PIPE JACKING

An introduction to pipe jacking prepared by the Pipe Jacking Association
Pipe Jacking
Pipe Jacking
Microtunnelling
Pipe Jacking - General Arrangement

Pipe Jacking is an integrated system linking:

- soils
- jacking shafts
- pipes
- shields
- jacking loads
- engineering
Machine Technology

Machines are available for pipe jacking in most ground conditions.
Machine Technology

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- Backacters
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- Backacters
- Open face cutter booms
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- Earth pressure balance
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- Backacter
- Open face cutter booms
- Tunnel boring machine
- Earth pressure balance
- Pressurised slurry
Microtunnelling

- Fully guided machines
- Controlled from surface
- Non man entry
- Two options:
  - Pressurised slurry
  - Screw auger
Benefits of Mechanisation

• Significantly safer working
• Efficient
• Hand arm vibration eliminated
• Quicker installation
• Ground support
• Remote control
• Risks mitigated
Computer Guidance

- Real-time line and level checks
- Maintains accuracy in difficult ground
- Allows remote operations
Drive Lengths, Diameter and Accuracy

Indicative jacking lengths achievable between shafts for mechanised drives, based on PJA members’ experience and lengths being achieved internationally for both straight and curved drives appear below:

<table>
<thead>
<tr>
<th>Diameter (m)</th>
<th>&lt;0.9</th>
<th>0.9</th>
<th>1.0</th>
<th>1.2</th>
<th>1.35</th>
<th>1.5</th>
<th>1.8</th>
<th>1.9</th>
<th>2.1</th>
<th>2.4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lengths (m)</td>
<td>150</td>
<td>200</td>
<td>250</td>
<td>450</td>
<td>550</td>
<td>700</td>
<td>900</td>
<td>1000</td>
<td>1000</td>
<td>2000</td>
</tr>
</tbody>
</table>

Accuracy:
In stable self-supporting homogenous ground typical tolerances for pipe installation are ±50mm for line and level at any point in the drive.

A risk analysis should be undertaken on all drives to ensure all foreseeable hazards to include access and egress of operatives and any other risks are adequately considered.
Pipe Jacking Pipes

- Concrete jacking pipes: BS EN 1916
- Clay pipes: BS EN 296-7 and BS EN 12899: 2000
- Installation forces are key
- Follow manufacturers recommendations
- Steel pipes: sleeves for pressure mains
Site Investigation
## Soil Conditions

<table>
<thead>
<tr>
<th>TEST</th>
<th>Non-cohesive</th>
<th>Cohesive</th>
<th>Mixed Soils</th>
<th>Fill Material</th>
<th>Rock</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit weight and moisture content</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Angle of friction</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Particle size distribution</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Abrasivity</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Cohesion</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Types and proportions of minerals</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Standard penetration tests</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Permeability and nature of ground water flows (seasonal/tidal changes)</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Toxic/hazardous constituents in the ground/groundwater</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Frequency and physical properties of boulders, cobbles or flints</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Pump down tests</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Presence of gases</td>
<td></td>
<td></td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Compressive strength</td>
<td></td>
<td></td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Rock quality designation (RQD)</td>
<td></td>
<td></td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Core logging (TCR, SCR, FI)</td>
<td></td>
<td></td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Tensile strength</td>
<td></td>
<td></td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Specific energy (excavatability)</td>
<td></td>
<td></td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Slake durability</td>
<td></td>
<td></td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Geological description</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Plasticity indices (SL, PL, PI)</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Disaggregation mixing test*</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>RF (x-ray fluorescence) mixing test</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
</tbody>
</table>

*See N. S. Phillips 2016 on www.pipejacking.org/research
Tunnelling in Unstable Ground

Note: Whilst open face handshield and compressed air are referred to above, these are only used in special circumstances.
Open Trench vs Pipejacking

- Carriageway
- Undisturbed soil
- Imported backfill
- Undisturbed soil
- Surround bedding
- PIPE
- PIPE JACKING
- OPEN CUT
## Open Trench vs Pipejacking

### Lorry Movements

<table>
<thead>
<tr>
<th>Aspect</th>
<th>600mm ID pipeline 4m deep, 100m length</th>
<th>1200mm ID pipeline 4m deep, 100m length</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Open trench</td>
<td>Trenchless</td>
</tr>
<tr>
<td>Excavated width</td>
<td>1400mm (trench width)</td>
<td>760mm (OD of jacking pipe)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2350mm (trench width)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1450mm (OD of jacking pipe)</td>
</tr>
<tr>
<td>Reinstatement width</td>
<td>1700mm</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2650mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>None</td>
</tr>
<tr>
<td>Excavated volume per metre of pipeline</td>
<td>6.1m³</td>
<td>0.5m³</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10.28m³</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.65m³</td>
</tr>
<tr>
<td>Imported stone fill and coated stone per metre of pipeline</td>
<td>11.9 tonnes</td>
<td>None</td>
</tr>
<tr>
<td>Number of 20 tonne lorry loads per 100m pipeline (muck away and imported stone)</td>
<td>136</td>
<td>8</td>
</tr>
</tbody>
</table>
Carbon Calculator

- Easy to use
- Options:
  - Feasibility
  - As designed
  - As built
## Carbon Calculator

**CO₂ Savings – 500 metres**

<table>
<thead>
<tr>
<th>Project Data</th>
<th>600mm diameter pipeline 500m length x 4m deep</th>
<th>1200mm diameter pipeline 500m length x 4m deep</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Method</strong></td>
<td>Open cut</td>
<td>Open cut</td>
</tr>
<tr>
<td><strong>Tonnes CO₂</strong></td>
<td>351.4</td>
<td>570.6</td>
</tr>
<tr>
<td><strong>CO₂ saving</strong></td>
<td>238.1 tonnes = <strong>68% saving</strong></td>
<td>268.8 tonnes = <strong>47% saving</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Project Data</th>
<th>600mm diameter pipeline 500m length x 6m deep</th>
<th>1200mm diameter pipeline 500m length x 6m deep</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Method</strong></td>
<td>Open cut</td>
<td>Open cut</td>
</tr>
<tr>
<td><strong>Tonnes CO₂</strong></td>
<td>492.4</td>
<td>765.5</td>
</tr>
<tr>
<td><strong>CO₂ saving</strong></td>
<td>367.8 tonnes = <strong>75% saving</strong></td>
<td>437.2 tonnes = <strong>57% saving</strong></td>
</tr>
</tbody>
</table>
Major Applications

- New sewerage and drainage construction
- Sewer replacement and lining
- Gas and water mains
- Oil pipelines
- Electricity and telecoms cable ducts
- Subways
Technical Benefits

- Inherent strength
- Smooth internal finish
- No secondary lining
- Fewer joints
- Watertight
- Inverts for combined systems
- Less settlement
- Minimal surface impact
- Fewer utility diversions
Safety Benefits

• Inherently safer method
• Quicker installation
• Reduced labour input
• Utility strikes minimised
• Public interface reduced
• Reduced confined space man hours
Sustainability: Environmental and socio-economic benefits

- Reduces disruption
- Reduces damage to services
- Maintains highway integrity
- 90% fewer vehicle movements
- Less spoil
- Less quarried material
- Reduced CO$_2$ emissions
- No secondary lining
- Economic alternative to deep open cut
- Socially acceptable
Research Projects at Leading Universities

University research programme initiated in 1986 – projects include:

• Laboratory testing of model jacked pipes
• Field testing of performance of pipes
• Finite element analysis of concrete jacking pipes
• Full scale testing of concrete pipes
• Soil conditioning and lubrication materials
• Field testing of soil conditioning and lubrication methods
• Slurry management and soil disaggregation
PJA Publications and Design Advice

- Introduction to pipe jacking
- Detailed design guide
- Videos and presentations
- Preferred pipe sizes
- Case studies
- Research
- Carbon calculator
- Contractors, pipe and other suppliers
- Safety guidance
- Downloadable from website
Additional Applications

Box Sections
- Subways
- Roadways

Other uses
- Jacked arches
- Bridge slide foundations
Summary

- Engineering integrity
- Low capital costs
- Low maintenance
- Cost-effective
- Safe installation
- Environmental benefits
- Reduced CO₂ emissions
- Extensively used
- 150mm to 2.4/3m diameters
- Long drive lengths
- Straight or curved drives