New England Municipal Outreach
Trenchless Technologies and Their Practical Applications
Tuesday October 16, 2012

Sponsored By:
Northeast Trenchless Association
U.S. Environmental Protection Agency
Louisiana Tech University
Trenchless Technology Center

Trenchless Piping
Materials and Design Considerations

Brian Dorwart, PE – Brierley Associates
Bill Haines, PE – VARI-TECH LLC
Dennis Doherty, PE – Haley & Aldrich
Topics – Product Material

- Pipe Material Selection
  Brian Dorwart PE, PG
- HDPE
  Bill Haines PE
- Jacking and Tunneling
  Dennis Doherty, PE
Common Trenchless Methods

- HDD
- Ramming
- Static Splitting
- Sliplining
- Bursting
- Lining
- Tunneling
Material Selection

- Each material offers its’ own construction and operation advantages and disadvantages.
- Most common pipe materials.
  - PVC
  - Ductile Iron
  - HDPE
  - Steel
- Others: Fiberglass, Clay, Polycrrete, RCP, CMP, Resins
CONSTRUCTABILITY
MATERIAL SELECTION
You Need to Get it in the Ground!

- Trenchless Alternatives
  MUST CONSIDER
  Construction Loads
  AND
  Handling Requirements
  AND
  Be a Structural Material
Trenchless Installation Methods

- **Horizontal Directional Drilling – New**
- **Pipe Bursting Replacement and Enlargement**
- **Slip lining/Lining Rehabilitation**

Pipe installations including: water, waste water force mains, gravity sewer, gas, petroleum, electrical.

Pipe installations including: gravity sewer, water, waste water force mains, gas, et al

Pipe installations including: gravity sewer, water, waste water force mains, gas, et al
Trenchless Installation Methods

- Pipe Ramming New and Rehabilitation
- Pipe Jacking New
- Micro-Tunneling New
- Tunneling New

Pipe installations including:
- casing, storm water
- storm water, gravity sewer, et al
- storm water, gravity sewer, water, waste, et al
- multiple usages.

Courtesy RSMS University of New Hampshire 1998
Pipe Material Selection

TRENCHLESS DESIGN APPROACH:

- Pipe MUST be installable by trenchless methods
- Pipe material MUST be structural to permit design
- Determine Construction/Installed Options
- Defined lifespan of the installation
- Dominant loadings generally during construction
- ALL failure methods must be evaluated and assessed
- Determine realistic O&M of system
OPTIONS
CONSTRUCTION/INSTALLED

- Primary pipe – no casing
  - Pull in ground
  - Push in ground
- Secondary pipe – casing
  - Pull in casing
  - Construct in casing
  - Push in casing
Pipe Loading

HDD Construction Loads are controlled by design depth/geometry/geology/material properties

Loading Stresses
- Bend radius
- Pipe Stress
- ST/LT soil/water

Other
- Corrosion
- Location-trace
Different Materials Have Different Short and Long Term Characteristics

- Steel
- RCP
- HDPE
- Fiberglass
- Clay
- Ductile Iron
- PVC
Pipe Materials Commonly Used In Trenchless Installations

**PVC**
- 1955 water
- Sizes up to 42”
- Lengths >5,000’

**HDPE**
- 1960’s gas
- 1978 water
- Sizes up to 48”
- Lengths up to 5,500’

**DIP**
- 1955 water
- Sizes up to 36”
- Lengths up to 2,300’

**Steel**
- 1858 water
- Sizes up to 48”
- Lengths >8,000’

*Courtesy: Oildom Publishing “Underground Construction” June 2007 9th Annual Survey*
Factors in pipe material choices

<table>
<thead>
<tr>
<th>Strength</th>
<th>3.25</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrosion resistance</td>
<td>2.6</td>
</tr>
<tr>
<td>Installation costs</td>
<td>2.5</td>
</tr>
<tr>
<td>Cost of pipe</td>
<td>2.0</td>
</tr>
<tr>
<td>Seismic considerations</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Average on a scale of 5 to 1, with 5 = most important, 1 = least important

Source: Pilot survey of 21 US utilities with a range of piping from 1,736 mi (2,794 km) to 36,456 mi (58,669 km), conducted by the AWWA Water Supply and Distribution Design and Construction Committee
Different Construction/Operation Methods REQUIRE Different Pipe Properties!

- Modulus of Elasticity
- Strength
- Thermal
- Thermal & Electrical Conductance
- Fusibility
Mechanical Properties

1.1 Stress-Strain Curves

1.2 Definition and Classes
- Plastic (thermoplastic)
  - Any material which undergoes a permanent change of shape (plastic deformation) when strained beyond a certain point (yield point)
- Plastics can be identified and characterized by the shape of their stress-strain curves
  - Hard-tough
  - Hard-strong
  - Soft-tough
  - Hard-brittle
  - Soft-weak

1.3 Definition and Classes
- Hard = high modulus (steep slope)
- Tough = high elongation before break, large area under stress-strain curve

1.4 Hard and Tough
- High density polyethylene, HDPE
  - Fairly high crystallinity ($T_m = 135 \degree C$, $T_g = -90 \degree C$)
- Polypropylene, PP
  - $T_m = 175 \degree C$, $T_g = -18 \degree C$
  - Slightly harder, higher tensile modulus than HDPE. Why?
- Poly(ethylene terephthalate), PET
  - $T_m = 265 \degree C$, $T_g = 70 \degree C$
  - Stiffer, higher tensile modulus than HDPE. Why?
- Typical applications

Modulus & Strength

Courtesy of University of Wisconsin
Mechanical Properties

Modulus & Strength

1.5 Definition and Classes
- **Hard**: high modulus (steep slope)
- **Strong**: moderate elongation and high modulus

1.6 Hard and Strong
- Poly(vinyl chloride), PVC
  - $T_m = 212 \, ^\circ C$, $T_g = 85 \, ^\circ C$
  - Would you expect this polymer to be brittle or pliable at 0 °C?
  - How can you change the flexibility of PVC?
  - Typical applications

1.7 Definition and Classes
- **Soft**: low modulus (shallow slope)
- **Tough**: high elongation

1.8 Soft and Tough
- Low-Density Polyethylene, LDPE
  - $T_m = 115 \, ^\circ C$, highly branched, lower crystallinity
  - Linear Low-Density Polyethylene, LLDPE
    - Moderate degree of branching
    - More crystalline than LDPE?
    - Higher tensile strength (stronger) than LDPE
  - Typical applications

Courtesy of University of Wisconsin
# Mechanical Properties

## METALS

<table>
<thead>
<tr>
<th>Material</th>
<th>Properties</th>
<th>Bend Radius</th>
</tr>
</thead>
<tbody>
<tr>
<td>STEEL</td>
<td>Hard and Tough</td>
<td>$100 \times \text{OD(in)}$</td>
</tr>
<tr>
<td>DIP</td>
<td>Hard and Strong</td>
<td>$100 \times \text{OD(in)}$</td>
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## NON-METALS

<table>
<thead>
<tr>
<th>Material</th>
<th>Properties</th>
<th>Bend Radius</th>
</tr>
</thead>
<tbody>
<tr>
<td>HDPE</td>
<td>Hard and Tough</td>
<td>$50 \times \text{OD(ft)}$</td>
</tr>
<tr>
<td>PVC</td>
<td>Hard and Strong</td>
<td>$20 \times \text{OD(in)}$</td>
</tr>
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</table>
Approximate Pipe Bend Radius

- Steel $R$ (ft) = $100 \times$ Pipe Diameter in inches
- HDPE $R$ (ft) = $50 \times$ Pipe Diameter in feet
- PVC $R$ (ft) = $20 \times$ Pipe diameter in inches
- DIP $R$ (ft) = deflection angle allowed by joints usually between 2.5 degrees to 6 degrees.
Degradation of Properties

**METALS**

**STEEL AND DIP**
- Oxidation of Iron
- Pin-hole corrosion
- Loss of material
- Thermally stable

**HDPE AND PVC**
- UV light molecular degradation
  - Becomes Brittle
  - Strength Loss
  - Time dependence
  - Thermal dependence

**NON-METALS**

- Oxidation of Iron
- Pin-hole corrosion
- Loss of material
- Thermally stable
Understand Failure Modes

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<th>NON-METALS</th>
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<tr>
<td>STEEL</td>
<td>HDPE</td>
</tr>
<tr>
<td>• Corrosion</td>
<td>• Slow Crack Growth</td>
</tr>
<tr>
<td>• Ductile deformation</td>
<td>• Burst</td>
</tr>
<tr>
<td>DIP</td>
<td>• Unconstrained Buckling</td>
</tr>
<tr>
<td>• Pin-hole corrosion</td>
<td>• Unconstrained Buckling</td>
</tr>
<tr>
<td>• Brittle Fracture</td>
<td>• Brittle Fracture/Burst</td>
</tr>
<tr>
<td>• Brittle Fracture</td>
<td>• Rapid Crack Propagation</td>
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<tr>
<td>PVC</td>
<td>• Unconstrained Buckling</td>
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Trenchless Design Elements

- Safety by engineering for failure
- Bending Radius
- Thermal Variance on Structural Capacity
- Design Sensitivity to Constructability
- Unconstrained Buckling
- Burst Strength
- Tensile Strength (Pipe/Couplings)
- Connections (Valves/Pipes/Manholes)
- Corrosion/Degradation
- Cost/Local Experience
Resources

- Ductile Iron: DIPRA
- Steel: Steel Manual
- PVC: Uni Bell
- HDPE: Plastic Pipe Association
- Corrosion: NACE International
- Water: AWWA
- Gas: AGA
- Oil: API
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HIGH DENSITY POLYETHYLENE PIPE
The Reliable Choice For Trenchless Applications

Bill Haines, P.E.
US Director of Engineering
VARI-TECH LLC
PROPERTIES OF HDPE PIPE
CORROSION RESISTANT
CORROSION RESISTANT
NON-BRITTLE MATERIAL
ABILITY FOR WATER HAMMER/SURGE

- 50% Allowance for Normal Recurring Surge Events (1.5xWPR)
- 100% Allowance for Occasional Dynamic Surge (2xWPR)
- Elasticity Allows Pipe to Expand & “Deaden” Surge Wave
- Superior with Cyclical Loadings (irrigation, pump stations)
**LEAKFREE/FULLY RESTRAINED**

- Butt Fusion = Zero Leakage
- Thrust Blocks Typically Not Needed
  - Pay attention to connections to unrestrained pipe (i.e. gasketed joints)
- Handle Ground Movement (frost, settlement, earthquake) without incident
  - Cornell Earthquake Studies
Technologies for New and Existing Infrastructure

- Existing Infrastructure
  - Bursting Slip Lining

- New Infrastructure
  - HDD
DESIGN CONSIDERATIONS FOR HDPE APPLICATIONS

- Safe Pull Strength
- Bend Radius
- Earth & Live Loads
- Site Access/Staging
- Operating Pressure
- Flow ByPassing Req’d?
- Alignment: bends, pits
- Traffic Control
- Environmental Issues

- Existing Pipe Materials
- Flow Evaluation(+-)
- Location of Utilities
- Geology/Soil Properties
- Historic Information
- Surface Topography
- Slope of Line
EVERY TRENCHLESS PROJECT IS UNIQUE!!!!
THERE IS NO SUBSTITUTE FOR GOOD FIELD INFORMATION!!
PROOFING THE LINES
FUSE ON PULL HEAD & SWIVEL
CREATIVE PIPE PLACEMENT
VAC TRUCK
TIE IN BETWEEN TWO DRILLS
New England Municipal Outreach

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JACKING PIPE
The Reliable Choice For Trenchless Applications

Dennis J. Doherty, PE, F.ASCE
National Practice Leader - Trenchless Technologies
HALEY & ALDRICH
3 Bedford Farms Drive
Bedford, NH 03110
Hobas Pipe

centrifugally cast fiberglass reinforced polymer mortar pipe (CCFRPM)

- Not used in Auger Bore
- Good for protection from Hydrogen Sulfide Attack
- Proprietary Pipe
Concrete Jacking Pipe

- Most common jacking pipe
- Not good in corrosive Atmosphere unless extra Protection added.
- Polymers can replace Portland Cement
Steel Jacking Pipe

- Continuous welded Pipe (time needed to weld each segment)
- Permalok Pipe (Snap together steel pipe eliminates time required for welding)
- Proprietary Pipe
Clay Jacking Pipe

- Not used in Auger Bore
- Good for Corrosive Conditions
- Size Limitations
Pipe Load Calculation

Face Pressure + Friction = Pipe Load
Earth Load Separate (except impact on friction)
Cumulative Jacking Load

Minimizing the Effect of Excessive Microtunneling Steering; No-Dig 2004 – Mark Bruce President Cam Clay
Minimizing the Effect of Excessive Microtunneling Steering; No-Dig 2004 – Mark Bruce President Cam Clay
Load Concentration due to Deflection

Use this slide when your text does not require a bullet.

- Load Stress Distribution
- Deflection from Actual Max. Stress Applied at This Joint (EXAGGERATED RELATIVE ANGLE FOR ILLUSTRATION PURPOSES)
- Packing Ring Compression Due to Loading at This Joint (Shaded Area)
- Original Thickness of Packing Ring (EXAGGERATED THICKNESS FOR ILLUSTRATION PURPOSES)

$D_2 = \text{Internal Diameter at Seal}$
Load Concentration due to Deflection

**Chart 3, Jacking Force vs. Position of Pipes**

**Interstate Highway Fill**

**Jacking Shaft**

**Microtunneling Machine**

Poor Launch Control - Offset 1 degree but steer back

**Pipe**

Face Pressure + Pipe Friction with Soil = 40 ton + 5 ton X 1 pipe

Face Pressure = 40 tons

**Chart 3, Jacking Force vs. Position of Pipes**
Load Concentration due to Deflection

**INTERSTATE HIGHWAY FILL**

**JACK SHAFT**

**PIPE**

**MICROTUNNELING MACHINE**

Position of 1 degree deviation in steering from pipe to pipe

**CHART 4, Jacking Force vs. Position of Pipes**

Face Pressure + Pipe Friction with Soil = 40 ton + 5 ton X 7 pipe

Face Pressure = 40 tons

Minimizing the Effect of Excessive Microtunneling Steering; No-Dig 2004 – Mark Bruce President Cam Clay
Load Concentration due to Deflection
Other considerations

- Pipe Type and Materials
  - Section lengths
  - Joints
  - Joint packers
  - Injection ports
  - Coatings / Linings
  - Special Pipe
  - Intermediate Jacking Stations (IJS)
Intermediate Jacking Stations (IJS)

- Used to assist in advancing pipe long distance while minimizing total load on pipe and shaft
- Used inline with pipe (Does not require separate excavation)
- Man-entry size pipe
- Location in pipe chain
How IJS Works

Typical Jacking Arrangement

Detail - Intermediate Jacking Station
Lubrication

- Friction reduction
- Overcut
- Borehole stabilization – reduces settlement
Ground Movement

- Very small movements generally associated with pressure balanced MTBM – Face Stability consideration
- Analysis considers the loss of ground into over-cut
  - Settlement trough calculations
  - Typical settlement
- Minimizing overcut versus higher jacking loads
Design your pipe and your trenchless installation method together and for compatibility.

QUESTIONS?