Foundation Construction

- Shallow Foundations:
  - consisting of footings or rafts foundation sized to control settlement and provide adequate margin of safety against shear failure in the foundation soil

- Deep Foundations:
  - piles and piers used to bypass unsatisfactory soils and transfer structure loads to a suitable bearing stratum
Excavations and Excavation Supports

- In many construction jobs deep excavations must be made before the structure can be built.
- When excavations have the potential to endanger lives or adjacent properties, bracing to support the soil must be designed.
- The Occupational Safety and Health Act (OSHA) requires that all trenches exceeding 5 feet in depth be shored.
- In large construction areas, excavation walls may be sloped, instead of providing structural support.

Slope Protection

- Temporary slope protection should be provided to prevent sloughing of soil materials into the excavation, such as coating or other impervious material applied to the slope.
- To prevent slope erosion in rainstorms, spray-on product are used on silty soil materials to bind the soil particles on the surface.
Slope Protection (Cont’d)

- Plastic covering can be used to prevent changes in moisture content on the surface of the slope to maintain stability.
- Chain link fence can be draped over a slope surface, when the slope contains significant amount of loose large rocks.

Shallow Trenches

- Cross-trench bracing are used in utility trench excavations.

Intermittent sheeting and bracing

Continuous sheeting and bracing

Trench shielding
Shallow Trenches

- Cross-trench bracing are used in utility trench excavations.

Deep Cuts

- Excavation depths exceeding 10 to 20 feet, require specialized planning for support.
- Lateral earth pressure is proportional to the vertical pressure.
- As a cut is made, the soil at the face tend to expand and move into the cut area.
- If a support is placed against the excavation surface to prevent the soil movement, then the pre-excavation stress is maintained.
Excavation Support Methods

Soldier beam and lagging

- Pairs of soldier beams are driven to a depth slightly below the final excavation.
- Their spacing is in the order of 6 to 12 ft so that available timber can be used for lagging.
- The lagging timber, which is slightly shorter than the spacing but on the order of 2 to 4 in. thick, are installed behind the front flange to retain the soil as excavation proceeds. Some hand excavation is usually required to get the lagging into the place.

- Soldier piles are installed with conventional pile-driving equipment or in augured holes.
- The horizontal sheeting or lagging is installed behind the flange closest to the excavation (inside flange).
- The sheeting can be installed on the inside face of the front flange and held in place by various methods such as clips, welded studs, or bars, etc.
Temporary Structures

Excavation Support Methods

**Soldier beam and lagging**
- The soldier pile and lagging method is inappropriate for perfectly cohesionless soil.
- For cohesionless soils sheeting must be used.

Workers install lagging

The soldier beam and lagging retaining wall
Temporary Structures

Excavation and Excavation Support

Excavation Support Methods

**Soldier beam and lagging**

Soldier beam and lagging retaining wall

Closeup of soldier beam and lagging

Tiebacks

- Tiebacks (or anchors) are structural system which acts in tension and receives its support in earth or rock.
- The system consists of:
  - The earth or rock, which provides the ultimate support for the system
  - A tension member (or tendon) which transfers the load from the soil-retention system to the earth or rock.
  - A stressing unit which engages the tendon, permits the tendon to be stressed, and allows the load to be maintained in the tendon.
Tiebacks

- Earth anchors are usually installed at an angle of 10 to 20° down from horizontal.

- If the acceptable soil is not encountered at these levels, it is necessary to change the angle to engage the proper soil stratum.

Anchors or tiebacks eliminate obstructions in the excavation inherent in rakers or struts.
Temporary Structures

Excavation and Excavation Support

**Tiebacks**

- They consist of rods that extend well beyond any potential failure surface into firm undisturbed soil or rock.
- Some tiebacks are made with high tensile cables grouted into rock and pre-stressed against a wale, and others utilizing ordinary steel rod or reinforcing steel.

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**Tiebacks**

- Tieback systems are generally very successful in preventing movements of the excavation walls.
- Usually, the excavation wall is left in place after the permanent construction inside the braced excavation is complete. Its is often used as the back form for the permanent basement of the structure.
Temporary Structures

Excavation and Excavation Support

**Tiebacks**

- Tiebacks, if left in place, are always cut to relieve tension when the permanent structure can safely carry the load.

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This is a 63-foot deep tiedback excavation. The subsurface material through which this major excavation was installed consisted of 25 feet of medium dense to dense sands and gravel, underlain by very dense sand, gravel and cobbles (SGC). The SGC contained a large percentage of cobbles up to 18 inches in diameter. The job consisted of 62,000 square feet of shoring and 500 tiebacks.
Soil Nailing

- Soil Nailing is an insitu reinforcing of the soil while it is excavated from the top down.
- An array of soil nails which are passive inclusions are installed in a grid that functions to create a stable mass of soil.
- This mass of reinforced soil functions to retain the less stable material behind it.
- In the right soil conditions, soil nailing is a rapid and economical means of constructing excavation support systems and retaining walls.

Soil Nailing

- In many applications soil nailing can be the least disruptive way to construct a retaining wall.
- Soil nailing requires an unusual amount of hand work, craftsmanship and geotechnical knowledge to construct.
- The typical construction sequence begins with the excavation of a shallow cut. Then shotcrete is applied to the face of the cut and soil nails are drilled and grouted. This sequence is then repeated until subgrade is reached.
Soil Nailing Examples
*NorthWest Animal Facility, UC Berkeley, Cal*

Construction of an underground laboratory at the UC Berkeley, required temporary shoring on all four sides of the excavation. The tolerances for the shoring was specified to be no more than plus or minus one inch. The excavation depth varied from 15 to 37 feet, and was constructed in colluvial soils, consisting of stiff sandy clays and dense clayey sands with gravel and some cobbles. Approximately 14,000 square feet of area was soil nailed.

Soil Nailing Examples
*Chemistry Building, WSU, Pullman, WA*

The 40-ft deep excavation at this site was made in stiff to hard, slightly clayey silt, with standard penetration resistances ranging from 15 to 45. The silt had a cohesion of 200 psf and a friction angle of 28 degrees. At one corner of the site, a two story brick auditorium was located ten feet behind the soil nailed wall. The movement was less than 0.3 inches at the face of the wall, less than 0.2 inches at 18 feet behind the wall, and less than 0.1 inches at 36 feet behind the wall. Eight rows of soil nails were designed to support the excavation.
Soil Nailing Examples

*The Beckman Center, UC San Diego, Cal*

Construction of the New Chemical Science Building at the Scripps Research Institute required an excavation of up to 57 feet deep. The job consisted of 75% soil nailing and shotcrete and 25% of soldier beam and tieback shoring - a total of 24,080 sq ft. The soldier beams and tiebacks were utilized where soil nails would have interfered with existing buildings and new or existing utilities. The deepest section was shored with 10 lifts of permanent soil nails. A permanent shotcrete facing was installed in front of the shoring system which was completed in ten weeks.

Excavation Bracing

- For narrow excavations, internal struts are most appropriate.
- Before struts are installed, a horizontal member called waler is placed against the soil support.
- Intermediate struts are then installed from waler to waler across the excavation.
- Cross-lot struts are not feasible for very wide excavations.
Excavation Bracing

Design of excavation bracing for a pump station adjacent to an active spring.

Excavation Bracing

Design of excavation bracing for a detention basin and related piping.
Excavation Bracing

- For very wide excavations, *raker bracing* is used.
- The support for the rakers (driven piles or footings) are installed at the bottom of the excavation.
Soldier Pile - Tremie Concrete (SPTC)

- SPTC is used for very difficult conditions in soft ground with a high water table.
- Soldier piles are set in predrilled holes, and the space between flanges of adjacent soldier piles is excavated and filled with bentonite slurry.
- Reinforcement is lowered into the trenches and tremie concrete is placed. As tremie concrete displaces the slurry, it is collected and recycled for future use.
- The final product is a continuous concrete wall beneath the ground surface prior to excavation. After completion of the wall, excavation and interior bracing can begin.
Temporary Structures

Excavation and Excavation Support

Soldier Pile - Tremie Concrete (SPTC)

Typical free-hanging mechanical clamshell for slurry trench excavation

Slurry Trench Method

free-hanging mechanical clamshell
Temporary Structures

Excavation and Excavation Support

Slurry Trench Method (Cont’d)

- Used in cases of troublesome dewatering and excavation support problems.
- It involves constructing an impervious barrier beneath the ground surface.

The excavated material is replaced with heavy clay slurry (the lateral pressure from the slurry will keep the trench open)

- After the excavation is completed, concrete placement follows using tremie concrete method, from bottom to the top of excavation.
- As tremie concrete displaces the slurry, it is collected and recycled for future use.
- When the concrete is cured, the construction site is enclosed within a rigid, impervious barrier.
- This method has been employed to depths exceeding 200 feet.
**Tremie Concrete**

- Underwater concrete plays an important role in the construction of offshore structures.
- It may be used to tie together various elements in composite action (i.e., to tie piling to the footing).

**Tremie Concrete Mix**

- Special mix with plasticizer
- High slump concrete with set retarders
- Smaller aggregate sizes
- Four-hour workability
- Designed for placement under water via tremie pipe
Temporary Structures

Excavation and Excavation Support

Tremie Concrete

Underwater Concrete Mixes:

- **Structural concrete**
  - **Coarse Aggregate**: Gravel of 3/4” max. size. Use 50-55% of the total aggregate by weight.
  - **Fine Aggregate**: Sand, 45-50% of the total aggregate by weight.
  - **Cement**: Type II ASTM (moderate heat of hydration), 600 lbs/yd³.
  - **Pozzolans**: ASTM 616 Type N or F, 100 lbs/yd³.

Tremie Concrete

- **Water/Cement Ratio**: 0.42 (0.45 Maximum).
- **Water-Reducing Admixture** (preferably it is also plasticizer): Do not use superplasticizers.
- **Air-Entrainment Admixtures**: To give 6% total air.
- **Retarding Admixture**: To increase setting time to 4-24 hours, as required.
- **Slump**: 6 1/2 in. ± 1 in.

- This mix will develop compressive strength in the range of 5,600 – 7,000 psi at 28 days.
- It will flow out on a slope of 6:1 to 8:1 horizontal/vertical and, if properly placed, should give nominal segregation and laitance.
**Temporary Structures**

**Excavation and Excavation Support**

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**CM 420**

**Temporary Structures**

**CM 420**

**Tremie Pipe**

*Breaking Tremie Tube* - In this operation the contractor is removing a 20' section from the 140' + tremie tube to continue the first full depth placement in the UR pylon. Concrete placed will be about 400 CYs.

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**CM 420**

**Temporary Structures**

**CM 420**

**Tremie Pipe**

Transition of the pipeline from vertical to horizontal.
Placement of Tremie Concrete

- The placement of tremie concrete is carried out through a tube, usually 10- to 12-inch pipe.
- The pipe may be sectional but joints should be flanged and bolted, with soft rubber gasket, so as to prevent any in-leakage of water.
- The tremie pipe must have sufficient wall thickness so that it negatively buoyant when empty.

Install a steel plate on the bottom end with a soft rubber gasket. The plate is tied with twine to the pipe.
Placement of Tremie Concrete

- The placement is started by placing the sealed pipe on the bottom and then partially filling it with the tremie concrete mix.
- When tremie has been filled to a reasonable distance (distance required to overcome the frictional head $\approx 1-2 \text{ m}$) above the balancing head of fresh concrete versus surrounding liquid, the pipe is raised 150 mm, allowing the concrete to flow out.
- The lower end of the pipe is kept embedded in fresh concrete, but no deeper than where the concrete has taken the initial set (with retarder to prevent the initial set, the depth of embedment becomes less sensitive).

- The tip of the tremie pipe should always be immersed about 1 meter as a minimum so as to prevent water inflow into the pipe.
- The flow of concrete should be smooth, consistent with the rate at which concrete can be delivered into the hopper at the top.
- The method of delivery should provide relatively even feed to the hopper rather than large batches being suddenly dumped.
- When large areas are to be covered, multiple tremie pipes should be used.
- The distance tremie can flow without excessive segregation is between 6 and 20 meter.
**Placement of Tremie Concrete**

**Tremie Concrete - Application**

- Tremie concrete procedures was used to repair damage to a reef in the Florida Keys caused by vessel impact.

- The impact site was located in six to ten feet of water off Miami, in a region of the reef frequented by sight-seeing boats and recreational divers. The ship impact destroyed the living surface of the reef over an area of approximately 50-ft by 70-ft, forming a shallow crater in the reef.

  Diver Places underwater tremie concrete between reef units and bottom. Bottom of the barge can be seen just a few feet above the diver's head.
Glossary of Terms

- **Waler**: Horizontal timber used to hold close sheeting in position.
- **Lagging**: Lengths of sawn hardwood timber planks used to support the sides, walls or roof as necessary of shafts and drives and to prevent material from those faces falling into the excavation. The term is also sometimes used when referring to the layer of poling boards doing the same duty in trenches. The lagging is supported in turn by walkings, legs, caps, sets or frames, as applicable. (See also "lathes" below).
- **Lathes**: Short lengths of hardwood timber usually split and about 1.25 to 1.5 meters long used to support the side walls (and roof in drives) and supported in turn by walkings, legs or caps as applicable.
- **Strut**: Hardwood timber (usually horizontal) in compression resisting thrust or pressure from the face or faces of an excavation.
- **Soldier**: Vertical upright hardwood timber used for supporting a trench wall, taking the thrust from horizontal walers and supported by struts.

Slurry Trench / Diaphragm Walls

- In recent years, the slurry trench method has been successfully developed to deal with particularly troublesome dewatering and excavation support problems.
- These methods involve constructing an impervious barrier beneath the ground surface.
Slurry Trench / Diaphragm Walls

Questions?

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