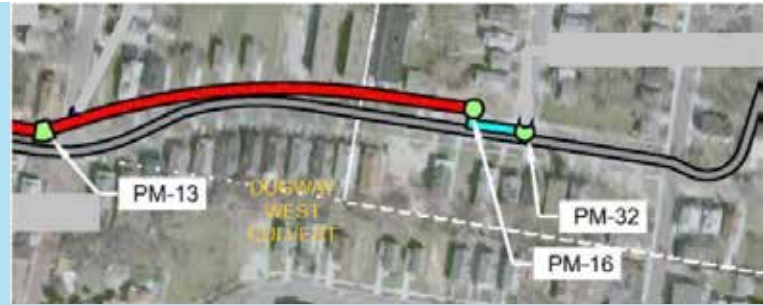
In June 2014, Super Excavators Inc. (SEI) prompted an informal discussion about a Value Engineering Change Proposal (VECP) that outlined a concept for a curved microtunnel run between PM-13 to PM-16.



PM-13 Shaft Excavation

Proposal: Benefits of the Curve

- Accelerated construction schedule
- Non-performance of two (2) shafts/manholes (PM-14 & PM-15). The designed three (3) short tunnel drives would not be required
- Both owner and contractor would gain knowledge and understanding of curve construction
- Constructed at a “No Cost/No Time” change basis
- Mitigation of overall construction impacts and disturbances to local community



Design:

- In December 2014, SEI retained S.J. Ludlow Consulting Engineers of Indiana to compose a design summary report/technical submittal for the Curve
- The design revised the designed location of PM-13 (24.3 ft. north) to “soften” the angle of the initial 140 LF long straight-of-way tunnel that would result in a more conducive (gentle) transition onto the curved microtunnel. At the end of the initial 140 LF straight drive, a 340 LF curve would be constructed at a 915.45 foot radius at 0.2% gradient. Finally, the modified tunnel run would transition back to a 210 LF straight drive that terminated at PM-16
- **Total tunnel run distance of 690 L.F.**



“In order to maintain proper safe distance from the existing Dugway West Culvert to the west, the proposed curve alignment was designed to mirror the curve of the existing culvert.....always maintaining a 15 to 20 feet buffer. The east side of the alignment was constrained by the right-of-way limits....”

Equipment & Modifications:

Microtunnel Boring Machine

- SEI selected the Akkerman SL74 MTBM that was skinned to an outer diameter of 88.5 inches (that resulted in a 2-inch overcut with the gage cutters = 90.5 inches)
- The required steering articulation for the MTBM to match the new curve would be 0.8 degrees (with a max. articulation of 3.0 degrees)
- As a contingency, SEI made an Intermediate Jacking Station (IJS) available on site (**design calculations estimated that the max jacking forces at the PM-13 thrust block would be 396 tons for the max amount of force produced by the line friction for the length of the pipe from PM-13 to the designed terminus of the curve run**)



MTBM Guidance Control

- “A critical component for the success of the proposed Curve was the selection of the guidance system. For the first time in the microtunneling industry, SEI utilized a VMT guidance system in an Akkerman MTBM”



- The VMT laser guidance system was selected because it provided significant advantages for the curved tunnel drive for its ability to determine and continually update and display the MTBM's position independent of drift or refraction, guaranteeing optimum control in the complex curve areas of the tunnel
- A VMT technician would be on-site for support

Pipe Design Modifications

The required 72", Class 3, "C" Wall RCP would be manufactured by Forterra of Columbus, Ohio.

To accommodate the anticipated higher jacking forces and geometrics that the new Curve would require, Forterra designed and implemented a special steel joint connection. The concept was to attain a robust pipe design with the joint connection by maximizing the available concrete on the 7.75" pipe wall by replacing the common bell/spigot design with one utilizing a 0.5" thick steel corrosion protected bell producing a concrete jacking surface greater than 6.5" wide.

Forterra produced 72" RCP for the Curve in 8 lengths to minimize the anticipated interior pipe joint openings and to obtain required pipe joint compression to navigate through the Curve.

By design, a 0.75" interior joint opening for the curve was anticipated.

As an additional consideration to reduce pipe resistance through the "curve" alignment, Forterra painted the exterior of each RCP with multi-purpose epoxy paint designed by Sherwin Williams (Dura-Plate Multi-Purpose Epoxy).

Construction & Conclusions

Curve Construction Facts

- The microtunnel curve drive began 7/5/2015
- City of Cleveland approved 24-hour operation for the microtunneling
- 9 days were needed to complete the drive once the Akkerman MTBM intersected the north quadrant of PM-16 on 7/14/2015
- SEI averaged 39 ft. per shift
- A maximum recorded jacking force of 246 tons was observed for the entire curve run (overall average was 99 tons)
- No downtime encountered. No grade/alignment issues



"European joint" with steel bell collar



PM-13 Site: delivered 72" RCP for Curved Microtunnel



Jacking station: PM-13 shaft

After completion of tunneling operations, SEI performed contact grouting to fill potential void areas around the annular space of the final 72" RCP lining (between the RCP exterior and surrounding soil). Approx. six (6) cubic yards of grout was utilized for the entire run.

An interior inspection of the final tunnel lining indicated that the widest interior RCP joint widths averaged 0.75-inches (which was anticipated during the design).

Conclusions

- Due to the Value Engineering , the DWIRS overall microtunneling operation was completed sixty (60) days ahead of schedule
- The Curve mitigated construction impacts to the local community and accelerated the overall tunneling schedule on the project
- Both SEI and the NEORS D gained valuable knowledge of curve construction for future considerations
- The Curve reduced the need for 2 manholes that would have to be serviced for life by the owner
- The DWIRS PM-13 to PM-16 microtunnel curve represents the first in the Midwest, and the Fourth in the USA

Acknowledgements



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Forterra

Forterra is a leading manufacturer of water and drainage pipe & products for a variety of water-related infrastructure applications. Based in Irving, Texas, Forterra is comprised of Drainage Pipe & Products, Water Pipe & Products, Structural & Specialty Products and Stormwater Management Systems. We employ more than 5,500 people and operate more than 100 facilities, with products available throughout the U.S. and Eastern Canada.



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