Underground Structures Worldwide

How Go Underground Construction Methods

Surface Tunnelling
Definition of Surface Tunnelling

- Surface tunnelling encompasses all construction methods of underground structures built by a temporary or permanent open trench in the surface.
Two Main Types of Underground Structures Built by Surface Tunnelling:

- Open Trench
- Cut-and-Cover Structures
General Construction Sequence of Surface Tunnelling

- Construction of retaining walls along the future underground structure (in competent ground, retaining walls may not be necessary)
- Ground excavation and support of the retaining walls, if needed
- Completing the underground structure
- In case of cut-and-cover, reestablishment of the surface use
Main Types of Retaining Walls:

- Steel Piles and Wood Sheets
- Diaphragm Walls (Slurry Trench)
- Tangent-Pile Wall
- Large Piles and Shotcrete Arch
Scheme of Construction Sequence of Retaining Walls
Steel Piles and Wood Sheet

- Steel piles, H shape, are pushed into the ground.
- Just after ground excavation, wood sheets are placed between steel piles, forming the retaining wall.
Diaphragm Walls (Slurry Trench)

- Trenches can be excavated by clamp shell or rotary headers
- Trenches are stabilised during excavation by bentonite slurry
- Diaphragm walls can be cast-in-place or built by pre-cast elements
Cast-in-Place Diaphragm Wall

- Trench excavation
- Stabilisation with slurry
- Placement of reinforcement bars
- Pouring concrete, from down to up, and simultaneously pumping out the slurry
Pre-Cast Diaphragm Wall

- Trench excavation
- Stabilisation with slurry
- Placement of pre-cast elements
- Grouting joints between elements
Tangent-Pile Retaining Walls

- Large pile excavation, one every two
- Concreting the first piles excavated
- Excavation and concreting of the pile in between every two (tangent or secant)
Large Piles and Shotcrete Arch

- Large pile excavation
- Placement of reinforcement bars
- Concreting large piles
- Ground excavation and simultaneous shotcreting of an arch between piles
Support of Retaining Walls are commonly done by:

- Struts
- Tie-Backs
Support of Retaining Walls by Struts:
- In diagonal for large sections
- In transversal for narrow trenches
Support of Retaining Walls by Tie-Backs:

- The shallower layer of tie-backs is usually applied by a beam for balancing loads.
Cut-and-Cover Construction Methods

- Direct Excavation
- Inverse Excavation
- Door-Frame Method
Cut-and-Cover Direct Excavation

- Surface reestablishment after completing all works
Example of the Brasilia Metro Station

- Retaining wall made with pre-cast structural elements
- Retaining wall supported by 3 lines of tie-backs
- Cut-and-cover structure by direct excavation
Cut-and-Cover Inverse Excavation

- Surface reestablishment just after completing the first-level slab of the underground structure
Cut-and-Cover Inverse Excavation

- View of the first-level slab
- View of the excavation underneath the first-level slab of the underground structure
Cut-and-Cover Inverse Excavation

- First-level slab construction
- Refill between the first-level slab and surface for reestablishment of the surface use
Door Frame Method

- This is a cut-and-cover method with a construction sequence similar to inverse excavation
- Instead of the retaining walls, foundation elements are built
- Ground excavation up to the tunnel-crown slab
- Concreting of the tunnel-crown slab
- Refill and reestablishment of the surface use
- Excavation underneath the tunnel-crown slab and completing of the underground structure
Door Frame Method
Door Frame Method – Cross-Section
Construction Sequence

**STEP 1**
- Surface
- Excavate for Roof Slab
- GWL

**STEP 2**
- Surface
- Temp. Shotcrete Sidewall Support
- Ground Water Cut-Off Walls

**STEP 3**
- Surface
- Concrete Roof Slab (Doorframe)

**STEP 4**
- Surface
- Pipes to Pumping Station
- GWL
- Backfill
- De-watering Wells
- Recharge Well

**STEP 5**
- Waterproofing System
- Shotcrete Lining

**STEP 6**
- Final Lining
Door Frame Method – Longitudinal Construction Sequence
Brasilia Metro – Taguatinga Tunnel