The Construction of Deep and Complex Basements and underground structures within extremely difficult urban environment

Presented by

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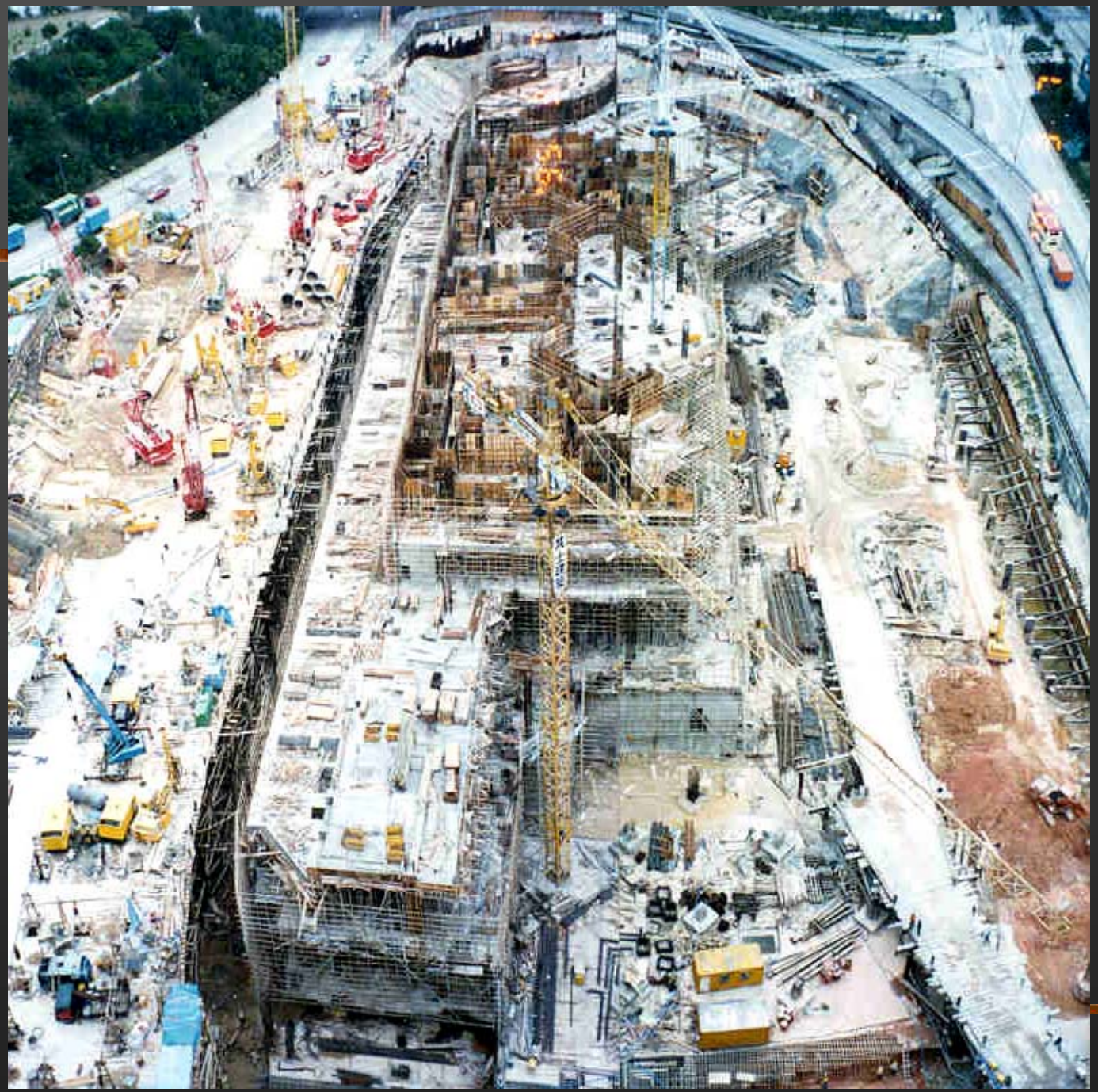
Attributes that affect the construction of deep basement:

1. Size of a site
2. Volume of work
3. Shape and Typographical conditions of site
4. Neighbourhood conditions of a site
5. Geotechnical conditions
6. Internal layout of the basement or other related structures
7. Availability of resources for the project
8. Availability of expertise skill
9. Appropriateness of the methods selected for the construction

Examples of projects – working in close proximity of sensitive and unstable slope

Hollywood Terrace

Belcher's Garden



Example of very large-scale project – the Hollywood Plaza

Basement Project in very congested urban environment – the Redevelopment of Kwong On Bank in Queen's Road Central, Central District, Hong Kong

Work in close proximity to seawall

Work in extremely small site

Examples of very difficult environment for constructing basement

Complicated soil support arrangement

Large-scale basement project involved very complex phasing planning

Festival Walk

Royal Peninsula

Attributes that affect the construction of deep basement (Cont.):

10. Special performance requirements imposed

- Complete the whole or part of the work at a prescribed time or at stages for handing back to the client.
- Protect some facilities according to prescribed requirements during the course of work.
- Coordinate with some other contracts or contractors to have related works carried out in the same or in close proximity of site.
- The nature of work required exceptionally high quality or accuracy in performance.
- Very high liquidated damages requirements is imposed in the contract.

Besides, there are situations like:

- where a new basement is required to construct simultaneously to replace an old one.
- working under very fast-track schedule.
- some basement works need to be carried out at the same time with the new foundation or even with part of the future superstructure.

This situations will create very difficult coordination problems that involve various contractors and complicate the contractual position of the entire job..

Complicated phasing arrangement in constructing the basement of Lee Garden

The Center - Foundation and Basement construction arrangement

Complicated contract interfacing situation – Construction of the MTR Tung Chung Station and the nearby advanced works

Tung Chung Station and its associated advanced work

Underpinning to a pedestrian footbridge for the KCR East Rail TST Extension

Underpinning to support piers of elevated roadway of Tun Mun Highway at Chai Wan Kok, Tsuen Wan

Underpinning/temporary support for a pedestrian footbridge at Connaught Road, Central

Underground services encountered during excavation

Construction of the TST East Station,
KCR East Rail TST Extension

Complicated surrounding environment as seen in the TST East Station – shoring to protect the existing multi-storey carpark at Middle Road

Complicated surrounding environment as seen in the TST East Station – underpinning to a section of pedestrian subway

Common managerial problems identified in the construction of deep basement:

1. Very expensive and time consuming in nature, often involved huge amount of work resources.
2. Inconsistent and sensitive to the quality of planning and management of individual projects.
3. Works are highly hazardous, both to human operatives working within and the life and properties of third parties that within the vicinity.
4. Works involved a lot of managerial challenges. Such as, in the preparation of a highly efficient working programme, monitoring and rectifying the progress of works in case problems arising, or in resources planning where materials, labours & plant equipment are involved.

There are many methods to construct large-scaled and deep basement

1. Deep basement can be constructed using some traditional ways such as cut & fill or bottom up methods. These methods are relatively economical and effective when dealing with certain jobs which are simpler in nature.
2. On the other hand where basement is going deeper and the surrounding environment getting more complex and sensitive, bottom up or combined method may be a more appropriate option to construct.

Construction of basement using traditional bottom-up arrangement

Church for the Witness of the Christ Project

Redevelopment of the Lee Theatre

Example of very large-scale and complicated project – the Hang Hau Station of the MTR Tseung Kwan O Line

Example of very large-scale project – the Kowloon Station of the Airport Railway

Other considerations when doing basement works

- Accurate cost analysis or work study is difficult to carry out for there is limited commonality to make comparisons.
- Every project, though look relatively similar from certain indicating factors, is in fact unique in itself.
- A great number of random and uncontrollable variances are likely to arise during the courses of work. This makes planning and scheduling almost cannot be exact.
- The actual effectiveness of works is highly depended on the as-constructed site environments.
- Quality of the management and the executing parties, as well as the problems solving ability of the frontline personnel, also seriously affects the performance and effectiveness of works.

Commonality found in recent basement projects

- Recent basement projects are usually very deep (below 20m) and very big in size (say up to 10,000m^2)
- Majority of the basements are constructed in a top-down manner. Some other methods such as combining top-down and bottom up, or combining open-cut and top-down arrangement, can sometimes be seen.
- Complicated coordination problems and teething arrangement often exist between various major contracts or other major building works.
- Layout planning especially in phasing and sectioning of the job forms a very important consideration mastering the success of the project.

An extremely large-scale and complex project – Construction of the International Finance Centre Phase II

(Top-down for the podium portion and bottom up for the building core portion)

Examples of very complicated phasing arrangement during the basement construction

Festival Walk

Lee Gardens Redevelopment

Commonality found in recent basement projects (Cont.)

- Dynamic layout arrangement is usually required for the removal of the excavated spoil from the basement. This may involve the forming of temporary ramp, provision of special equipment, or the taking over of part of the completed building as temporary access in an advanced stage.
- Diaphragm walling is the most common cut-off provision being used.
- System formwork can hardly be applied for most basement jobs due to access problems as well as the confined working condition inside the excavated.

Special arrangement for the removal of spoil to facilitate basement excavation

Commonality found in recent basement projects (Cont.)

- Constructing the basement in “double bit” arrangement is becoming common.
- Protection and safety measures in particular to the life and property of third parties are highly concerned in basement jobs. Accident in this area is maintained at a relatively very low rate.
- Progress of work can hardly be predicted or monitored accurately due to the existence of numerous unforeseeable problems during the construction process

Basement construction using “Double Bit” arrangement – i.e. excavate two levels of basement, form the lower slab and fill in the intermediate level at a later stage

Construction of Deep Basement and Large-sized Underground Structures

Examples of underground structures include:

- Basement of buildings
- Semi-basement with slope stabilization purpose
- Transport facilities such as railway station, tunnel and pedestrian subway
- Access or services shaft

Construction of Deep Basement and Large-sized Underground Structures

Involvement/provision when constructing these structures

- Ground stabilization provisions
- Cut-off walling provisions
- Lateral soil support provisions
- Excavation arrangement
- Dewatering arrangement
- Spoil removal arrangement
- Basement construction arrangement

Ground stabilization and cut-off provisions

Grouting as a common form of soil stabilization method

Soldier pile wall constructed as a means of cut-off walling

Ground stabilization
and cut-off provisions

Caisson wall

Lagged bore-pile wall

Two means of lateral support for excavation

Using steel strut

Using ground anchor

Excavation arrangement

Excavation in section as in congested site

Excavation in benched arrangement for open site

Dewatering arrangement

Active dewatering method
using suction type well point

Passive dewatering
method using sump pit

Soil removal arrangement

Removal of excavated spoil using grab mounted on gantry crane

Removal of spoil using excavating machine placed on staged platform

Methods for basement construction

Basement or similar underground structures can be constructed using the following approaches:

1. Open cut arrangement
2. Bottom-up arrangement
3. Top-down arrangement

Construction of basement using open-cut approach

- suitable for site with abandon of unobstructed working space

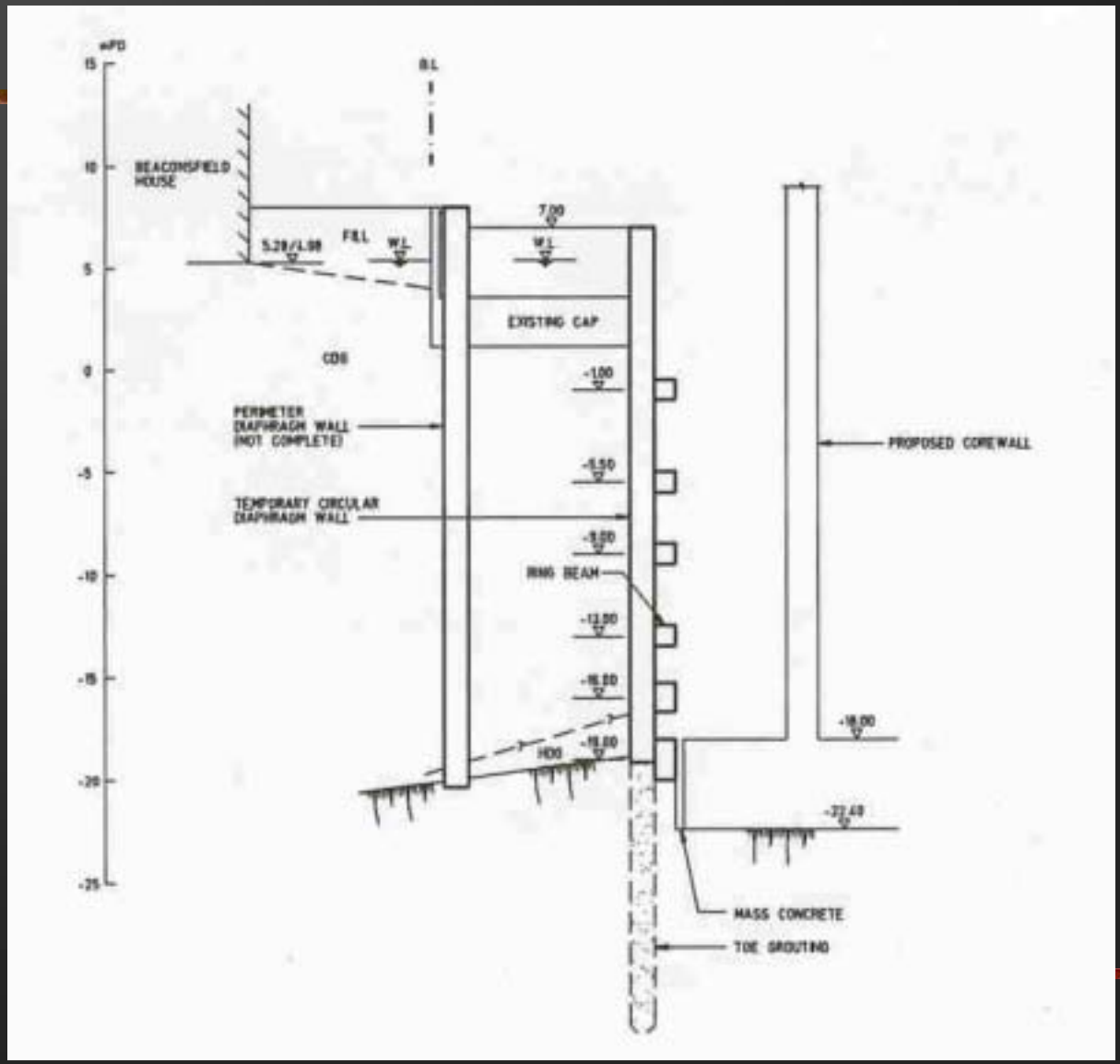
Open-cut arrangement for the Kowloon Station of the Airport Railway

Construction of basement using Bottom-up approach

- suitable for basement of small to medium size

The Witness of the Christ Church project in Kowloon Tong

Construction of basement using Bottom-up approach



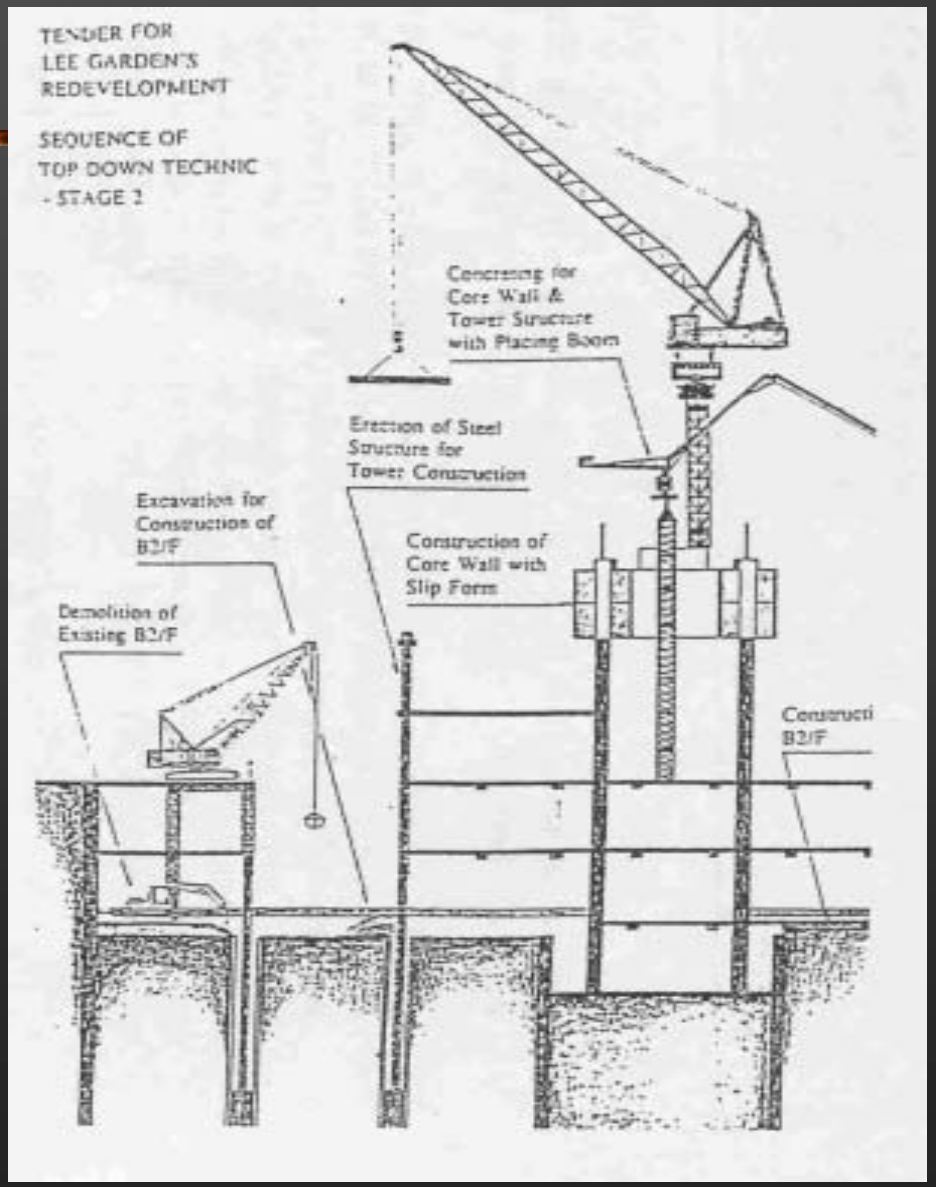
Typical arrangement shown in section

Construction of basement using Top-down approach

- suitable for basement of very large size with complex environment

Typical Top-down arrangement as in Pioneer Center (left) and Cheung Kong Center projects

Construction of basement using Top-down approach



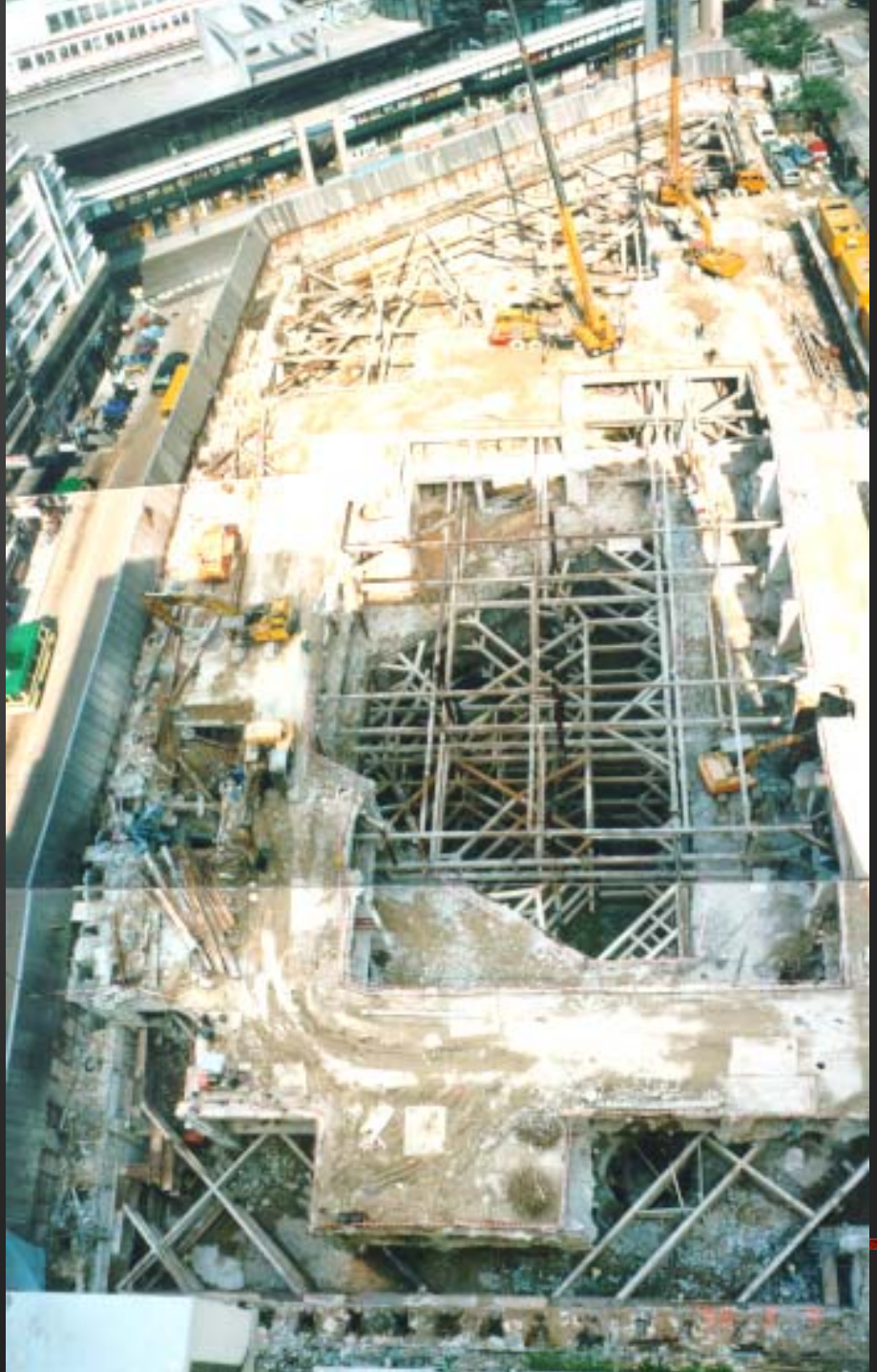
Typical arrangement shown in section

Compare the features of various basement construction methods

	Open-cut	Bottom-up	Top-down
Size of site	Very large open site	Small sized site	Large sized site
Site environment	Unobstructed	Adaptable to most environment	Adaptable to most complex environment
Protection	Simplest protection	Complex lateral support required	Limited shoring support where req'd.
Special provision	Not much	Not much	Temporary vertical support required
Machine suitable	Large machine	Small machine	Large machine
Spoil removal	Using ramp	Staged platform or bucket	Ramp, vertical shaft or bucket

Project Case 1 – Redevelopment of Lee Garden's Hotel

- Site area 5,750 m^2
- the project required to demolish the 22-storey Lee Garden Hotel, with a 2-level basement structure in it. A new 50-storey office building together with a 4-level basement will be built.
- All the new foundations and the required ground strengthening and permanent basement supporting works had to be carried out in the old basement before it was demolished.
- The old basement could only be demolished in small sections to allow for room and to cope with other associated works.
- When part of the basement was demolished and cleared, temporary or sometime permanent supporting structures have to be built as soon as possible to infill the void until the old basement was completely replaced by the new.
- Provisions were made for the construction of the future building including the central core in RC and part of the new basement constructed in top-down manner.



Demolish the central part of the old basement and excavate further down to form a pit to construct the raft for the core wall of the new building

Demolition extended to the outer portion of the old basement and raft foundation in the centre for the core wall proceeded

80% of the old basement structure being demolished, cut-off wall being completed, and steel columns for the new tower erected in position

Close up view seeing the construction of the new core wall from the completed raft foundation. Demolition to the remaining portion of the basement in progress

Shoring arrangement at the central pit
where the new raft foundation was located

Forming the new ground floor slab and the demolition of the remaining portion of old basement took place at the same time

Construction of the new basement slab to replace the old basement structure in phases

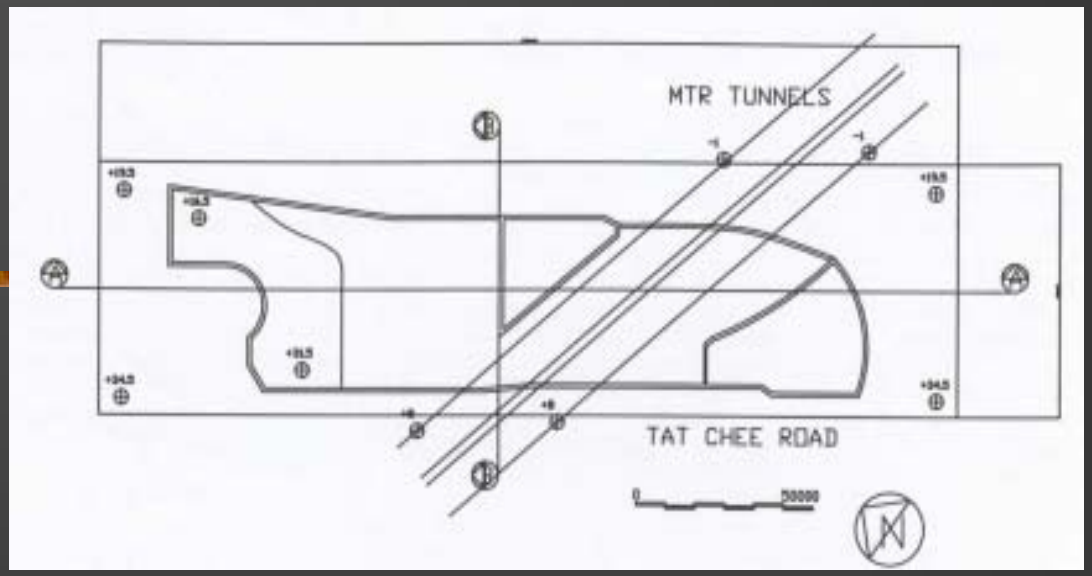
Superstructure and basement construction at the same time

Excavation inside the top-down basement

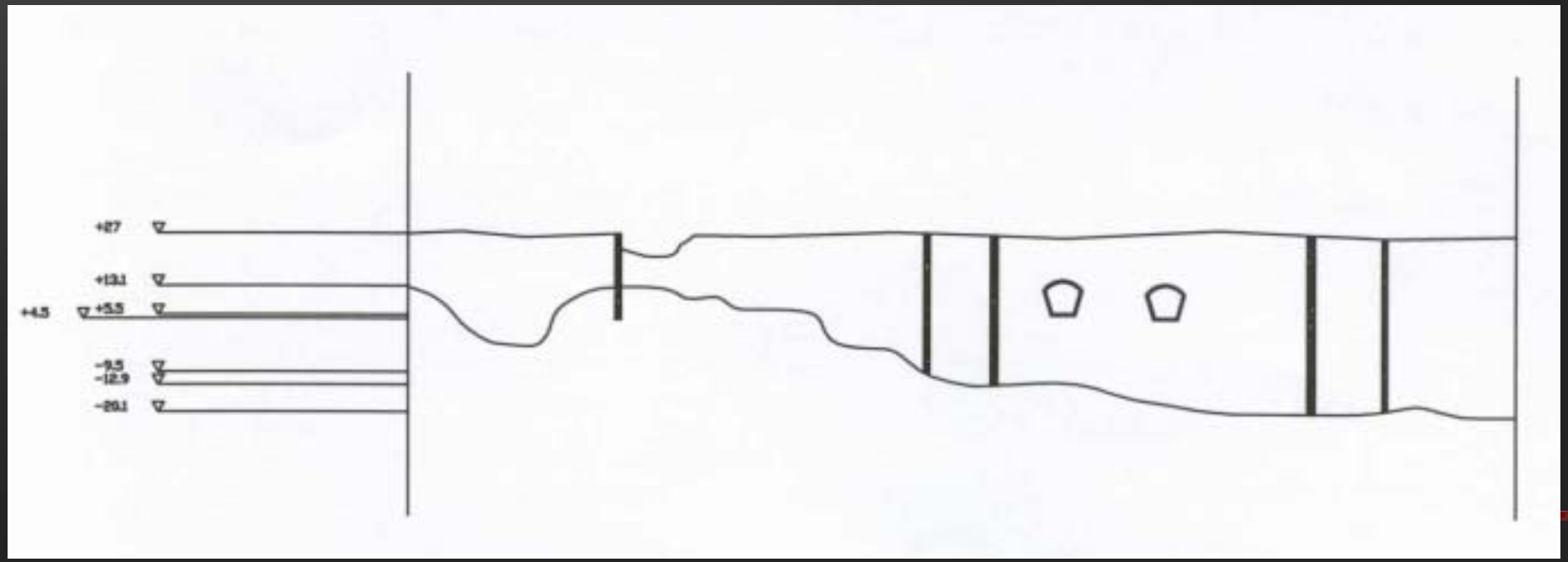
Forming the ground beams at the formation level of the lowest basement level

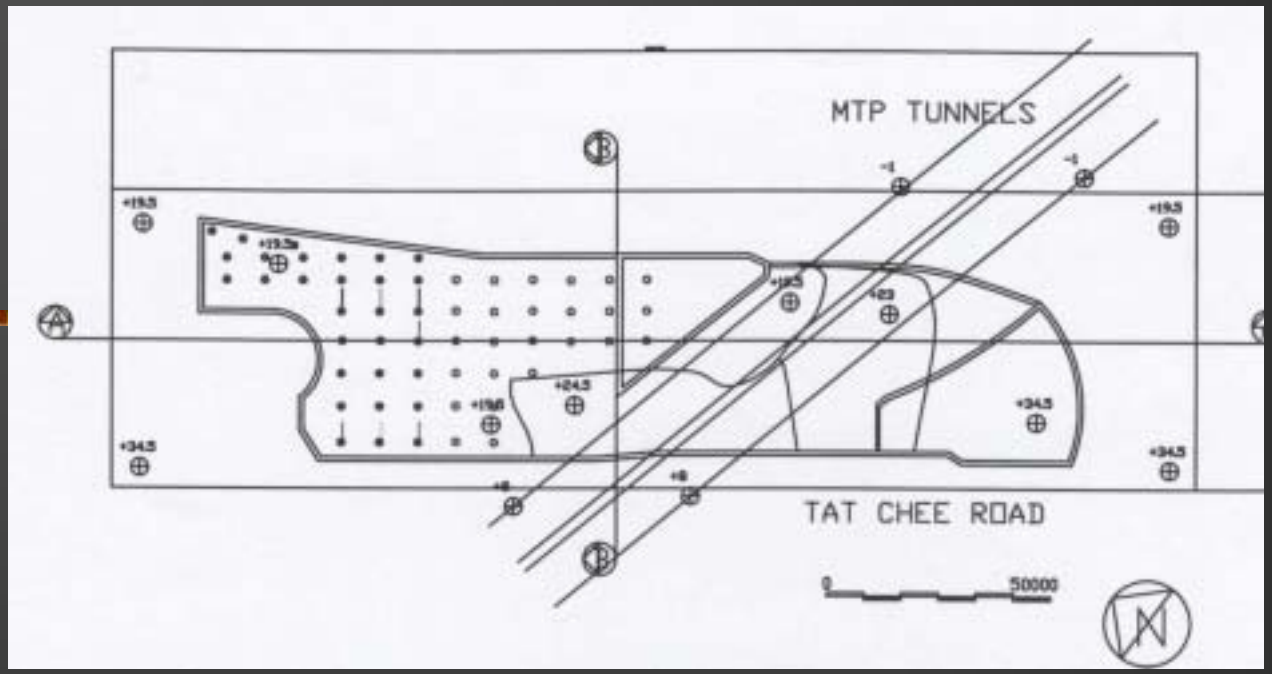
Project Case 2 – Festival Walk (Commercial Complex)

- Site area 21,000 sq m.
- Two major railway systems running nearby:
  - Kowloon Canton Railway (KCR) running on one side
  - Mass Transit Railway (MTR) tunnel tube running across the site almost in the middle
- works sub-divided into two contracts
  - site formation (including cut-off walling and foundation)
  - basement and superstructure
- 4-level basement and 3-level semi-basement was built.
- Very shallow rockhead exists one several spots that involved a lot of underpinning work when constructing the basement

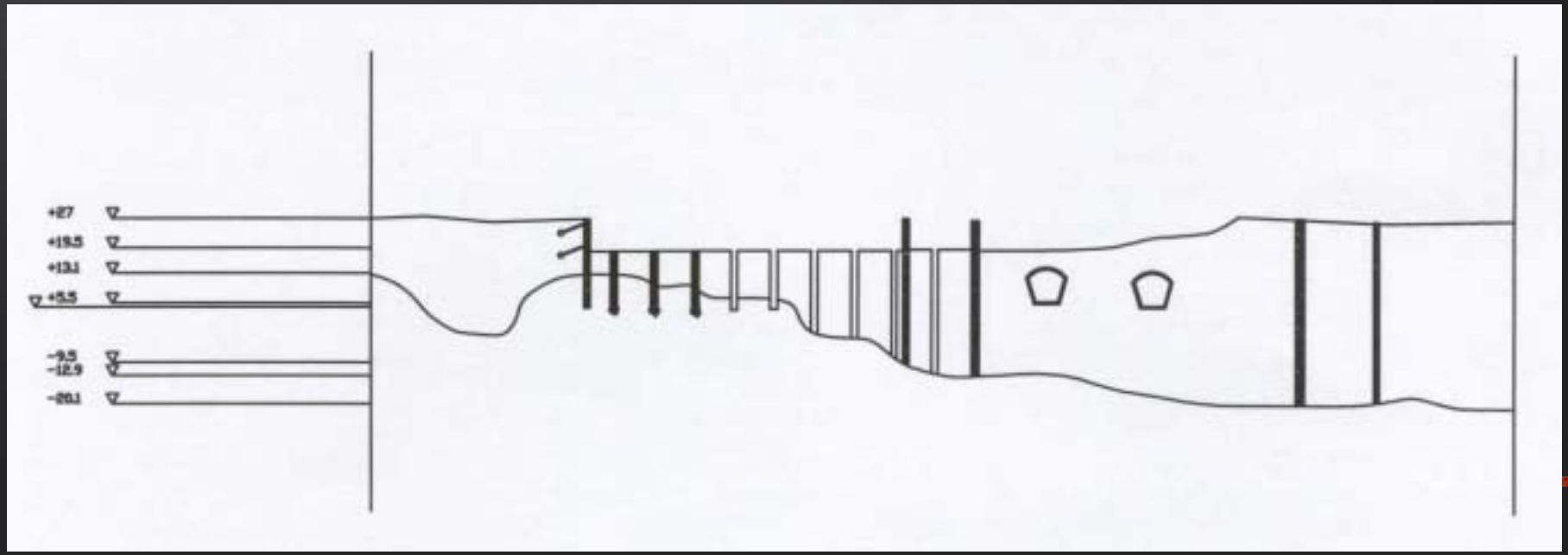


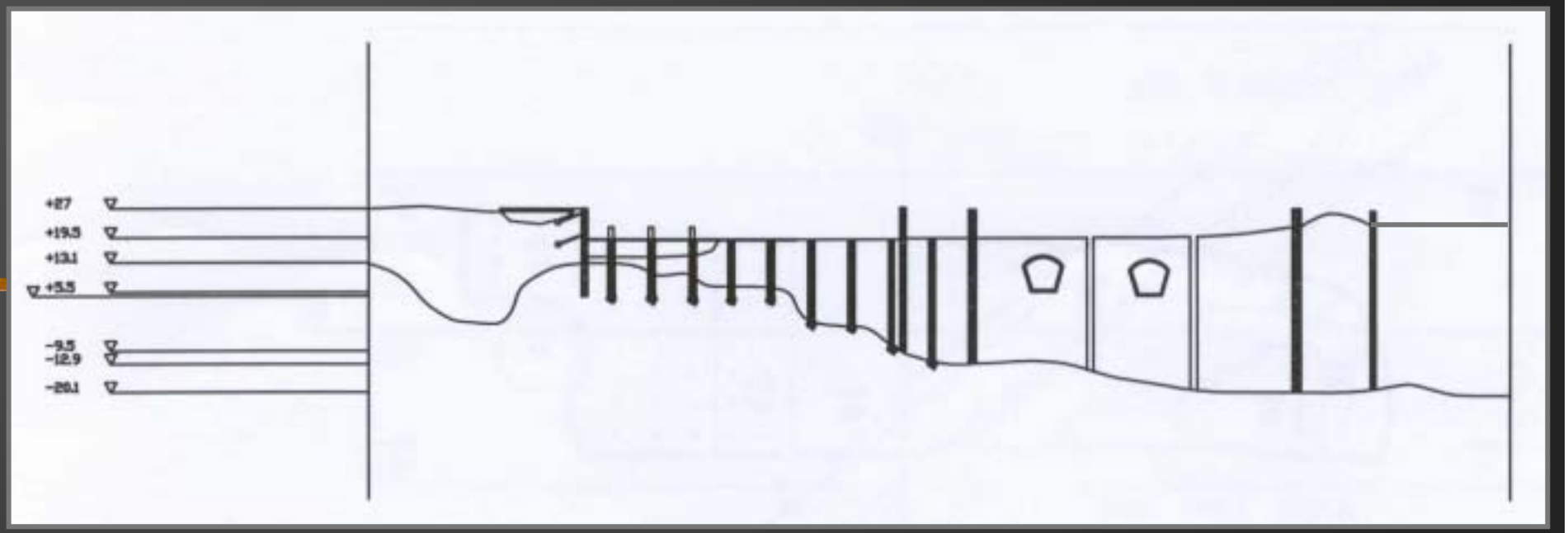
Stages 1 – forming of diaphragm wall

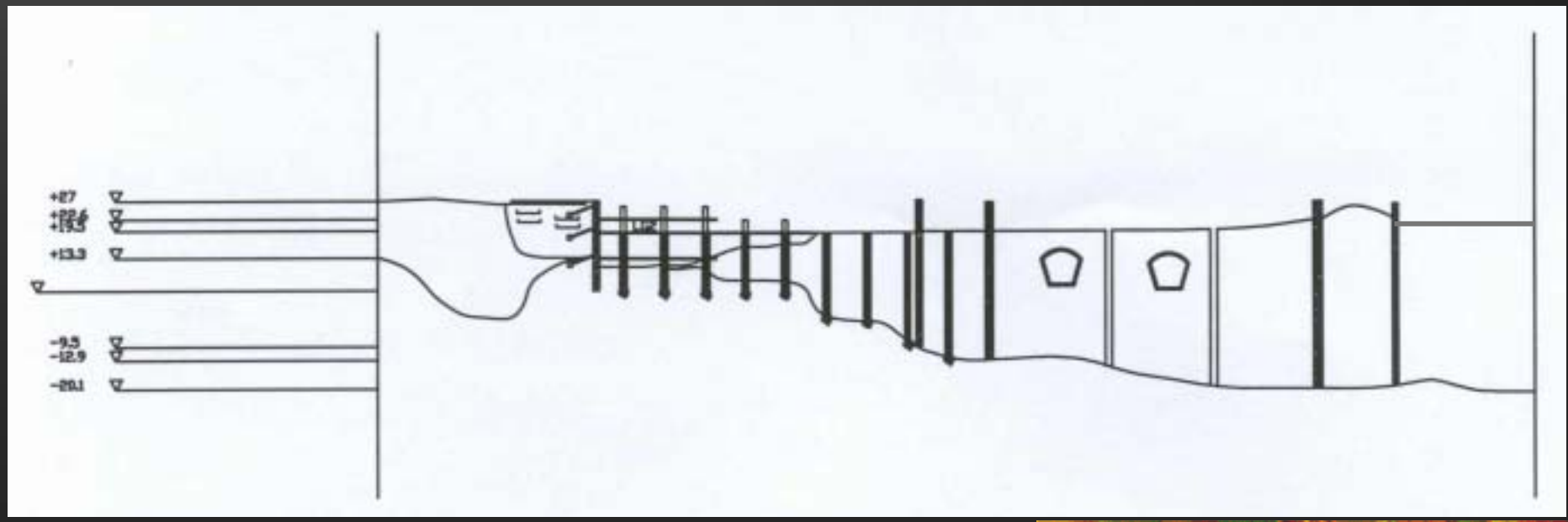




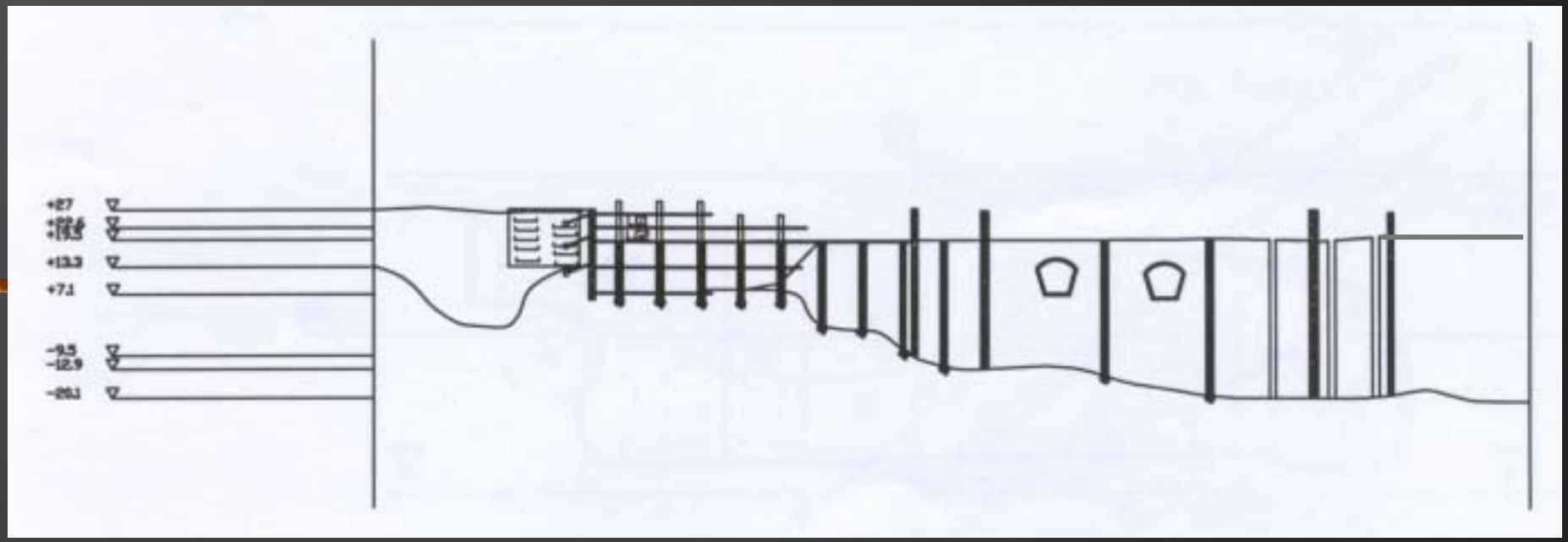
Stages 2 – forming of bored piles and early stage of site formation

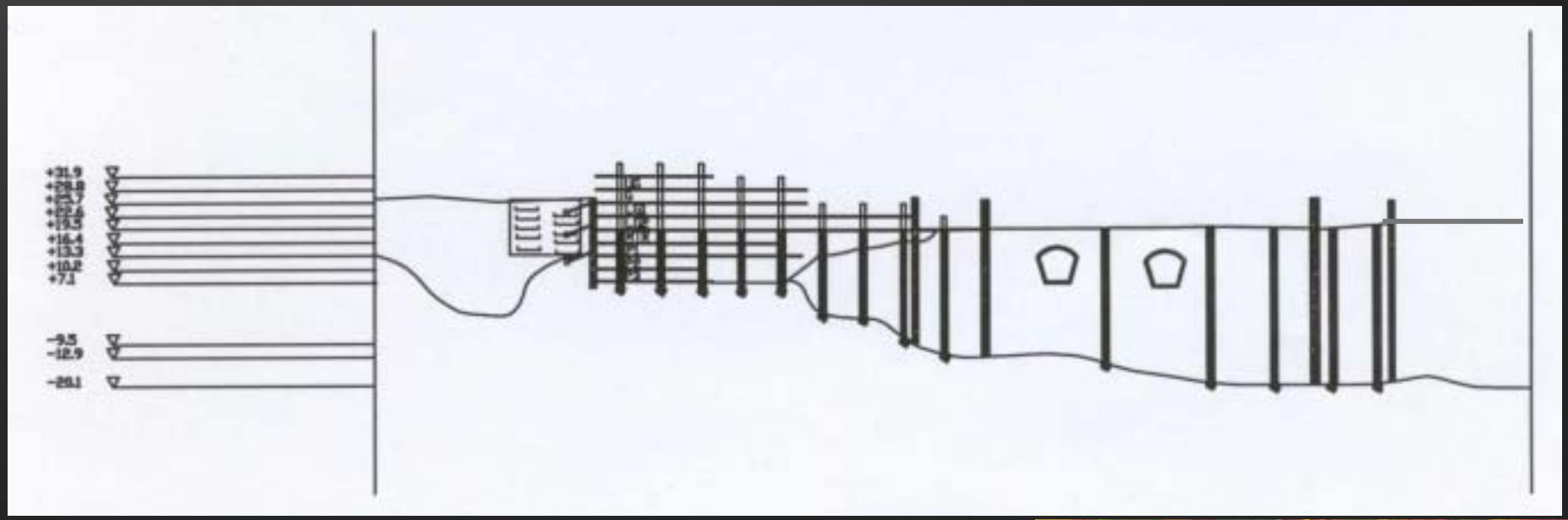




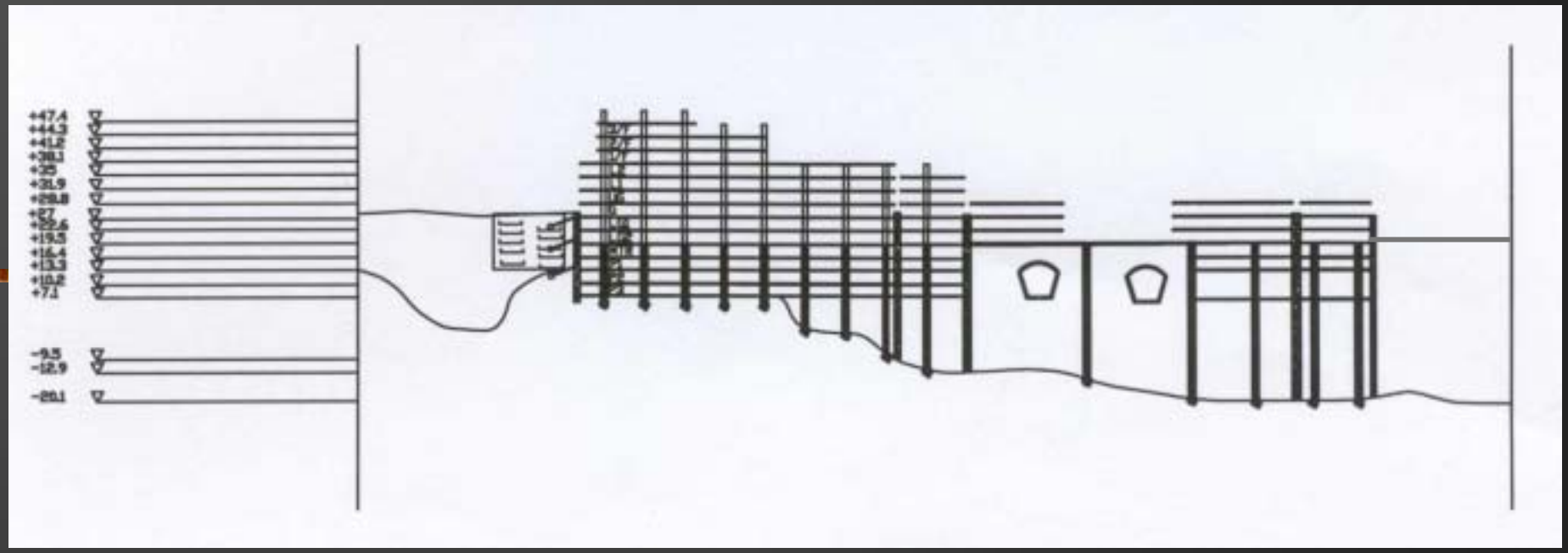


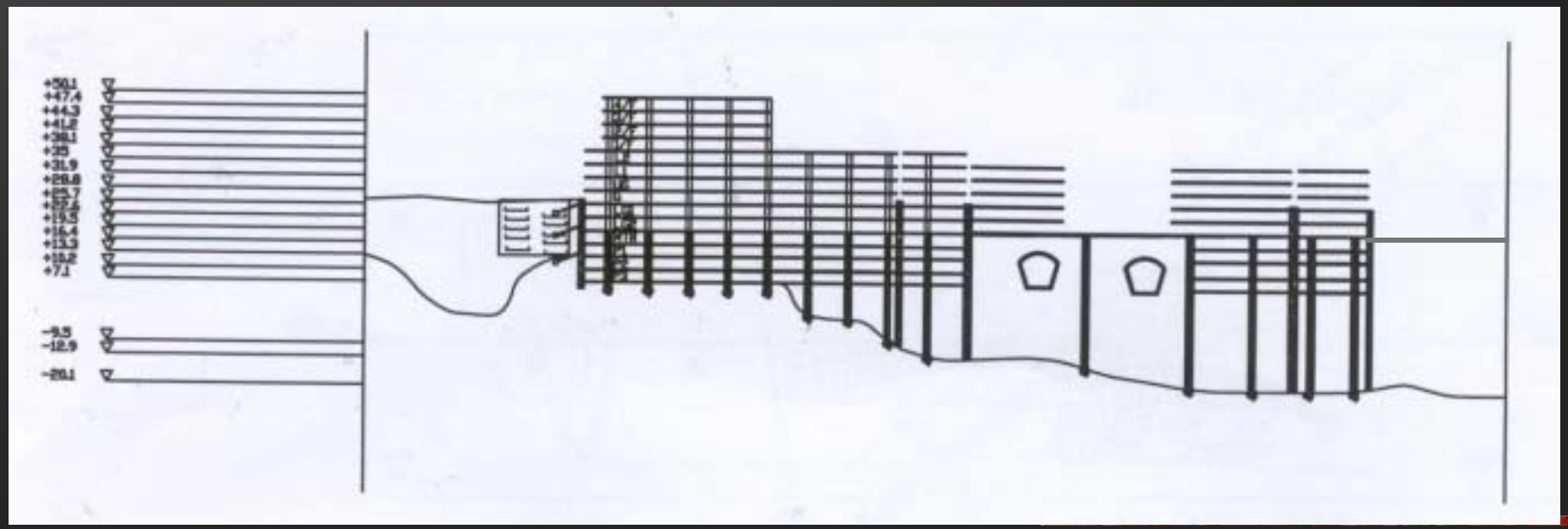
Stages 3 – construct the first slab and commence top-down basement



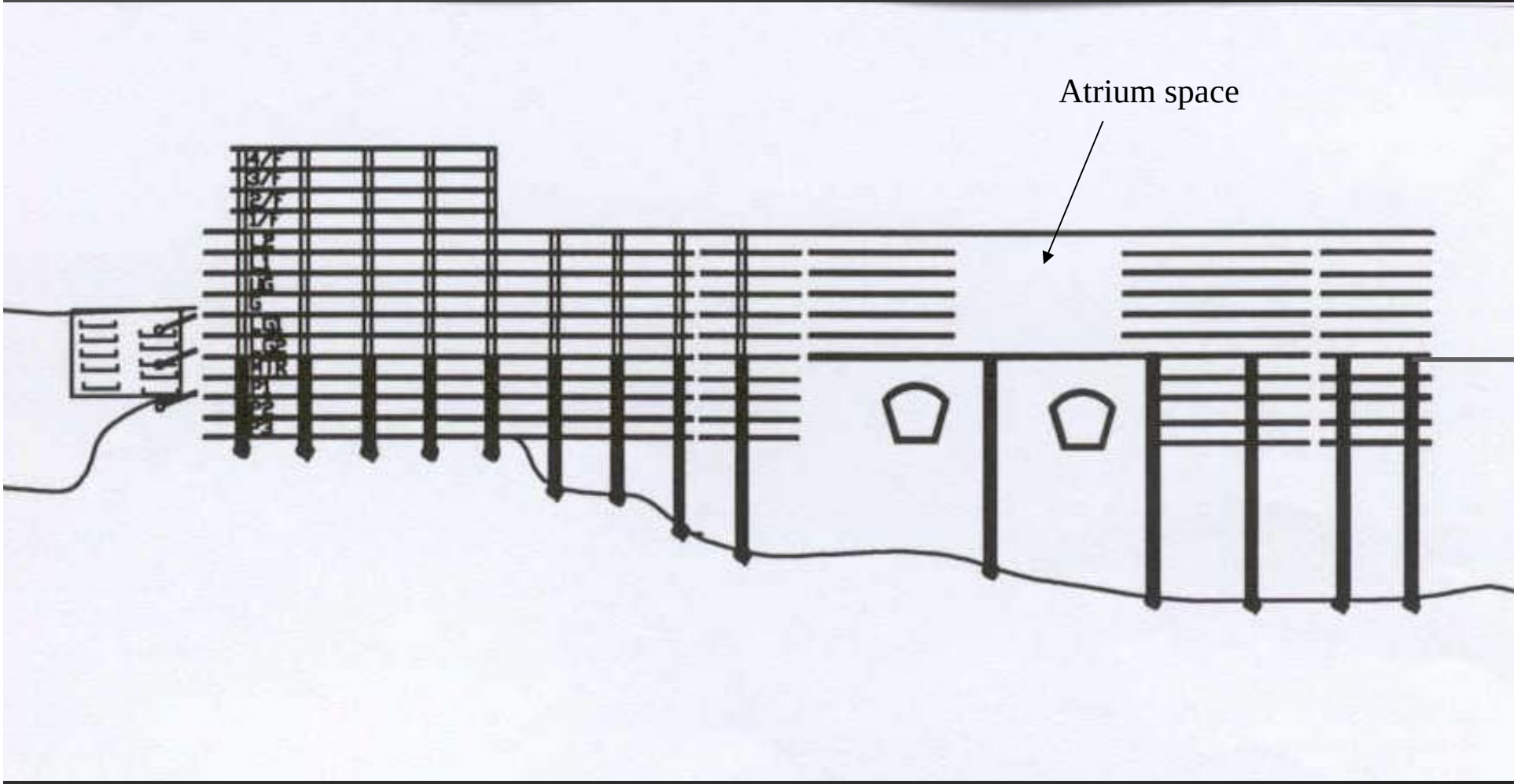


Stages 4 – construct the superstructure and basement proceed and extend





Stages 5 – completing the superstructure and basement

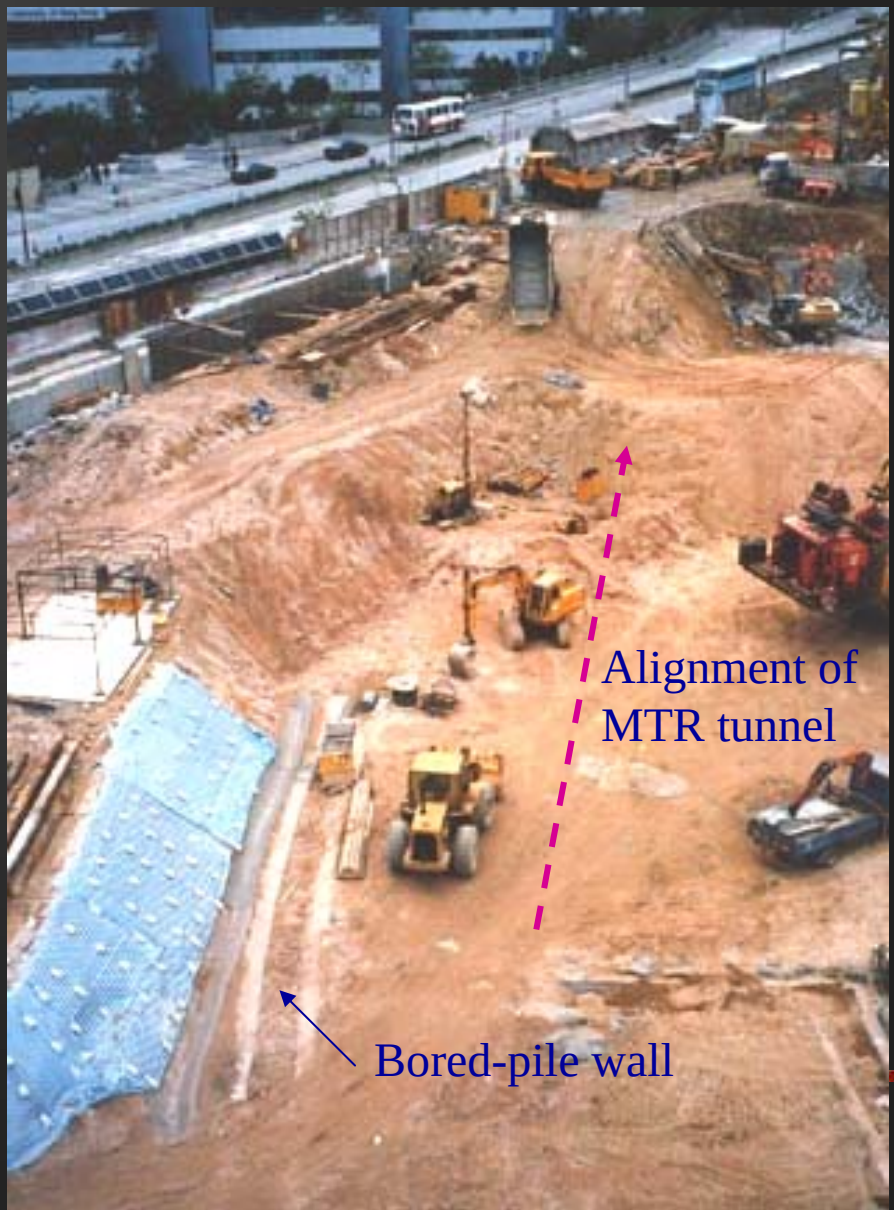


Stages 6 – Final completion of the superstructure and basement

Early stage of site formation – by the time excavation to form the site, diaphragm wall construction and foundation works were carried out at the same time under carefully phased manner

Forming the site and with diaphragm wall as the side support

Protecting the MTR tunnel by forming a cut-off bored-pile wall on the sides



Site formation to the formation level where the basement work would be commenced

Provision to protect the servicing MTR pedestrian access shaft

Work around the MTR pedestrian access shaft

Underpinning work at the base of the diaphragm wall along the Tat Chee Avenue side

Early stage of the basement construction and the forming of an access route into the basement to facilitate excavation

Entrance arrangement to facilitate the basement excavation/construction

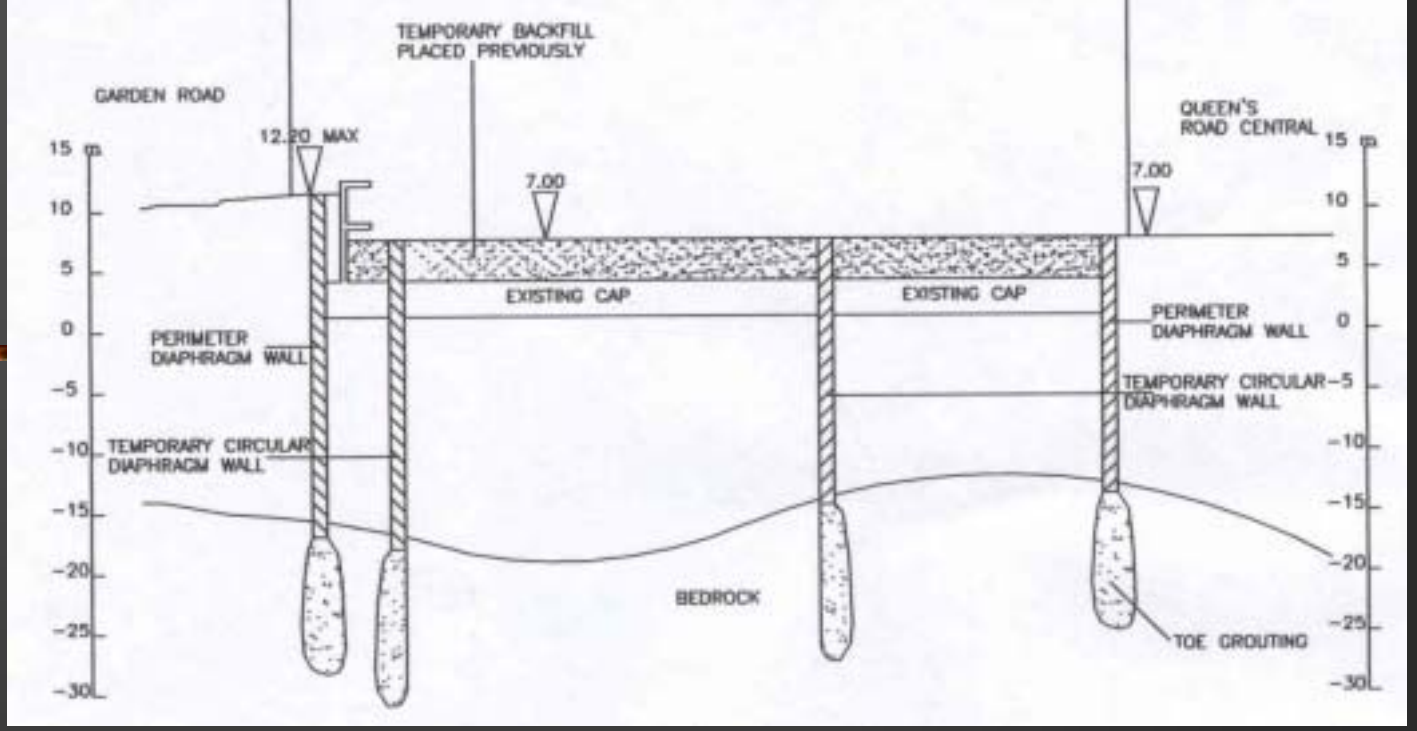
Forming of the vehicular ramp as a means for access for spoil removal purpose during the basement excavation process

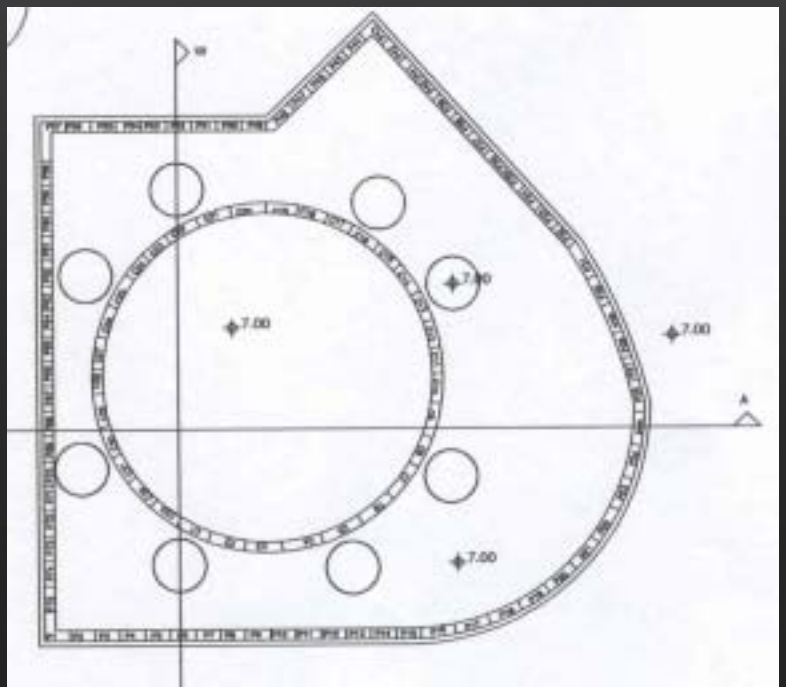
Construction of the superstructure and the top-down basement at its peak

Project Case 3 –

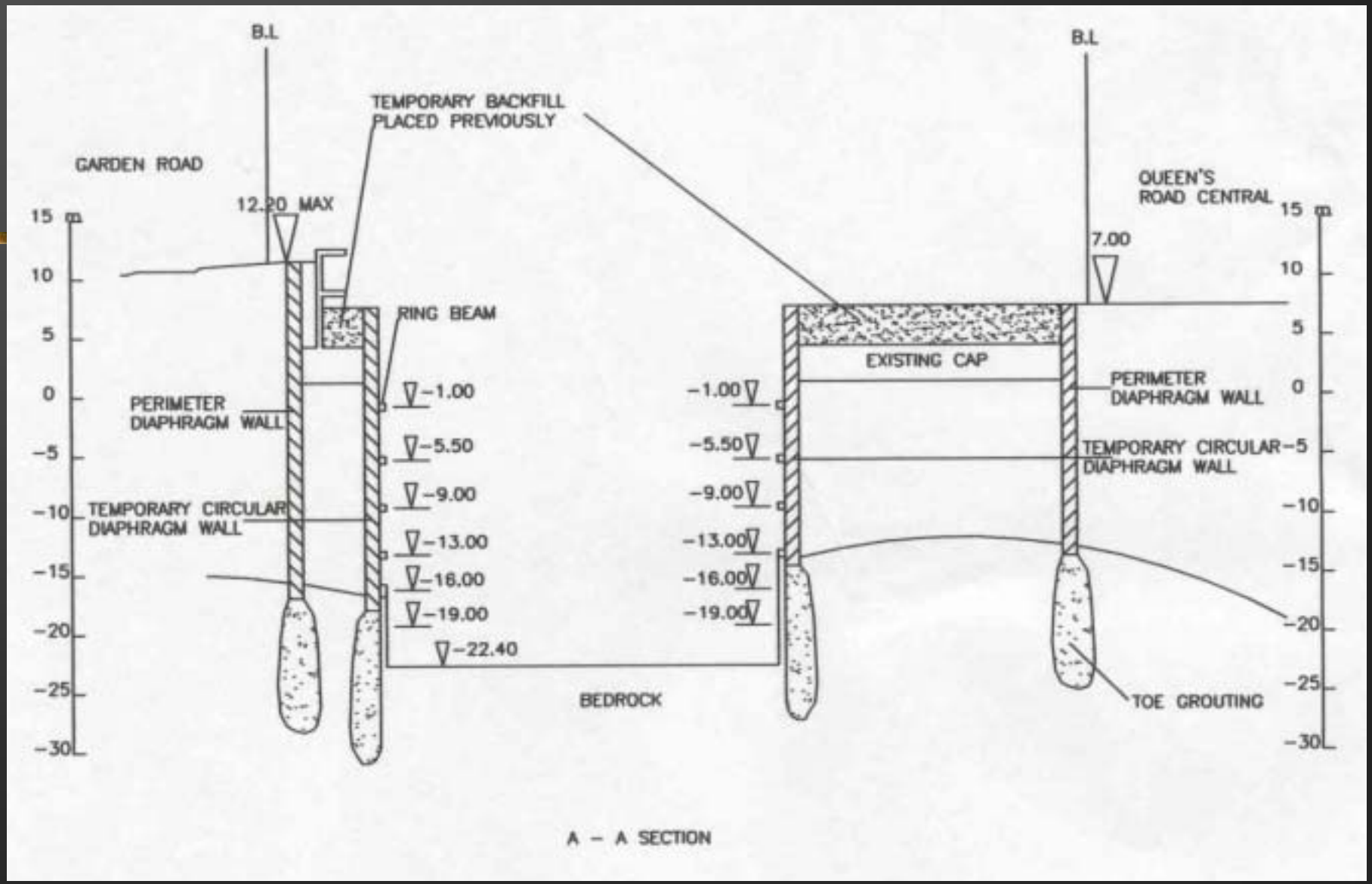
Cheung Kong Center (Previous Hilton Hotel)

- Overall site area: about 8000 sq m
- 5-level basement constructed using top-down arrangement
- basement construction done in 2 stages with a lapse of 2.5 years in between
- a 36m diameter cofferdam down to -28m was constructed to form the raft foundation for the future building core



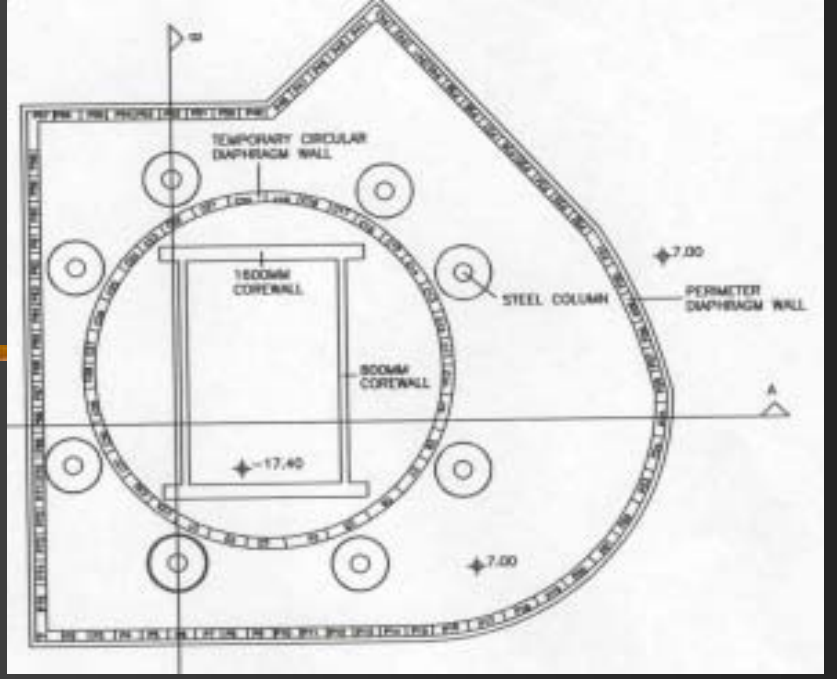


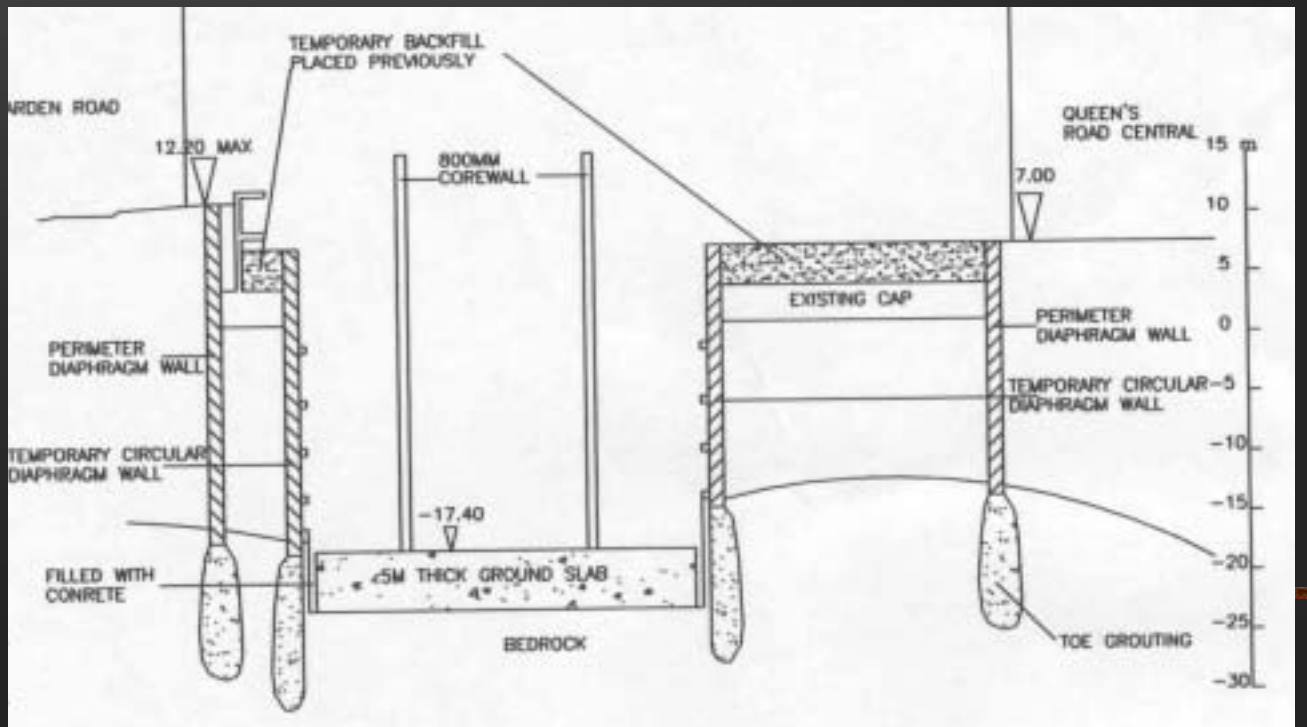
Location of diaphragm wall

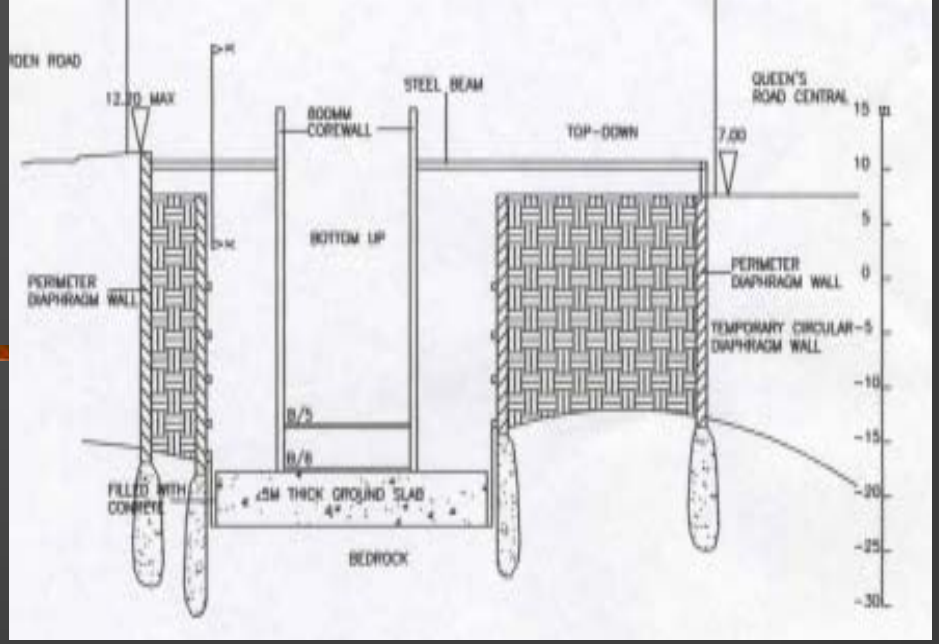


Forming a 37m dia. Cofferdam to construct the core wall for the new Tower

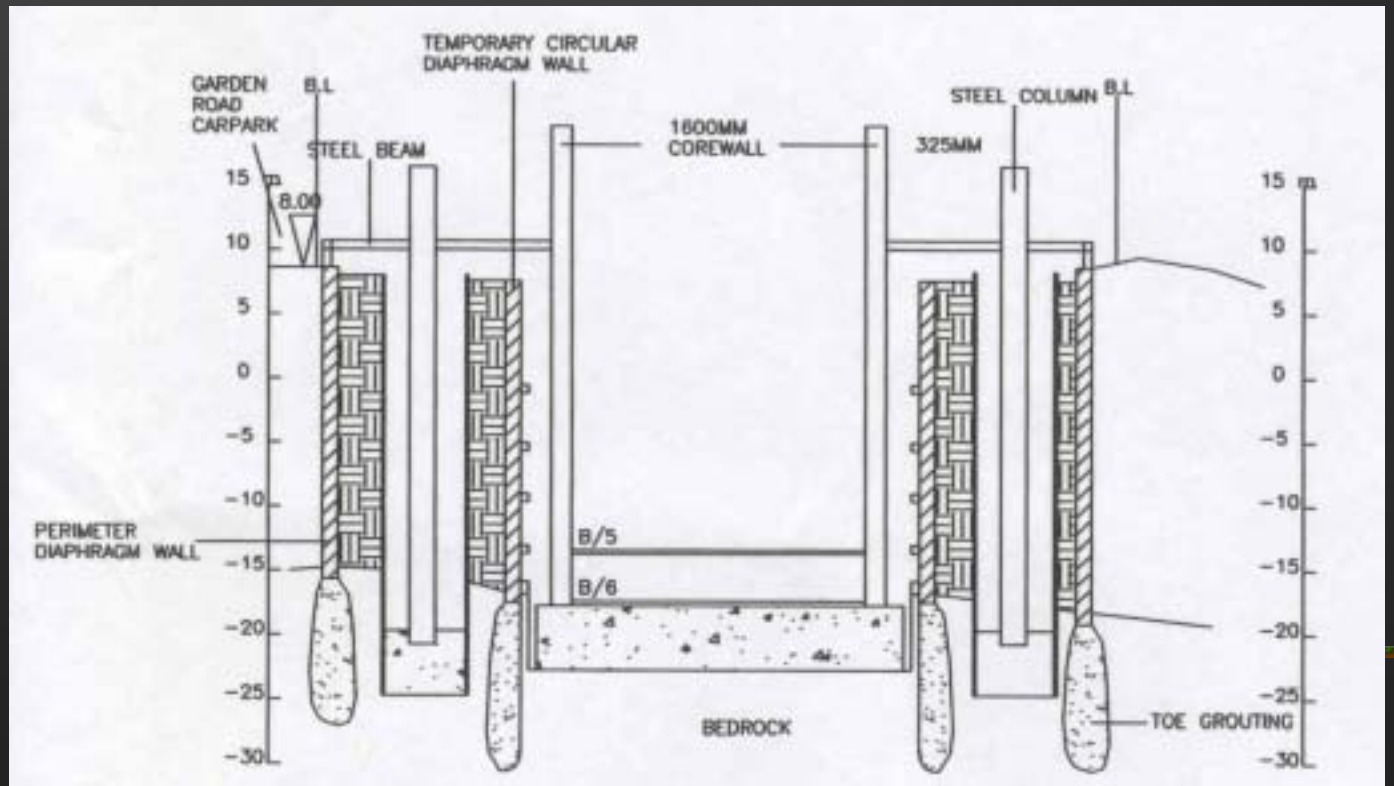
Construction of the core wall inside the cofferdam

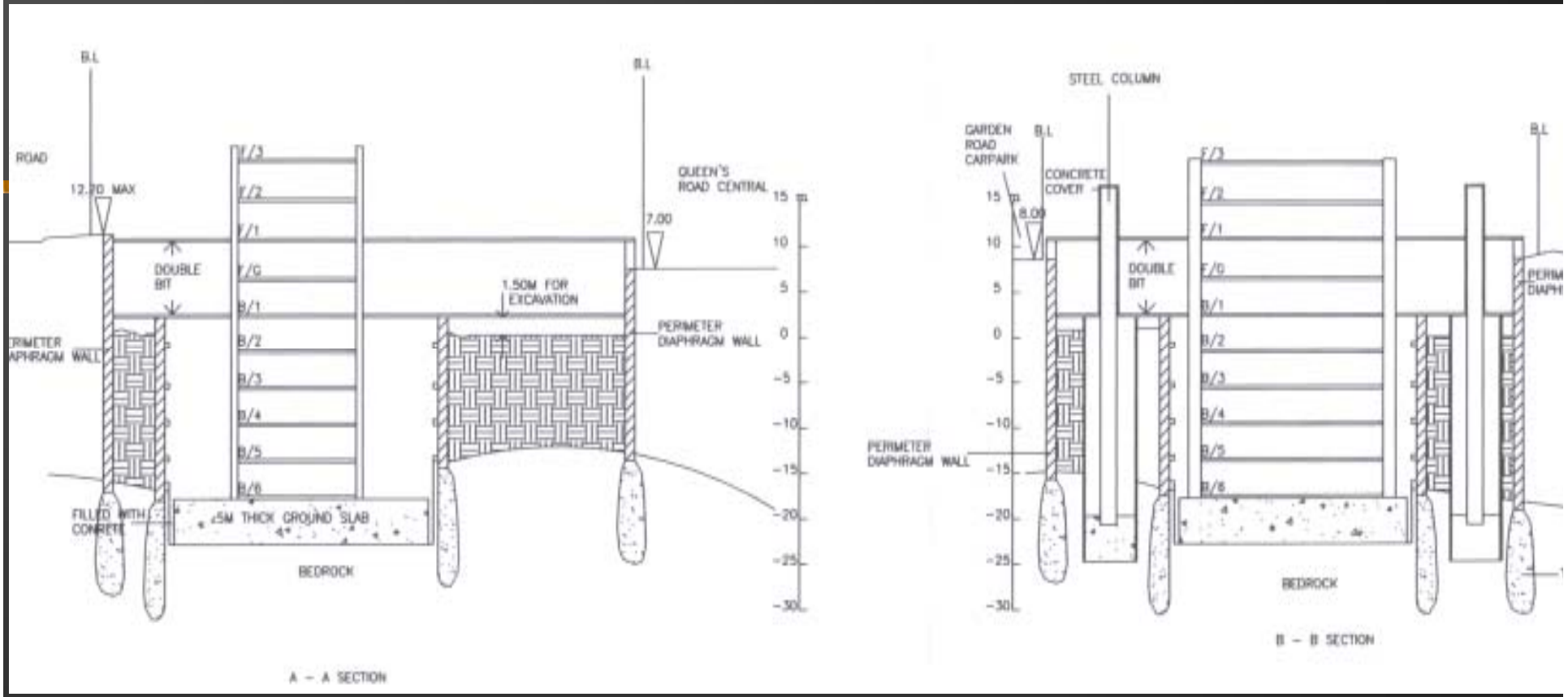




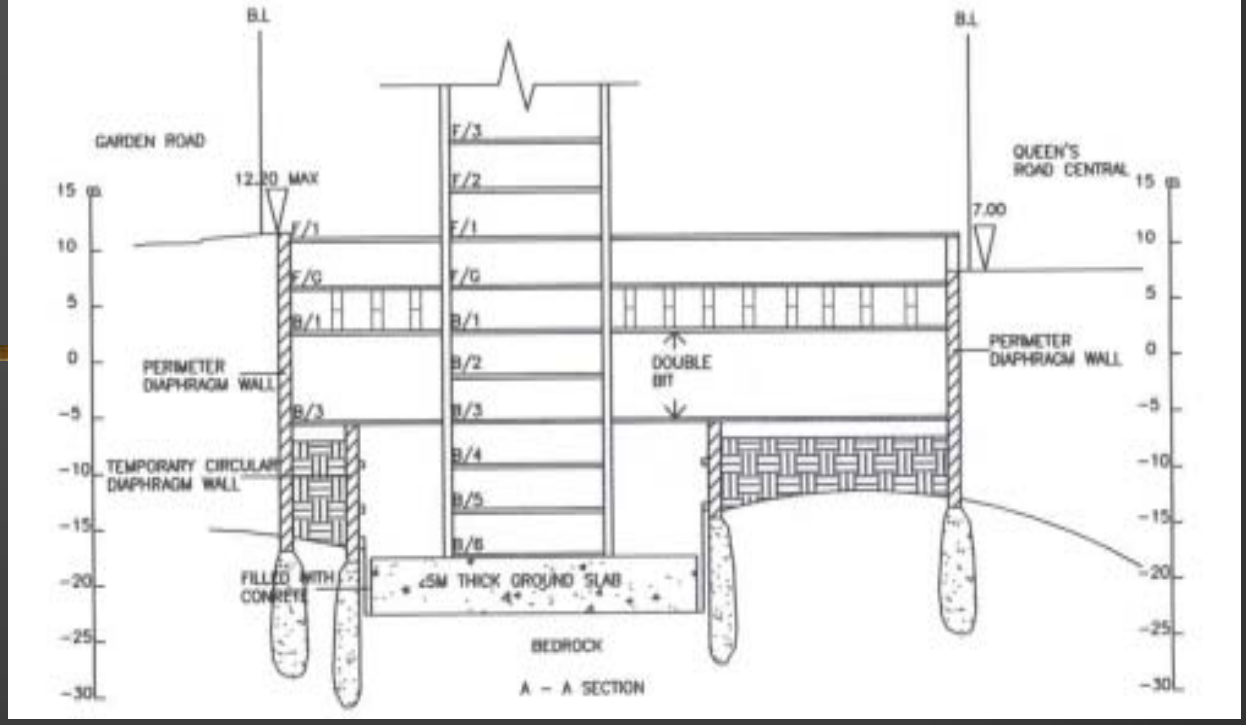


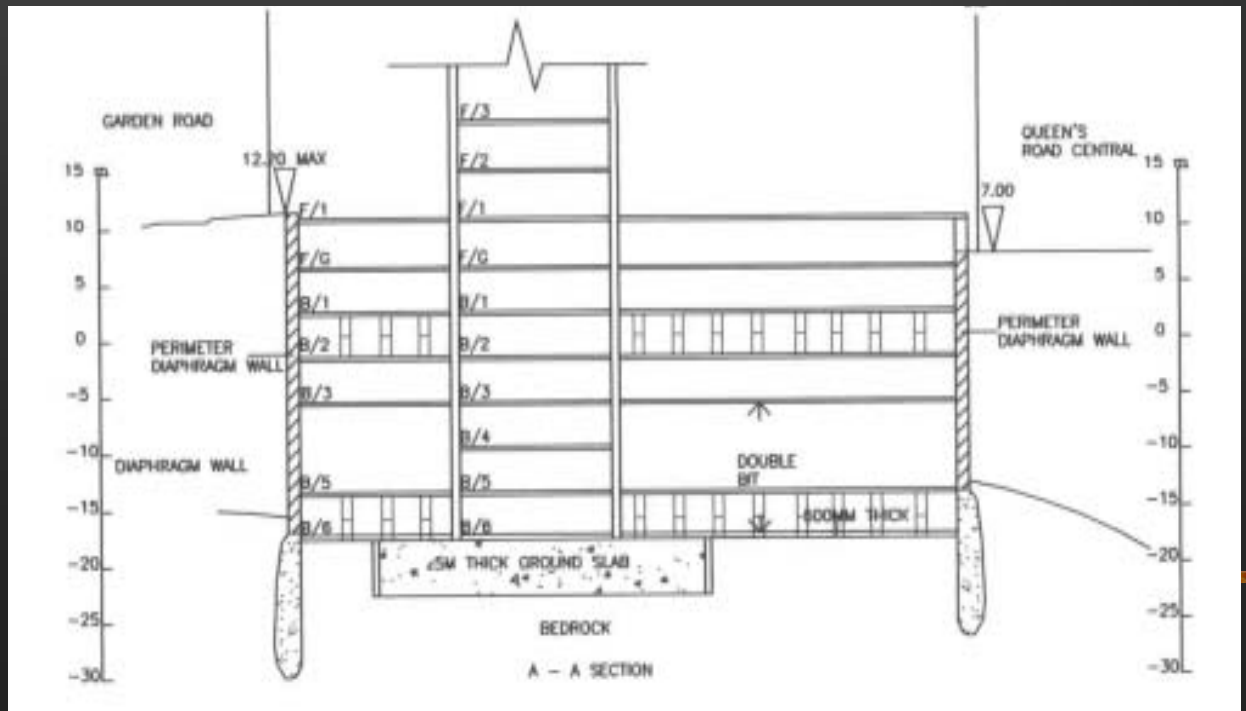
Forming the ground slab and commence excavation in a top-down manner





Top-down excavation and basement construciton proceeded





Basement constructed in a double-bit manner

Demolition to the old Hilton Hotel including the 2-level basement structure

Forming a 36m diameter cofferdam supported with diaphragm wall panels on the sides to facilitate the construction of the raft foundation for the core wall of the new building

Foundation and core wall work at the same time with the top-down basement

Forming the basement slab
using “double bit” method

Temporary shoring arrangement to stabilize temporary shaft opening during the basement construction

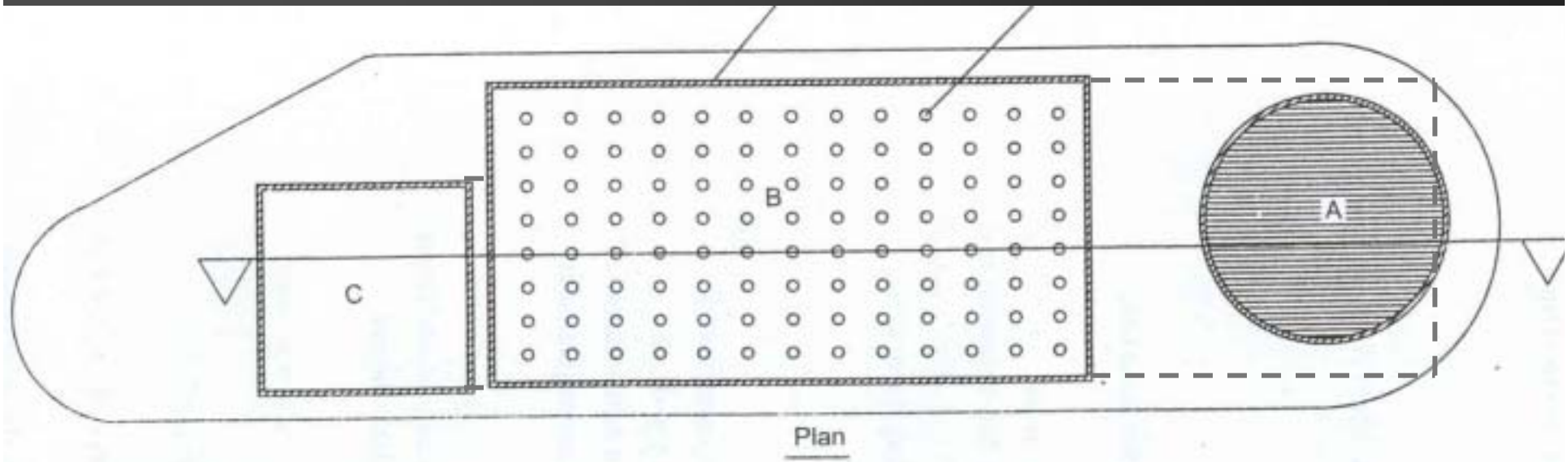
Forming of the basement slab and wall

Erection of temporary shoring

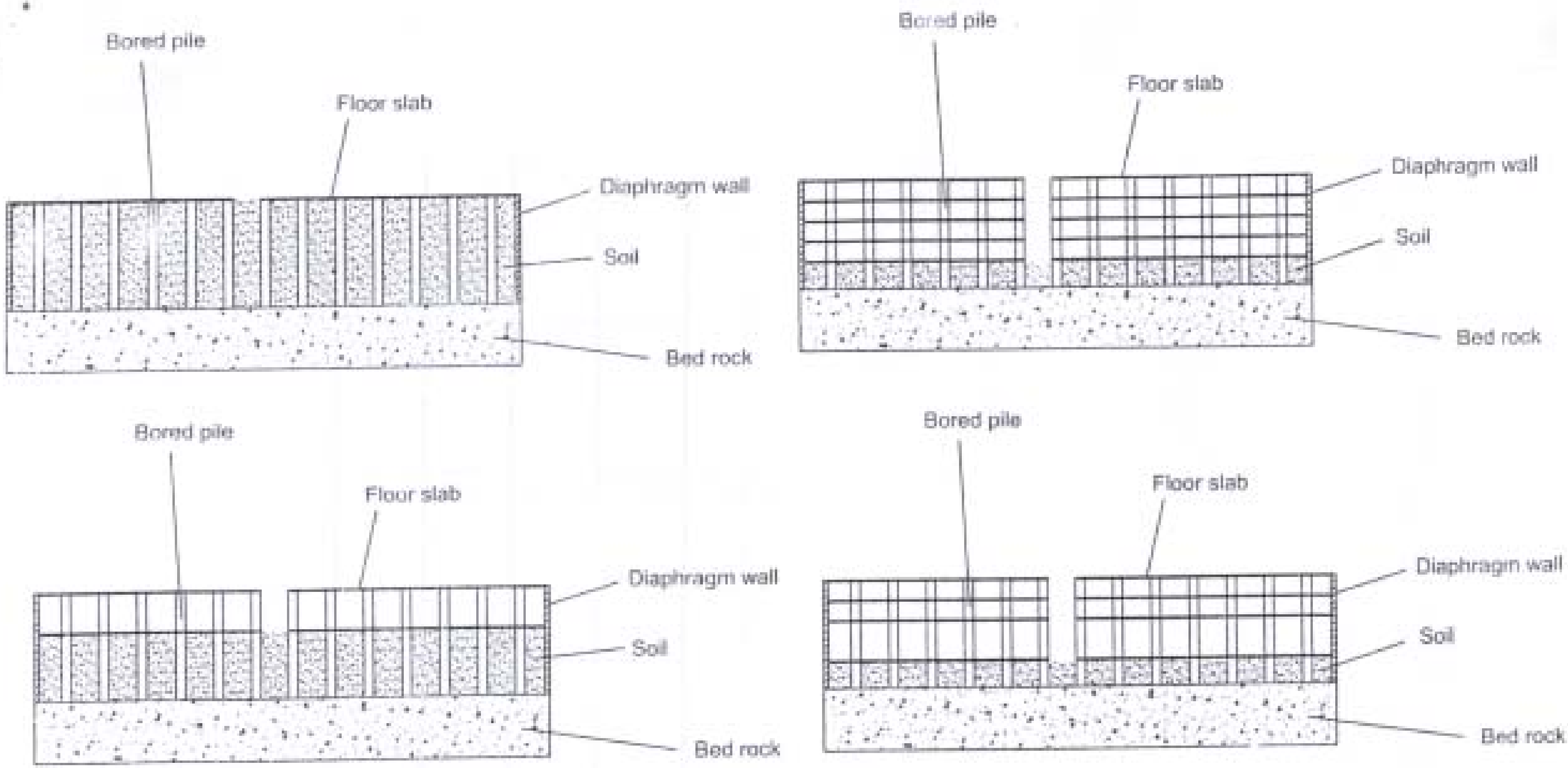
Forming the caisson cap at the basement final formation level

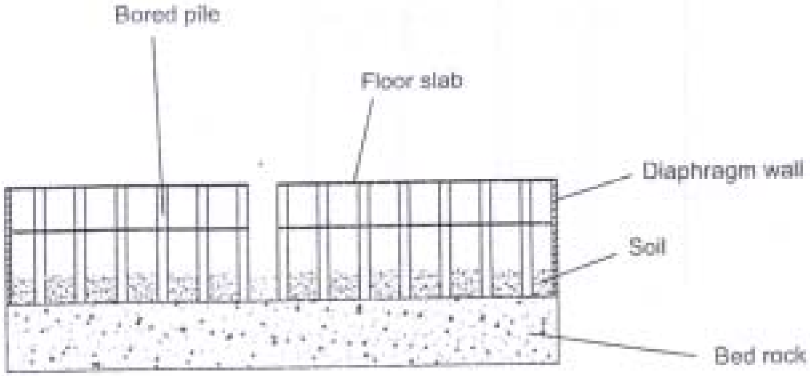
Project Case 4 – International Finance Center Phase II

- Overall site area: about 20000 sq m
- 5-level basement constructed using top-down arrangement
- basement works involved
  - portion under the Main Tower
  - portium under the retail podium
- a 71m diameter cofferdam down to – 35m was constructed to form the raft foundation for the building core of the Main Tower
- portion under the retail podium was constructed using top-down approach
- breaking through into the existing station concourse of the MTR lines took place inside the basement



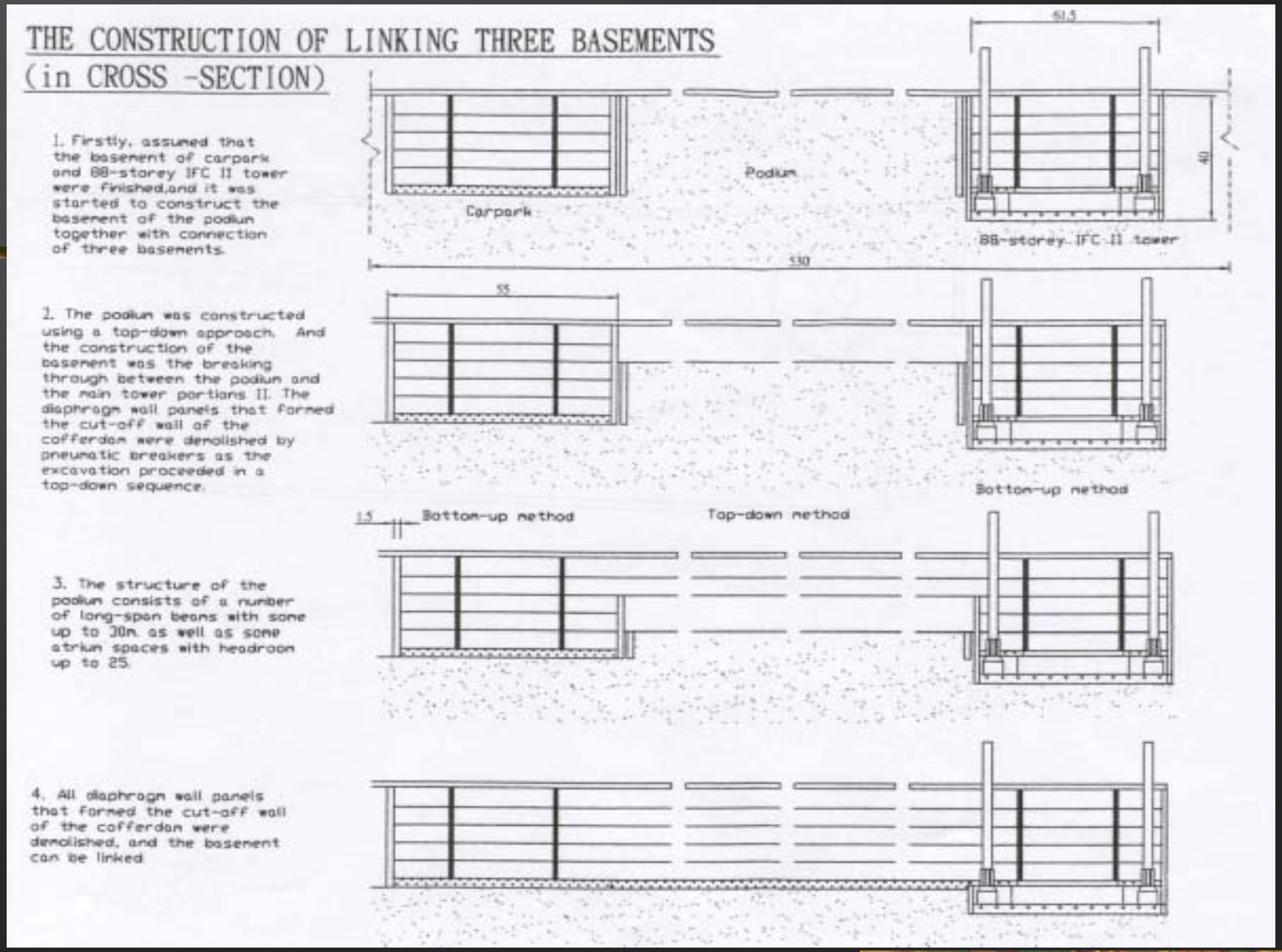
Overall foundation and excavation layout





Footnote: This drawing is shoe the process of building the baement B in the IFC 2. the method of building this basement is using the top-down method. Firstly, worker will put the 72 bored pile to the soilwhich is the foundation of the basement. And then worker will remove the top soil in the site to make the upper slab of the basement. After making the upper slab, worker will start to excavate the soil. the work will excavate two floor level soil firstly. And then,they will make the floor of the level 3. Then, they will continuous excavate the soil.The worker also excavate two floor level soil and building the lower level floor slab. After this, the worker will build the level 2 and level 4 floor slab at the same time. this method is called double-bit method. It can save much construction time. This basement is used about 18 month to build.

Stages of the top-down basement construction



Stage of basement construction – longitudinal section

The ground slab as the separating plate

Forming the ground floor slab as the first separating plate before the top-down excavation process

Forming the remaining portion of the ground slab after a suspension of about 2 years as seen in early 2000

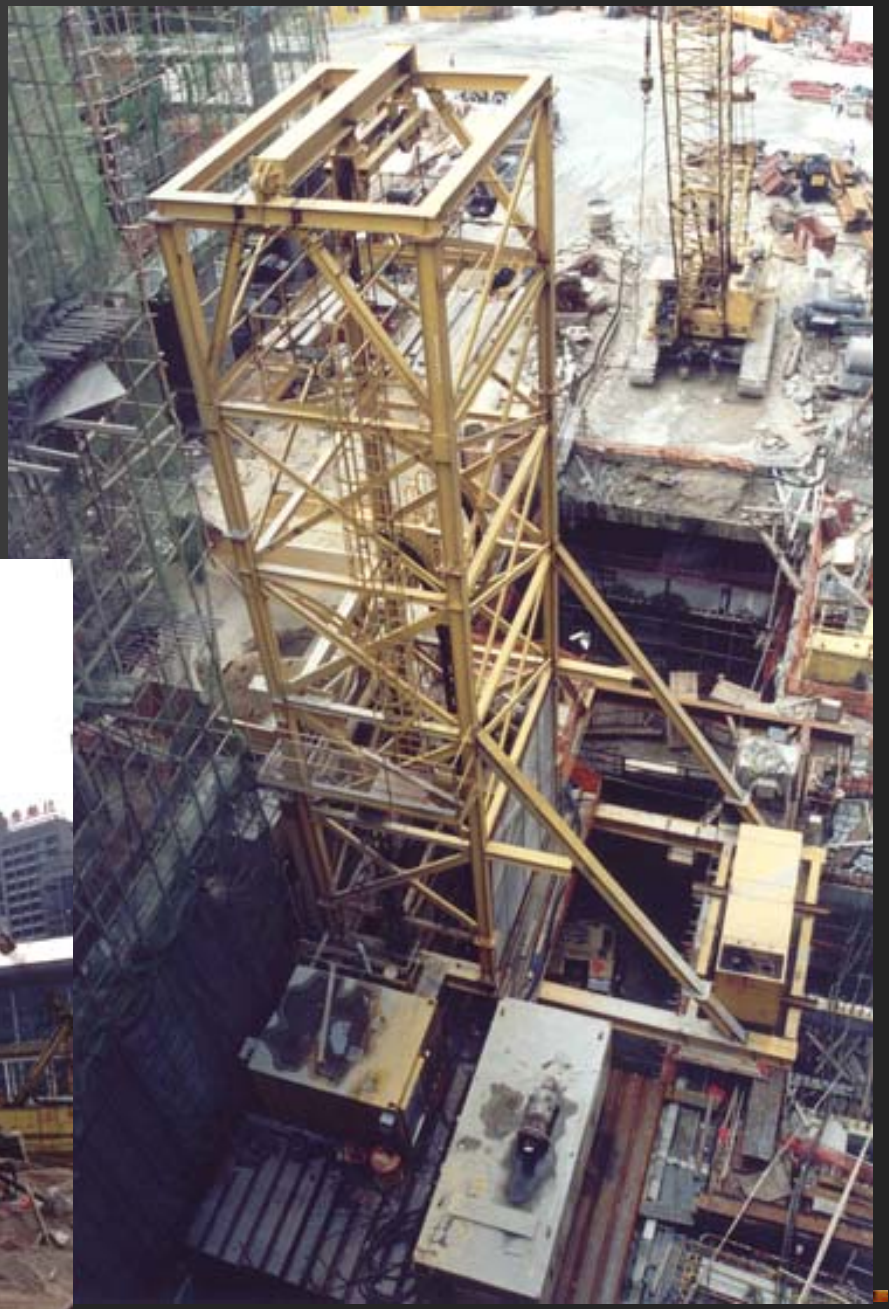
The excavation process

Muck opening provided on the ground slab for the removal of spoil

Excavation inside the basement

Excavation down to the formation level with pile head exposed

The use of a material hoist for the removal of spoil from the basement interior



Constructing the basement structure

Construct the basement in a “double Bit” manner

Forming the basement slab and encasing the stanchion to form the column

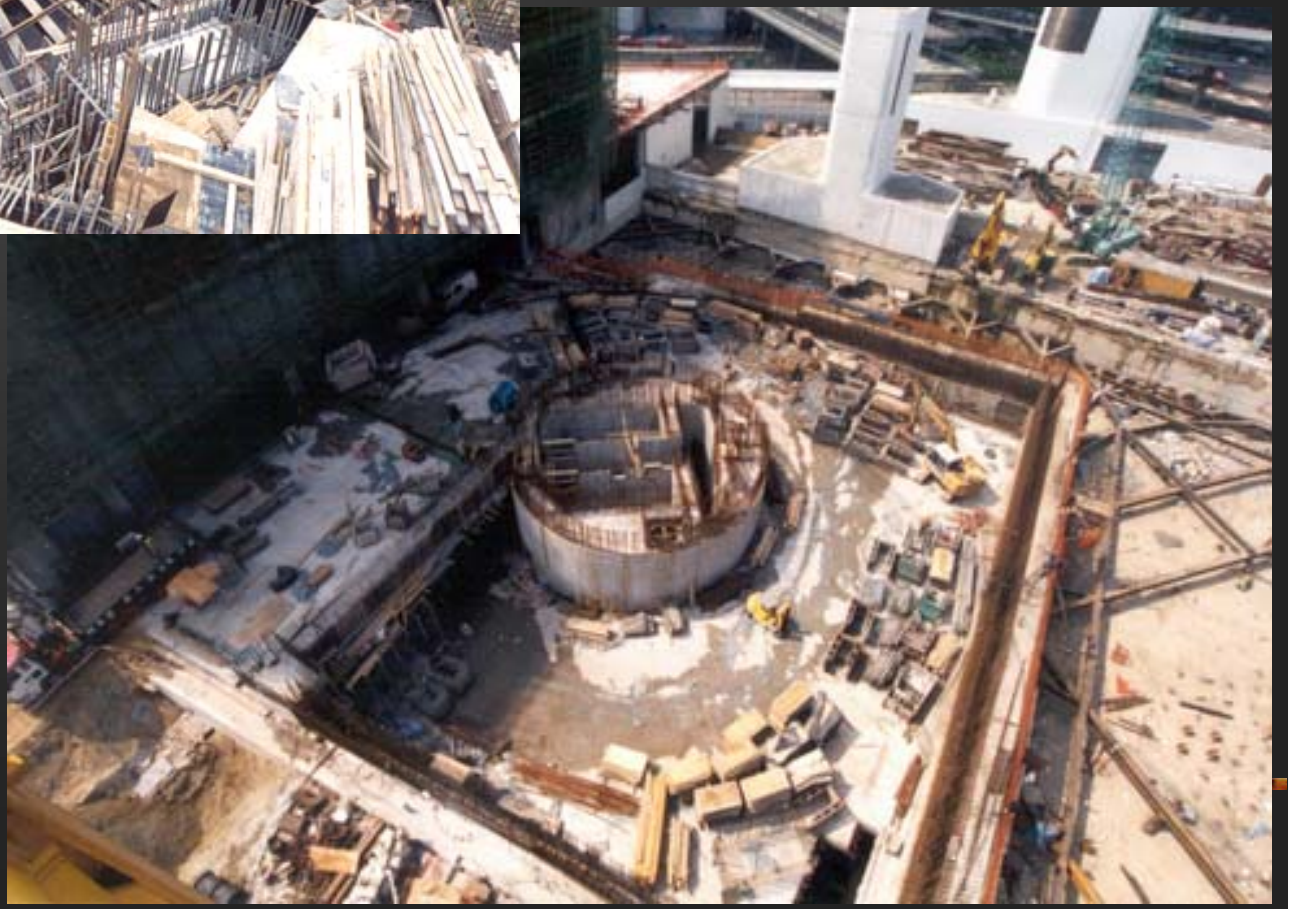
Basement structure around the muck opening soon to complete, slab will be reinstated afterward

The forming of the vehicular ramp

The shaft lined by diaphragm wall forming the vehicular ramp into the basement carpark. The ramp serves also as an dump access during the basement excavation process

Forming the circular ramp

Completing the ramp for temporary spoil removal purposes



Conclusion

- The construction of basement bears a very spectacular status in the entire construction process. It often marks the success of a project in terms of:
  - profitability,
  - effective use of valuable resources,
  - ensurance of contract time,
  - quality and safety considerations.

2. Various professions would have their own involvement in the basement construction process and each of them has their own concerns. It is not easy to formulate a simple yet straight forward solution to get everything right.
3. Better understanding of the variety of possible methods and practices, as well as knowing the constraints when handling basement works, there is higher chance to complete the work with a more acceptable result.

Conclusion (Cont.)

4. Single-issued methodology or managerial system can hardly serve the targets of completing a relatively large-scaled yet complex basement project.
5. A highly dynamic, tailor-made and quick-responded approach may be the most workable way in solving problems in basement construction
6. The competency and practical experience of the key players work in accordance to the unique physical environments and other confining conditions inherited in each project is very helpful.
7. Abundant supply of resources, strong support in IT and computer facilities, or even with plentiful funding backup, may not be a guarantee to the success of basement projects.

End of Presentation