Tunneling Overview
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• Discussion is limited to tunneling for utility applications:
  – Sewer
  – Water
  – Power

• Typical diameter range: 36” to 84”
Tunneling Overview

YOU CAN TUNNEL!
TENBUSCH CAN HELP!
Tunneling Overview

The first and most important detail when considering trenchless work is to have as much information as possible regarding the existing conditions.

• Underground geology
• Ground water or lack of it
• Existing utilities or other underground obstacles
• If working in an existing embankment – what is the existing material?
• Is there a chance of existing pilings or tree stumps?
Your must have control at all times.

- For safety of the men
- For proper advancing (and therefore ultimate completion) of the drive
- To protect any structures above from
  - settlement due to over excavation
  - heave due to advancing without proper excavation
Now let’s discuss different ways of excavating and controlling the face.

- **Rock – hard or soft**
  - Can be blasted and removed by hand
  - Can be cut with a rotating head with disc cutter

- **Soft rock can be mined with**
  - A rotating cutter head with disc cutters or teeth
  - A road header

- **Stable dirt**
  - Hand mined (labor with hand held air tools
  - Rotating cutting head.
Different ways of excavating and *controlling* the face – cont’d

- Unstable ground

  **CAN THE GROUND BE STABILIZED?**

  - Dewatering
  - Ground freezing
  - Pressure grouting

If it *cannot* be stabilized, then the equipment used must be set up to accommodate the conditions.

- Control must be retained
  
  - The face must not be allowed to inundate the equipment
  - Steering control
  - Muck removal v advance rate control – see the next frame
Muck removal must be coordinated with the advance of the machine.

• This is called “earth pressure balance”.

• In other words if a 48” diameter machine is advanced two and half feet it will displace approx one cubic yard of material.

• If more than one yard is removed while advancing two and a half feet– a void will be created. If less than one yard is removed – the advancing machine will try to compact the material in place and create a heave on the surface.

• While one might expect that the microtunneling equipment set up for earth pressure balance is the only way to accommodate unstable ground, any tunneling scheme that allows the men to simply control the advance rate of the equipment in coordination with the amount of material excavated will be successful.
Tunneling Overview

• Types of Tunnels – Categorize by Lining Method Used:
  – Steel Casing
  – Segmented Pipe Products
  – Steel Liner Plate
  – Beam and Lagging
Different tunnel linings

- **Steel** – Steel casing is a very dependable tunnel liner.
  - It can be welded
  - Or a joint known as Permalok can be used.
  - Steel must be pushed into place from the work pit through to the other end of the tunnel.
    - This can require around the clock work to ensure that the advancing column will not get stuck.
    - Different lubricants can also be used to ensure that skin friction along the column will not overwhelm the ability to advance it.
  - Steel necessitates a longer work pit. The pit must accommodate the new pipe being added to the column as well as the jacking unit that is used to advance it.
Tunneling Overview

• Steel Casing
  ✓ Articulating Shield
    ✓ allows for grade control
    ✓ allows for emergency bulkhead if needed.
    ✓ protects the men as they work.
  ✓ Steel Casing Inserted in 10’ to 12’ Lengths
  ✓ Jacking Unit Pushes Pipeline From Work Pit
  ✓ Muck Cart Removes Spoil
The photo above shows the shield in the staging area ready to work.

The photo to the left shows the shield attached to the first piece of steel casing – ready to go.
Work pit – needs to be long enough to accommodate the jacking unit & the length of casing being inserted.

In this graphic we see the shield being advanced by the casing. The casing must be pushed from the work pit to the receiving pit.
Different tunnel linings – cont’d

- **Segmented pipe** can be used as a tunnel liner, these pipes would include
  - RCP (reinforced concrete pipe)
  - Clay (vitrified clay jacking pipe)
  - CCFRPM (Hobas)
  - Polycrète (polymer concrete jacking pipe)
  - Ductile Iron pipe
-Segmented pipe products must be pushed into place from the work pit through to the other end of the tunnel.

-This can require around the clock work to ensure that the advancing column will not get stuck.

-Different lubricants can also be used to ensure that skin friction along the column will not overwhelm the ability to advance it.

-The pit must accommodate the new pipe being added to the column as well as the jacking unit that is used to advance it.
Tunneling Overview

- Segmented Pipe Products
  - Articulating Shield
    - allows for grade control
    - allows for emergency bulkhead if needed.
    - protects the men as they work.
  - The shield can be fitted with hydraulic cylinders to push off of the column of new pipe.
  - Intermediate Jacking Stations add thrust and allow for longer pushes.
  - Pipe joints are available in shorter lengths
  - Jacking Unit Pushes Pipeline From Insertion Pit
  - Muck Cart Removes Spoil
Concrete Jacking pipe

Polycrete Jacking pipe

Clay Jacking pipe

Polycrrete Jacking pipe
When using segmented pipe – the pit need only be long enough to accommodate the pipe segment length and the jacking unit.

Intermediate jacking stations allow the pipe string to be “inch wormed” through the ground and thereby reduce the thrust exerted upon the pipe product. This is very important when using concrete pipe.
Different tunnel linings – cont’d

- **Liner Plate** - tunnel liner plate is an old and dependable lining product.
  - It comes in both two flange and four flange configurations. It comes in both 16” and 24” lengths.
  - It comes coated and uncoated, with grout holes and without grout holes.
  - It comes in different thicknesses.
  - The use of liner plate can allow for a very short entrance or work pit.
  - Liner plate tunnels should be grouted daily.

✓ This ensures that the tunnel constructed at any given time is complete and no ground settlement will occur.

✓ Because there is no column to advance – around the clock work and the use of lubricants is not required.
Liner plate cont’d

- The assembly of liner plate is always done by laborers and should be done from within a shield.

- The shield will always be advanced by pushing itself forward off of the constructed liner plate.

- Liner plate can be used with different excavation methods including hand mining.

- When using a TBM with liner plate, care should be taken to ensure that the axial strength capability of the liner plate will not be overwhelmed by the TBM as it is advanced.
Tunneling Overview

- Steel Liner Plate
  - Articulating Shield
    - allows for grade control
    - allows for emergency bulkhead if needed.
    - protects the men as they assemble the liner plate
  - The shield will push off of the column of assembled liner plate.
  - Grout the annular space as the tunnel is advanced
  - Muck cart removes spoil
The picture in the center shows a shield with a muck bowl & cart & track.

The muck bowl and cart in the center photo is still clean – this picture was taken as the tunnel was begun with the shield still in the work pit.
The cutaway to the right shows the wood bulkhead that can be placed to control soft sloughing soil.
Normal sequence of construction:

1. Excavate the pit to the appropriate elevation taking into account the launch track and the liner plate dimensions.
2. Set the launch track on a firm stabilized floor.
3. Excavate a short entrance hole for the shield.
4. Set the shield on the launch track and assemble the liner plate behind it. This will allow the shield to advance by pushing off of the assembled liner plate. The liner plate must be only partially assembled at the rear of the pit for the egress of the men and to allow the muck bowl to be removed.
5. When the liner plate assembly has advanced beyond the wall of the pit, the annular space will be grouted. This grouting will be done at least as often as the end of each day. When sufficient liner plate has been grouted, the liner plate in the pit can be removed. Note – the lower sections of liner plate will remain to support the muck cart track in the launch track.
6. The new liner plate sections will be assembled at the rear of the shield and the shield will be advanced forward. When the shield is advanced enough, another section of liner plate will be assembled and the tunnel will progress to the other end.
7. Note – the work pit and the tunnel require specific safety procedures and training.
Different tunnel linings – cont’d

 Beam and Lagging

- Beam and lagging normally consists of a beam that is bent into a circle.
- It comes in sections so that it can be assembled in the tunnel.
- The lagging is installed between the beams and is normally hard wood planking, however it can be steel of one shape or another.
Examples of Beam and Lagging tunnel construction

The photo below shows a conveyor ready to load a muck cart.
Muck removal

The most effective way to transport the excavated material from the face out of the tunnel is a muck cart and bowl system.

If the bowl is separable from the cart – the cart can be used to transport liner plate or beam and lagging into the tunnel.

The bowl must be small enough to allow fast exit over the top of it by the men.

If the tunnel is advanced up hill. The empty bowl and cart will be pushed uphill by the men and the loaded cart will be pushed downhill by the men.

An air tugger can be used as well. (This is an air operated winch that can be mounted in the middle of the launch track or jacking unit)
These pictures show a 12” gauge track – this is appropriate for tunnels up to 60” tunnels.

Larger tunnel diameters will require a larger muck bowl and cart and therefore a wider track.
The Muck Bowl separates from the cart and dumps quickly and efficiently.
Support equipment

- Hydraulic power pack
- Lubricant system
- Compressed air
- Water tank for use with a water level
This equipment is supporting a 54” Jacking Unit that is pushing 54” steel casing for a 200’ crossing.
This 23 horsepower hydraulic power pack supported a 48” *tunnel liner* shield as it advanced itself forward off of the assembled liner plate – the tunnel was 90’ long.
Custom Power Units
Custom Bentonite/Polymer Lubrication Systems
Jacking units custom built for specific

- Pit size
- Pipe materials and lengths
- Thrust ratings
Shields custom built for specific

- Pit size
- Pipe materials
- Expected ground conditions
Tenbusch, Inc. fabricates

- Articulating tunnel shields
- Jacking units
- Hydraulic power systems
- Lubricant mixing systems
- Muck bowls, carts, and track systems for the removal of spoil.

Thank you for your time, if you have any questions,

We can be reached at

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