Civil Engineering Construction I (CBE5031) Basement
1.1 Problems arising from basement construction
   a) Excavation method.
   b) Surface and ground water control
   c) Lateral stability of basement excavation.
   d) Stability of adjoining building.

1.2 Ground water control - dewatering
   a) Open Sump Pumping
   b) Wellpoint System.
   c) Shallow-Bored Well System
   d) Deep-Bored Well System
1 Quick Revision

1.3 Basement Excavation

a) Open excavation

b) Sheet pile cofferdam
   • Supported with raking struts
   • Supported with struts and wallings
   • Supported with ground anchors
Ground support and ground water control for deep excavation

Cut off wallings:

a. Thin grouted diaphragge
b. Mixed in place wall
c. Ground treatment
d. Circular cofferdam
e. Diaphragge wall
2. Cut-off wallings

2.1 Thin grouted diaphragm

- A series of touching universal beams or columns are driven into the ground to the required depth.
- A grout injection pipe is fixed to the web the section and this is connected to a group pump at the ground.
- As the sections are withdrawn the void created is filled with cement grout to form the thin membrane.
- This is a non-structural wall and services only as a cut-off wall.
- It is suitable for subsoil of silt, sand and gravel.
2. Cut-off wallings

Thin grouted diaphragm (Source: R. Chudley)
2.2 Mixed-in-place wall

- A hollow churn drill is drilled into the ground.
- Intrusion grout is pumped through the hollow kelly bar during the drilling operation.
- When the required depth is reached, the auger rotation is reversed and withdrawn while grout injection continues.
- The grout is mixed with the existing soil to form a mixed-in-place pile.
- The above process is repeated with the piles
2.2 Mixed-in-place wall

Mixed-in-place pile
(Source: Jufri & Wellmen)
2.3 Ground treatment

- The major disadvantage of pumping is causing settlement of surrounding ground.
- In urban areas, settlement would seriously affect the stability of adjacent properties.
- In this situation, grouting method can be used to control ground water.
- The basic method is to inject the soil or rock with fluids which, on setting, seal or reduce the permeability of the material.
- There are various types of grouts.
- The choice of grouts, the pattern and spacing of the injection pipes will depend upon the particle sizes of the soil or the size of fissures in the rock.
2.3 Ground treatment

**Cement Grouting** (Source: R. Chudley)
2.3.1 Ground treatment

• Cement grout is suitable for injecting into coarse materials which have a high permeability.

• This method not only can form an impermeable barrier to ground water but also solidify loose soils which prevents from collapsing during excavation.

• It is usual to commence grouting with a batch of thin grout and then to increase the viscosity of the grout as the process continues, by reducing the water-cement ratio.
2.3.1 Ground treatment

- The grout used may be composed of neat cement grout, or a mixture of cement and sand in the ratio of $1 : 4$.
- The adding of sand reduces the cost of material but it also reduces the workability.

- pulverized fuel ash (PFA) may be used to replace part of the cement (up to 50%) to reduce the cost of the material.
- The spherical particle shape of PFA improves the flow quality of the grout without reducing its strength.
2.3.3 Silicate grouting

- two main processes of silicate grouting: ‘
  - one-shot’ and ‘two shot’.
- In the ‘two-shot’ process, pipes are driven into the ground at about 600 mm centres, and the first chemical, sodium silicate, is injected.
- This is followed immediately by the injection of the second chemical, calcium chloride.
- The reaction between the two chemicals resulting in a tough, insoluble ‘silica-gel’.
- The process gives considerable strength to the soil and greatly reduces its permeability.
2.3.3 Silicate grouting

• ‘two-shot’ process superseded by the ‘one-shot’ process, which consists of mixing together prior to injection two chemicals whose gel time can be sufficiently delayed to allow full penetration of the soil before gel occurs.

• The extent of the delay can be accurately controlled by varying the proportions of the two chemicals.

• The extra time available for placing this grout allows wider spacing of the boreholes.
2.3.3 Silicate grouting

Two-shot process for chemical grouting
3. Circular cofferdam

- Steel sheet pile cofferdams may be arranged in circular shape in plan.
- Circular cofferdams are supported with ring walings.
- The walings are subject to tangential thrust and act as a continuous arch hence transverse struts are not required.

- Large diameter circular cofferdams may be formed by concrete diaphragm wall and reinforced with ring concrete beam.
- advantage of this method is that it provides a clear excavation un-hampered by struts.
- the method is restricted to circular shape
3. Circular cofferdam

Sheet pile circular cofferdam
Support with ring walings

R.C. circular cofferdam
(Basement construction of IFC)
4. **Diaphragm Walls**

- Diaphragm walling describes the construction of continuous concrete walls into the ground.

- The process, sometimes called the slurry trench method, involves the excavation of a narrow trench to the required depth which supported with bentonite slurry.

- The trench is then filled with concrete to form the wall.
4.1 Reinforced Concrete diaphragm wall

4.1.1 Construction procedures of cast-insitu concrete diaphragm wall:

1. A perimeter trench, 1 to 1.5 m deep and with a width equal to the wall thickness plus 300 mm is excavated.

2. The trench is lined on both sides with 150 mm thick in-situ concrete. (The linings provide a guide for the grab and protect the top of the excavation from collapse.)
4.1.1 Construction procedures of cast-insitu concrete diaphragm wall:

3. Wall is divided into panels of about 4.5 to 7 m width each

- The sequence of construction for the panels is in an alternatively way.

- That is, an intermediate panel is excavated after panels on its both sides have been cast.
4.1.1 Construction procedures of cast-insitu concrete diaphragm wall:

4. The trench is then filled with bentonite slurry from a large storage tank before excavation.

- Excavation is done by a grab.
- During excavation, it is important to maintain the slurry level at about 0.5 m below the top of the trench.

- The function of the bentonite is to prevent the ingress of water and soil into the trench.
- Excavation is continued until the founding is reached.
4.1.1 Construction procedures of cast-insitu concrete diaphragm wall:

5. Stop end pipes of diameter equal the wall thickness are placed at both ends of the panel.

   – A reinforcement cage is lowered through the bentonite and panel is cast with tremie concrete.

   – The displaced bentonite is recovered, strained to remove the soil particles and then stored for future use.
4.1.1 Construction procedures of cast-insitu concrete diaphragm wall:

6. When the concrete has set, the stop end pipes are removed.
   - Semi-circular sockets are formed which provide key for the adjacent panels.

7. Further panels of the diaphragm wall are then formed in a similar manner until the wall is completed.
4. **Diaphragm Walls**

Construction of diaphragm wall

*Source: R. Chudley*
4.1.2 Precast Concrete Diaphragm Walls

Diaphragm walls can also be formed with precast concrete panels. The construction sequence is:

1. A perimeter trench, lined on both sides with concrete walls, is prepared.

2. The trench is filled with bentonite slurry and excavated with a grab.
   - During excavation, the slurry level is maintained at about 0.5 m below the top of the trench.
   - Excavation is continued until the founding is reached.
4.1.2 Precast Concrete Diaphragm Walls

3. Cement grout is introduced to the bottom of the trench with a spreader.
   - The displaced bentonite is recovered, strained to remove the soil particles and then stored for future use

4. Precast posts or panels are inserted into the trench to form the wall

5. When the grout has set, it seals the joints of the precast panels effectively, and the diaphragm wall is formed.
4.1.2 Precast Concrete Diaphragm Walls

Precast Concrete Diaphragm Wall
(Source: R. Holmes)
4.2 Advantages of using diaphragm walls for basement construction

1. The process of constructing the wall is relatively quiet and has little vibration.
2. The wall can be constructed to a great depth.
3. The wall provides temporary ground supports during excavation hence expensive steelwork is eliminated or minimized.
4. The wall provides a good water cut-off; no dewatering is required and hence has little effects on adjacent structure.
5. The wall serves both as external wall for the basement and the foundation for the superstructure.
6. For deep basement, diaphragm walling is more economical than using steel sheeting cofferdam.
5. Soldier pile wall

- The wall of a basement must be watertight.
- A soldier pile wall is used as a basement wall, the piles of the wall will be constructed to overlap with each other, known as a secant pile wall.
- Overlapping is about 120 to 200 mm and is cut by a hydraulic actuated casing fitted with a cutting ring at the lower end.
- The cutting must be done within one or two days after the concrete has been cast to prevent it from becoming too hard.
5. Soldier pile wall

Secant pile wall
5. Soldier pile wall

- Alternatively, the piles of the wall are cast contiguous.
- Boreholes are drill at the joints of the piles which cut the edges of the piles.
- The boreholes are then filled with bentonite-cement grout to seal the joints.

Secant pile wall (Source: R. Chudley)
6. Top-Down Basement Construction

It is to construct the basement in the downward direction to the final levels of the basement. The sequence of work is as follows:

1. Construct the permanent basement wall using diaphragm wall or soldier piles wall.
2. Construct bored piles with temporary steel casings as the foundation of the basement. The cut-off level of the piles is at the final basement level.
3. Place steel columns inside the steel casings of the bore piles from the foundation level up to the ground level.
4. Backfill the shafts with granular material to hold the steel columns.
6. Top-Down Basement Construction

5. Construct the ground floor slab supported on the steel columns and the diaphragm walls.
   – (This slab provides a working platform for superstructure construction and acts as the lateral support for the basement excavation.)
   – Access opening in this slab shall be provided for further excavation.

6. Excavate beneath the ground floor slab down to next basement floor soffit.

7. Cut the steel casing, remove the gravel and expose the steel column.
6. Top-Down Basement Construction

8. Cast the second basement slab.
   – (The slab is connected to the columns with shear studs and connected the diaphragm wall with dowels)

9. Repeat the process for the successive basement floors until down to the final basement slab.
6.1 Main Advantages

1. Superstructure can be constructed at the same time as the basement construction takes place and therefore the overall construction time is reduced.

2. Temporary and permanent works are combined and therefore there is no need for extensive steel temporary works.

3. Stiff rigid walls allow an almost watertight construction and basement construction to great depth. These stiff walls provide at the same time a limitation to ground movement.
6.1 Main Advantages

Operation no. 1
Form guide trenches and construct perimeter reinforced concrete diaphragm wall. Install 2.3m dia steel cylinder casings through the gravel and obtain a seal into the clay. Auger and install smaller diameter steel cylinders in the clay down to founding level. Auger shafts below this level and form bolls. Place cylinder reinforcement and concretise the bolls and shafts. Erect structural steel columns.

Operation no. 2
Concrete the shafts from base plate level of steel columns to level of the soffit of the lowest suspended floor. Backfill the shafts with granular material.

Operation no. 3
Excavate ground surface to soffit of roof slab. Construct roof slab on ground.

Operation no. 4
Excavate to next floor level. Cut away steel cylinders and remove gravel filling. Construct floor slab on prepared ground surface.

Operation no. 5
Continue this procedure on successive floors downwards.
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