Hesed Consultants Limited
希石顧問有限公司

Seminar for
The Hong Kong Institute of Surveyors

Practical Considerations in Estimating the Foundation Cost in HK

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18 February 2016

Contents

1. Introduction

Introduction

- Foundation projects are one of the most complicated construction activities - risk and uncertainty cannot be avoided (Tam *et al*, 2007)
- Foundation contractors would adopt different risk management approaches – high premiums may be incurred
- Ultimately, the high premium would be transferred to the Employer

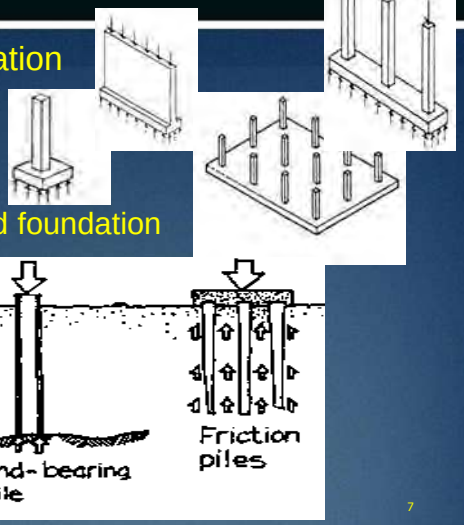
Introduction (Cont'd)

- It increases difficulty in estimating the foundation cost
- Therefore, knowing the practical considerations of foundation contractor and understanding the risks and difficulties that may be encountered are necessary prior to estimating of the foundation cost

2. Common Foundation / Pile Types in HK

Common Foundation/Pile Types in HK

- Classification of Foundation
  - Shallow
    - Pad / Strip Type / Raft
  - Deep foundation - Piled foundation
    - End bearing
    - Friction
    - Replacement
    - Displacement



Common Foundation/Pile Types in HK (Cont'd)

- Common Type of Piles
  - Bored Pile
  - Pre-bored Socket H-pile
  - Mini-pile
  - Driven H-pile
- Other Type of Piles
  - Precast concrete Pile, Pakt-in-place Pile, etc.
  - Shaft Grouted Barrette pile, Shaft Grouted Piles, etc.
  - Hand-dug Caisson, Jack piles, etc.

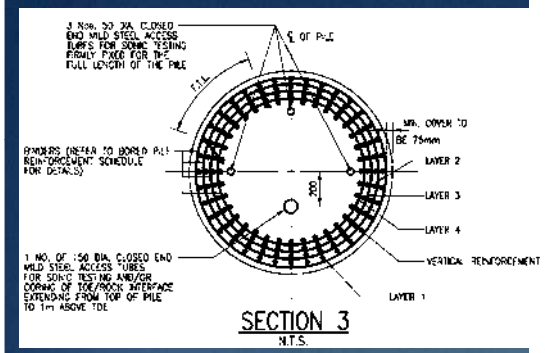
Common Pile Types in HK (Cont'd) – General Procedures

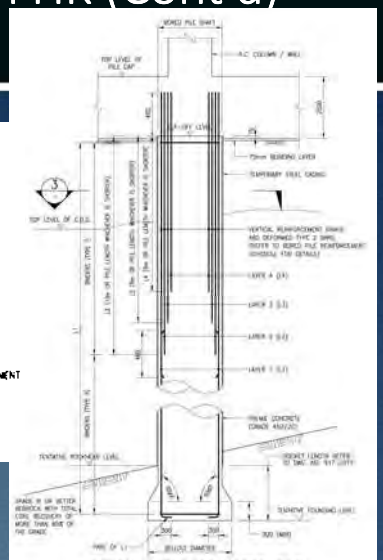
- Design, submission & approval
- Submit Form BA10 and SSP (and documents required under BD approval letter) to BD 7 days before commencement of work (for private projects)
- Carry out predrilling work
- Construct trial pile (if applicable)
- Construct piles
- Carry out testing, submit test report
- Submit Form BA14 (for private projects)
- Proof tests

Common Pile Types in HK (Cont'd) – Bored Pile

- Generally
  - Common size - from 1m to 3m in diameter
  - By oscillating or rotating a steel casing into the ground
  - Using grab to remove materials inside the casing
  - Using Reversed Circulation Drilling (RCD) to crush hard materials
  - Crushed materials are retrieved by circulation of fluids within the drill hole - reduce effectively noise and vibration during construction of rock socket
  - Temporary steel platform required to support heavy machineries and equipment for sloping sites

Common Pile Types in HK (Cont'd) – Bored Pile





Common Pile Types in HK (Cont'd) – Bored Pile

- Predrilling work
  - At centre of each bored pile location
  - Sunk at least 5m into rock
    - measured from founding level of bored pile; or
    - rock socket bottom level; or
    - the designed rock socket length of the pile, whichever is the deeper
- Install temporary casing by Oscillator / Rotator

Common Pile Types in HK (Cont'd) – Bored Pile

- Remove soil by hammer grab and jack down the temporary casing
- When bedrock level is reached, set up Reverse Circulation Drill (RCD) for drilling and forming rock socket
- Use bellout tool to form bellout (if required)
- Clean pile shaft by air-lifting
- Carry out Koden test to verify pile verticality and bellout size

Common Pile Types in HK (Cont'd) – Bored Pile

Oscillator

Common Pile Types in HK (Cont'd) – Bored Pile

Grabbing soil

RCD Setup

Common Pile Types in HK (Cont'd) – Bored Pile

Drill bit

Bellout bit

Under reamer

Common Pile Types in HK (Cont'd) – Bored Pile

Common Pile Types in HK (Cont'd) – Bored Pile

- Install steel reinforcement cage
- Concrete is injected into the bored hole by using a concreting pipe; temporary steel casing is extracted along with concreting
- Carry out sonic test / Interface core (1m above & below the interface)
- Report completion to BD (for private projects)
  - Submit Form BA14, piling records & plan, mill certificates, test reports, etc.
  - BD selects piles for full core test

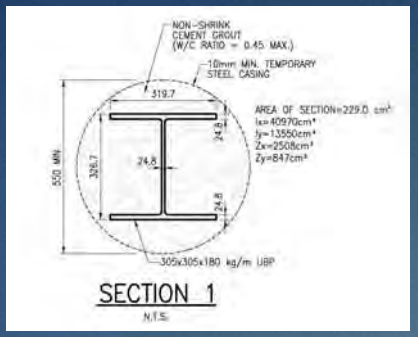
Common Pile Types in HK (Cont'd) – Bored Pile

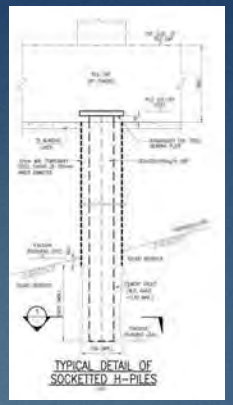
Common Pile Types in HK (Cont'd) – Bored Pile

- Full core test
  - Down to a depth of at least half diameter of the pile base or, 600mm, whichever the larger, below the interface
  - Core compression test
  - Submit core compression test report

Common Pile Types in HK (Cont'd) – Socket H-pile

- Generally
  - Pile shaft is formed by boring and steel H section is inserted afterward



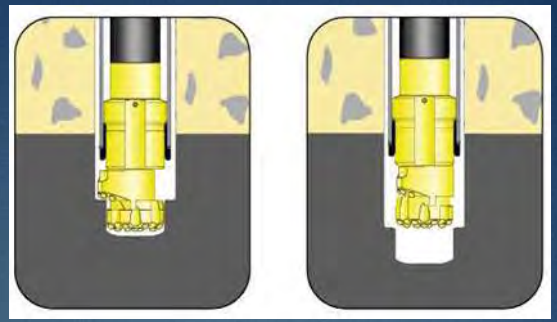


Common Pile Types in HK (Cont'd) – Socket H-pile

- Generally (Cont'd)
  - Overburden Drilling with EXcentric bit (ODEX) method used for shaft boring works
    - Bottom pilot bit and an eccentric "swing out' reamer bit
    - Hole drilled slightly larger than casing
    - ODEX uses compressive air as flushing medium
    - May cause significant ground subsidence during the preboring works
    - After two incidents in 2008, ODEX method generally not allowed in urban areas, especially adjacent to old buildings

Common Pile Types in HK (Cont'd) – Socket H-pile

ODEX Method

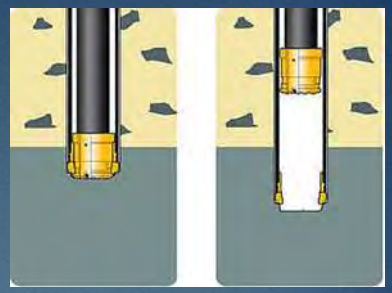


Common Pile Types in HK (Cont'd) – Socket H-pile

- Generally (Cont'd)
  - Concentric drilling system
    - Less disruption to the ground and reduce ground loss significantly
    - Comprising a centre bit and a ring bit
    - High pressure air to air-lift the soil and rock cuttings out of the bored hole
    - Better at minimising disturbance to surrounding ground during drilling
    - However, ring bit is left in place and sacrificial

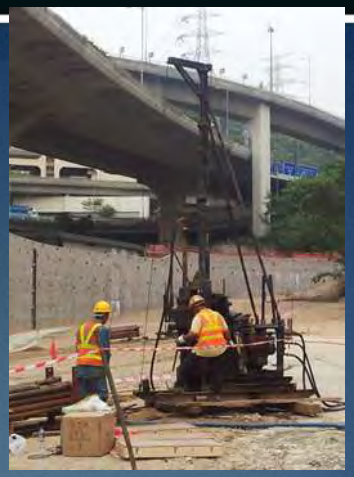
Common Pile Types in HK (Cont'd) – Socket H-pile

Concentric drilling system

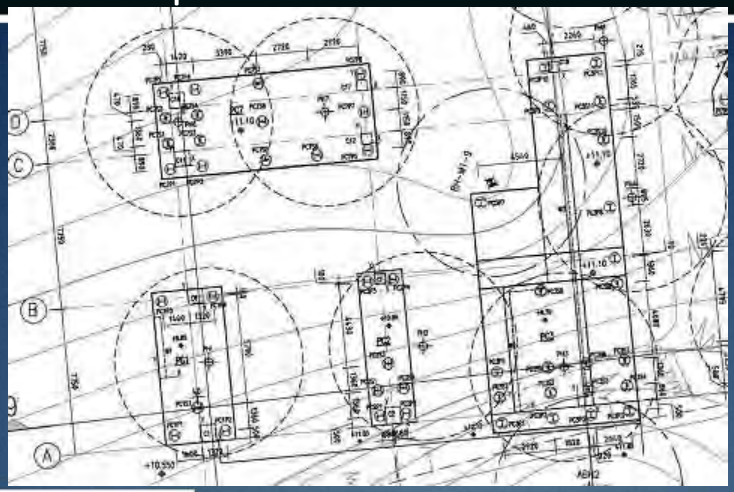


Common Pile Types in HK (Cont'd) – Socket H-pile

- Predrilling work
  - Pile tip of every working pile should be within 5m from predrilling hole
  - Sunk into rock for at least 5m below rockhead or the designed socket length, whichever is deeper



Common Pile Types in HK (Cont'd) – Socket H-pile



Common Pile Types in HK (Cont'd) – Socket H-pile

- Test boring as required in BD Approval Letter (under BD inspection)
  - Drill hole and install 610 mm diameter temporary casing by Odex or Ring Bit Method
  - Form rock socket by Down-the-Hole hammer
  - Carry out air-lifting to the hole and install H-pile
  - H-pile connection to be tested by laboratory
  - Grout the hole and withdraw the temporary casing

Common Pile Types in HK (Cont'd) – Socket H-pile

Test Boring, welding casing, H-pile & Grouting

Common Pile Types in HK (Cont'd) – Socket H-pile

- Carry out other working piles with same procedures
- Post construction proof drilling
  - Verify rockhead profile after completion of piles
  - Number of drill holes
    - At least 2 for 100 piles or less
    - 1% of total number of piles if more than 100 piles
  - Location determined by RSE
  - Depth - 5m below rockhead or designed socket length of adjacent piles, whichever is deeper

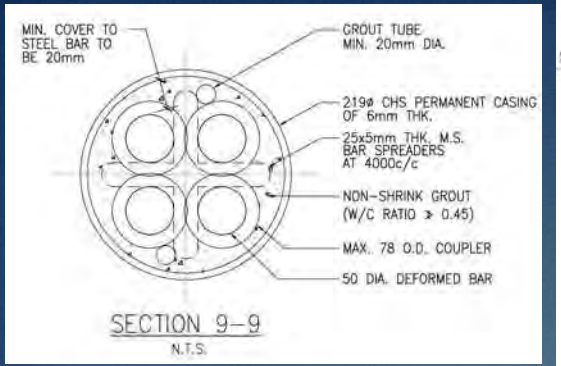
Common Pile Types in HK (Cont'd) – Socket H-pile

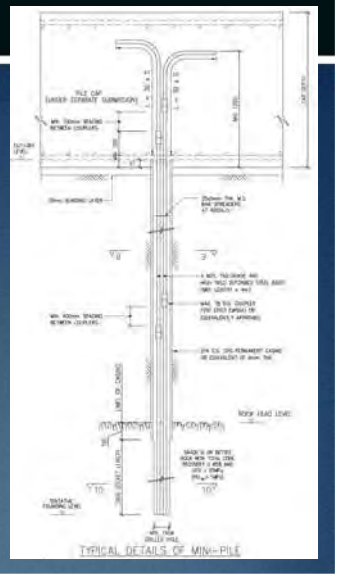
- Report completion to BD (for private projects)
  - Submit Form BA14, piling records & plan, mill certificates, test reports (incl. 28 days grout cube test), predrilling and post-drilling report, etc.
  - BD selects piles for loading test (normally 1% of total number of piles)
- Carry out loading test for 72 hours
- Submit loading test report to BD

Common Pile Types in HK (Cont'd) – Mini-pile

- Generally
  - Common size: 219 mm, 273 mm & 324 mm in diameter; with steel casings, rebars (normally Y40 or Y50) & cement grout
  - Requires relatively small mechanical plants
  - Suitable for sites with restricted working space or accessibility difficulties
  - Also with minimal environmental disturbance comparing with other types of piles
  - Raking mini-pile to be used for resisting lateral loads

Common Pile Types in HK (Cont'd) – Mini-pile





Common Pile Types in HK (Cont'd) – Mini-pile

- Predrilling work
  - Pile tip of every working pile should be within 5m from predrilling hole
  - Sunk into rock for at least 5m below rockhead or the designed socket length, whichever is deeper

Common Pile Types in HK (Cont'd) – Mini-pile

- Install test pile as required in BD Approval Letter (under BD inspection)
  - Drill hole and install permanent casing by Odex or Ring Bit Method
  - When rockhead is reached, form rock socket by down-the-hole method
  - Carry out air-lifting to the hole and install bundled together rebars into the drilled hole
  - Fill the hole with cement grout and with casing left in to provide protection to the pile

Common Pile Types in HK (Cont'd) – Mini-pile

Piling Rig for mini-pile

Rebar fixing

Common Pile Types in HK (Cont'd) – Mini-pile

Grouting after air-lifting and rebar installation

Common Pile Types in HK (Cont'd) – Mini-pile

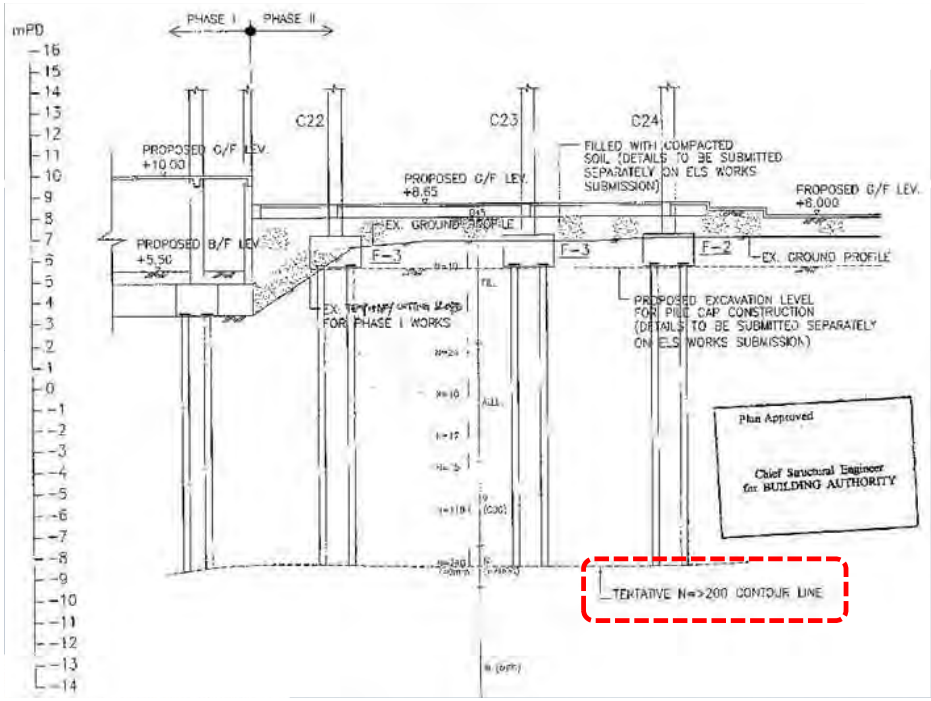
- Carry out other working piles with same procedures
- Post construction proof drilling
  - Verify rockhead profile after completion of piles
  - Number of drill holes
    - At least 2 for 100 piles or less
    - 1% of total number of piles if more than 100 piles.
  - Location determined by RSE
  - Depth - 5m below rockhead or designed socket length of adjacent piles, whichever is longer

Common Pile Types in HK (Cont'd) – Mini-pile

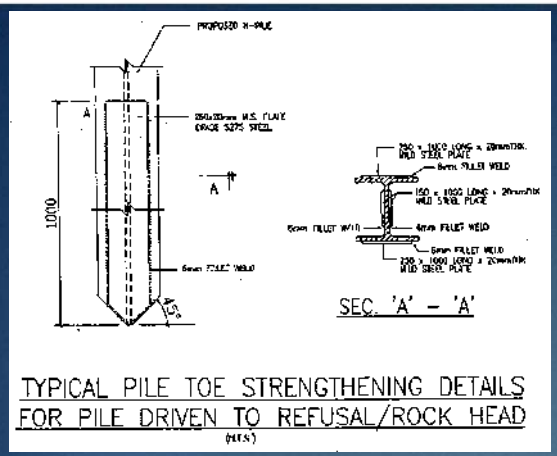
- Report completion to BD (for private projects)
  - Submit Form BA14, piling records & plan, mill certificates, test reports (incl. 28 days grout cube test), predrilling and post-drilling report, etc.
  - BD selects piles for loading test (normally 1% of total number of piles)
- Carry out loading test for 72 hours
- Submit loading test report to BD

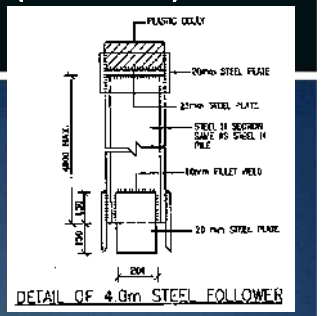
Common Pile Types in HK (Cont'd) – Driven H-pile

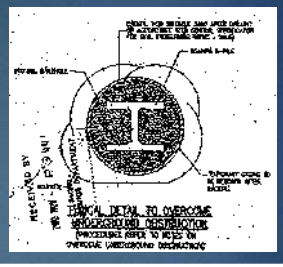
- Generally
  - One of the displacement piles
  - Driven in soils (Friction piles) or Driven to Bedrock
  - Common pile size:
    - 305 x 305 x 149kg/m
    - 305 x 305 x 180kg/m
    - 305 x 305 x 223 kg/m
  - May easily be damaged due to underground obstruction / boulders



Common Pile Types in HK (Cont'd) – Driven H-pile







Common Pile Types in HK (Cont'd) – Driven H-pile

- Generally (Cont'd)
  - Generates significant nuisance (noise & vibration) to neighbourhood
  - Noise Control for Percussive Piling work
  - Often driven by hydraulic hammers

	Weekdays	Sundays & Holidays
0700 Hours	Permits needed for Percussive Piling Unrestricted use of Powered Mechanical Equipment	
1900 Hours	No Percussive Piling	
0700 Hours	Permits needed for use of Powered Mechanical Equipment	

Common Pile Types in HK (Cont'd) – Driven H-pile

- Application of Construction Noise Permit (CNP) for Percussive Piling Works to EPD

Common Pile Types in HK (Cont'd) – Driven H-pile

- Predrilling work
  - Friction pile
    - No statutory requirements of predrilling for friction piles
    - Sufficient GI to determine tentative founding levels of piles
    - Normally, 10 to 20 for one block of building for normal ground condition
    - Additional bored holes at locations with boulder layers
    - Standard Penetration Test (SPT) N values - correlates the relative density of granular soils
    - Friction pile is designed to be driven to the level that SPT N value >200 (prepare tentative pile toe contour plan for SPT N value > 200)

Common Pile Types in HK (Cont'd) – Driven H-pile

- Predrilling work (Cont'd)
  - Driven to Bedrock
    - Predrilling is required by BD if driven to bedrock
    - Every working pile should be within 5m from predrilling hole
    - Prepare tentative pile toe contour plan using rockhead level
- Fabricate pile shoes according to approval drawings

Common Pile Types in HK (Cont'd) – Driven H-pile

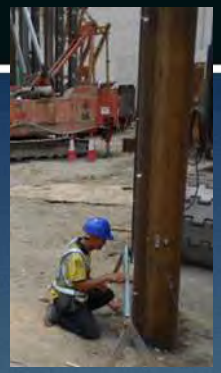
- Trial pile (under BD inspection)
  - Install trial pile
  - Carry out Pile Driving Analyzer (PDA) test by a HOKLAS accredited laboratory
  - Submit test pile Performance Review Report to BD
  - Upon satisfaction of the trial pile report, consent for working piles will be issued

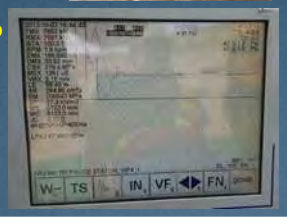
Common Pile Types in HK (Cont'd) – Driven H-pile

- Working piles
  - Set out pile location
  - Install 1st section of pile (set up steel guide frame if necessary to control the location and orientation)
  - Check verticality regularly

Common Pile Types in HK (Cont'd) – Driven H-pile

- Pile Driving Analyzer (PDA) test
  - Assess the structural integrity of pile and detect pile defects
  - Estimate the pile capacity
- For piles driven to bedrock - CAPWAP (CAse Pile Wave Analysis Program)






Common Pile Types in HK (Cont'd) – Driven H-pile

- Carry out H-piles connection
- Non-destructive weld test - visual inspection, magnetic particle inspection & Ultrasonic test



Common Pile Types in HK (Cont'd) – Driven H-pile

- Final setting
  - When pile is driven to the required depth and has achieved a low penetration rate, it can proceed to final setting
  - Hydraulic hammers are usually used for pitching while drop hammers are used for final setting for BD and HKHA projects
  - Hydraulic hammer is used for final setting for ASD projects

Common Pile Types in HK (Cont'd) – Driven H-pile

- Final setting
  - Hiley Formula
  - For friction pile - allowable maximum final set limit is designed not less than 25mm and not more than 50mm per 10 blows
  - For pile driven to bedrock - not more than 10mm per 10 blows

Common Pile Types in HK (Cont'd) – Driven H-pile

- Post construction proof drilling
  - Not required for friction piles
  - Required for piles driven to bedrock
  - Number of drill holes
    - At least 2 for 100 piles or less
    - 1% of total number of piles if more than 100 piles
  - Location determined by RSE
  - Depth - 5m below rockhead or designed socket length of adjacent piles, whichever is deeper

Common Pile Types in HK (Cont'd) – Driven H-pile

- Report completion to BD(for private projects)
  - Submit Form BA14, piling records & plan, mill certificates, final set record, test reports, predrilling and post-drilling report, etc.
  - BD selects piles for loading test (normally 1% of total number of piles)
- Carry out loading test for 72 hours
- Submit loading test report to BD

Common Pile Types in HK (Cont'd) – Driven H-pile

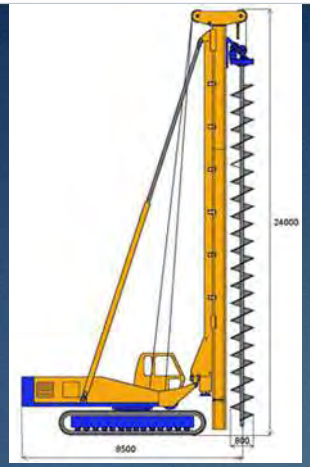
Common Pile Types in HK (Cont'd) – Driven H-pile

- Other Issues
  - Limited piling hours (assessed by EPD)
  - Pile damage - high if bedrock profile is sloping
  - Pile offset and verticality
  - Effect on existing structures, roads, utilities adjacent to site
  - Nuisance to Public
  - Final set by hydraulic hammer in lieu of drop hammer due to safety reason

Common Pile Types in HK (Cont'd) – Pakt-in-Place pile

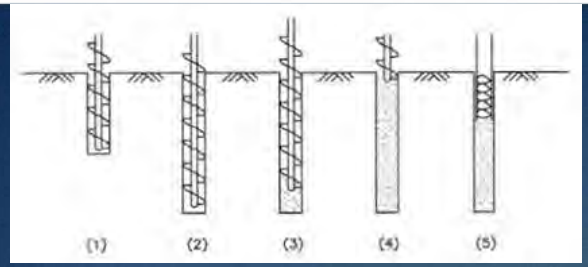
- Generally
  - Using auger drilling method.
  - Most common PIP pile sizes is 610mm diameter
  - Ending bearing and friction between the pile and soil
  - Major advantage: no pneumatic tools and hence is virtually vibration free
  - It is therefore suitable for sites in urban areas where sensitive structures exist in close proximity
  - Ineffective and costly in overcoming underground obstructions and boulders

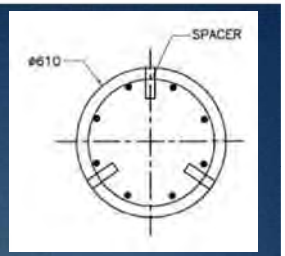
Common Pile Types in HK (Cont'd) – Pakt-in-Place pile



Auger flight

Common Pile Types in HK (Cont'd) – Pakt-in-Place pile





(1) Boring by a continuous flight auger machine
(2) Until the required depth is reached
(3) Inject cement grout into the drillhole; the auger is rotated in the reversed direction and slowly lifted up
(4) Pile is filled with the mortar
(5) Reinforcement cage is lowered into the fluid mortar

Common Pile Types in HK (Cont'd) – Pakt-in-Place pile

Boring by flight auger

Common Pile Types in HK (Cont'd) – Pakt-in-Place pile

3. Foundation Contractor's Consideration in Pricing

Foundation Contractor's Consideration in Pricing

- How to complete the foundation work?
  - Scope
  - Site location / condition
  - Resources / Productivity
  - Construction time / period & LD
  - Risk / difficulties
  - Other Factors

Foundation Contractor's Consideration in Pricing (Cont'd)

- Scope
  - To include design or not ?
  - Extent of works
    - Types & number of piles
    - Pile location & distribution of piles

Foundation Contractor's Consideration in Pricing (Cont'd)

- Site location / condition
  - Location of the Site
  - Access
  - Overall site arrangement / Logistics
  - Adjacent building, structures, etc.
  - Site and working conditions
    - size, shape
  - Scheduled Areas
  - Any constraints (e.g. environmental concern, working hours)

Foundation Contractor's Consideration in Pricing (Cont'd)

- Resources & Productivity
  - Plant / Equipment / Labour
  - Production rate per day
  - Underground condition
- Construction time/period & LD
  - Time for design or design amendment
  - Submission for approval
  - Construction time
  - High/low LD amount?

Foundation Contractor's Consideration in Pricing (Cont'd)

- Risk / Difficulties
- Other Factors
  - Market condition
  - Financial capability
  - Type of Contract (Lump sum with or w/o quantities)
  - Reputation of the Employer and Consultants
  - Measurement method

4. Risks / Difficulties in Piling Works

Risks / Difficulties in Piling Works

- Generally, risks / difficulties significantly affect the following:
  - Production Rate
  - Construction Period
  - Resources Availability
- Issues include: Design Issues, Scheduled Areas, Site Access / Location / Condition, Underground Condition, Contract period, Market condition / resources, Construction details

Risks / Difficulties – Design Issues (Cont'd)

- Design and submission time
  - Foundation Plan BD Submission Procedures
    - Piling Plan Submission to BD by RSE, may need RGE involvement for complicated ground condition
    - Piling Plan approval time by BD
      - 1st submission - 60 days
      - Major amendment after approval - 60 days
      - Minor amendment - 30 days
    - Obtain Piling Consent from BD (Submission of Form BA8)
      - 28 days for approval
      - May require submission of Public Relationship Plan / Condition Survey

Risks / Difficulties – Design Issues (Cont'd)

- Originally designed piles not feasible
  - E.g. due to pile type, resources, size, etc.
- Design of temporary work
  - Temporary platform
  - Shoring
  - ELS
- Design & build other works

Risks / Difficulties – Design Issues (Cont'd)

- Pile sizes and distribution to be affected by Rigid cap / Flexible cap design issue
  - Rigid cap
    - Arrange the piles to the edge of the cap to obtain larger stiffness
    - Less piles but more reinforcement at cap
  - Flexible cap
    - Arrange pile near the column/wall
    - More piles but less reinforcement at cap

Risks / Difficulties – Scheduled Areas

- One of the Control Systems under Buildings Ordinance
- Defined in the Fifth Schedule of the Buildings Ordinance
- More specific consideration may be needed in various building operations, including site investigation, design and construction phases of foundation installations

- Website : http://www.bd.gov.hk/english/ScheduledAreas.html

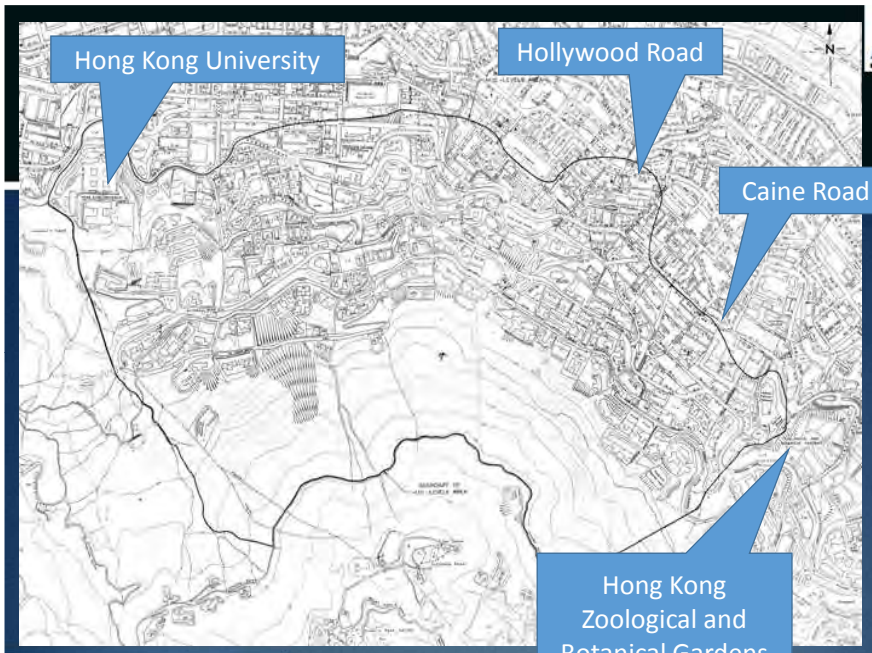
Risks / Difficulties – Scheduled Areas (Cont'd)

- Area 1 - Mid-levels
- Area 2 - North-western New Territories
- Area 3 - MTR Protection Area
- Area 4 - Ma On Shan
- Area 5 - Sewage Tunnel Protection Areas

- Designated Area of Northshore Lantau

Risks / Difficulties – Scheduled Areas (Cont'd)

- Area 1 - Mid-levels
  - PNAP APP-30/ PNAP 85
  - Located in the region of sloping ground - RGE involvement in particular at the early planning stage of the building works
  - GI work - prior approval and consent from the Building Authority
  - Foundation plan to be submitted with the site formation plan - due consideration to effects on the stability of the hillside



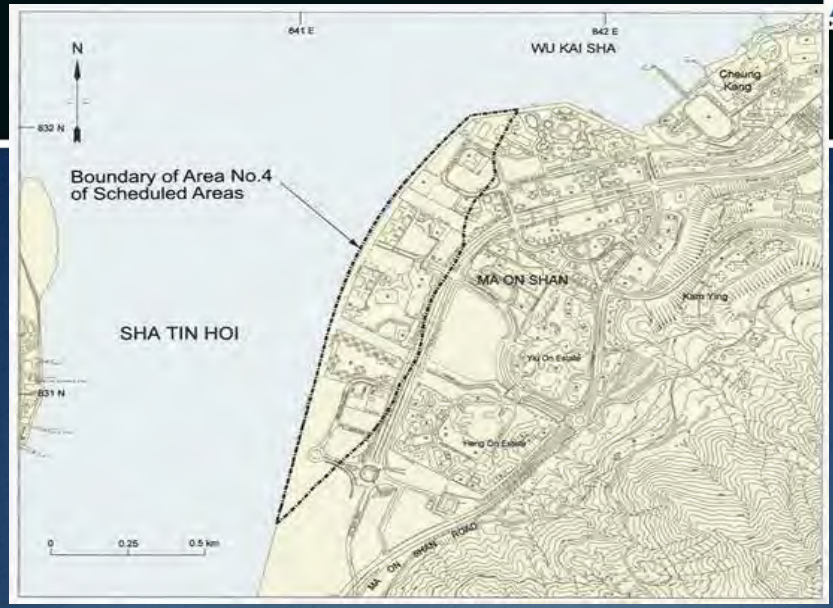
Risks / Difficulties – Scheduled Areas (Cont'd)

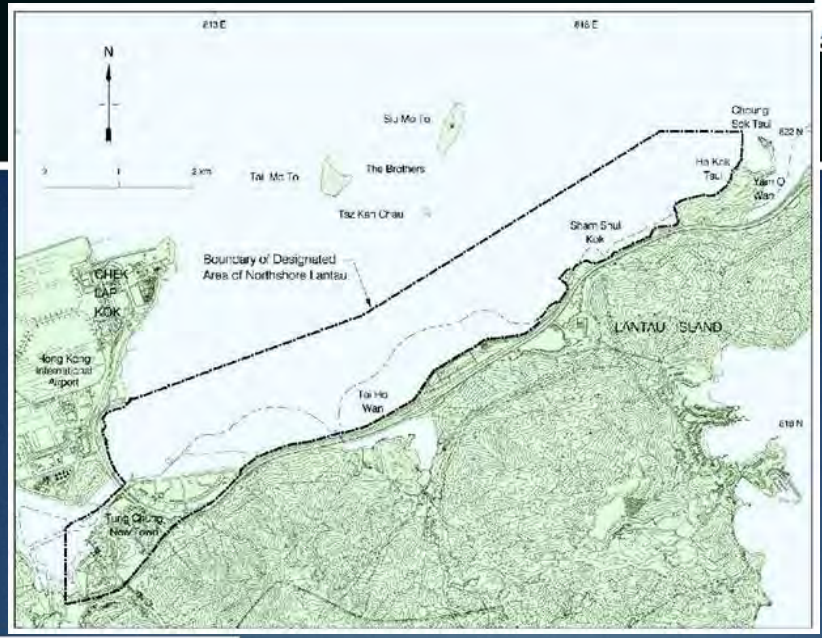
- Area 1 - Mid-levels (Cont'd)
  - In Sloping Ground / Slope
    - Stability of the affected slope
    - Retaining structure
    - Temporary platform required
    - More piles to support lateral forces

Risks / Difficulties – Scheduled Areas (Cont'd)

- Area 2 - North-western New Territories / Area 4 - Ma On Shan / Designated Area of Northshore Lantau
  - PNAP APP-61 / PNAP 161
  - Technical Circular (Works) No. 4/2004

  - Ma On Shan, Yuen Long and Tuen Mun
  - Tung Chung





Risks / Difficulties – Scheduled Areas (Cont'd)

- Area 2 NW NT / Area 4 Ma On Shan (Cont'd)
  - Superficial deposits overlying metamorphosed sedimentary strata (siltstones, sandstones and marble) as well as igneous rocks表面沉積物覆蓋的變質沉積地層（粉砂岩、砂岩和大理岩）以及火成岩
  - Marble usually has a karstic upper surface with solution features 有溶液迹象的岩溶
  - Large cavities occur within the marble in some locations 有體積較大的溶洞

Risks / Difficulties – Scheduled Areas (Cont'd)

- Area 2 NW NT / Area 4 Ma On Shan (Cont'd)
  - Underground Channel
  - Ground investigations, excavations, foundations or groundwater pumping may encounter significant difficulties
  - RGE early involvement is essential - in planning and assessment of GI results
- Designated Area of Northshore Lantau
  - Complex geological conditions
  - Cavities; Deep, or steeply inclined, rockhead

Risks / Difficulties – Scheduled Areas (Cont'd)

- Area 2 NW NT / Area 4 Ma On Shan (Cont'd)
  - Special requirement in GI works
    - GI plan - prior approval and consent from the BA
    - Carry out GI in stages
      - Initial stages of the GI prior to the finalization of general layout plans
      - In certain circumstances, adjustments to the locations of certain structures
      - Further investigation normally be required once the layout of the development and locations of piles be decided
      - Allowance should be made in the project programme and cost estimates in this respect

Risks / Difficulties – Scheduled Areas (Cont'd)

- Area 2 NW NT / Area 4 Ma On Shan (Cont'd)
  - Special requirement in GI works (Cont'd)
    - Extensive enough to ascertain whether marble with cavities exists beneath the site or complex geological conditions
    - Some deep boreholes will be required
    - A minimum penetration of 20 m into sound marble rock

Risks / Difficulties – Scheduled Areas (Cont'd)

- Area 2 NW NT / Area 4 Ma On Shan (Cont'd)
  - Foundation Design & Construction
    - For heavy structures on sites underlain by marble, driven or machine-bored piles will usually be the most suitable foundation
    - For low-rise buildings and structures with, small-diameter cast-in-place piles founded in soil well above the of the marble top can be used

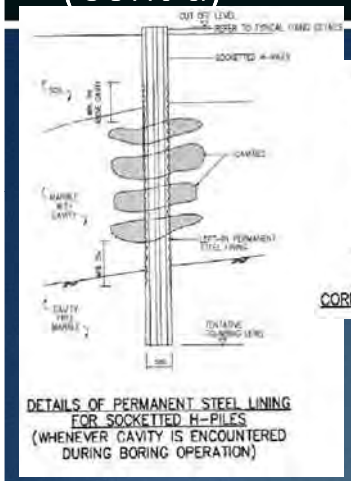
Risks / Difficulties – Scheduled Areas (Cont'd)

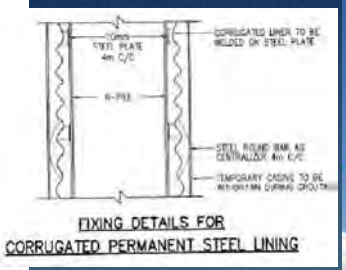
- Area 2 NW NT / Area 4 Ma On Shan (Cont'd)
  - Foundation Design & Construction (Cont'd)
    - For driven piles
      - Suitably heavy section to withstand hard driving and with modified or strengthened shoes
      - Pre-drilling may be necessary when very deep bedrock is expected, or when the piles have to penetrate a thick karst zone
      - As it is not possible to determine the exact extent and configuration of subsurface cavities, it is therefore necessary to increase the number of piles to be used above the minimum

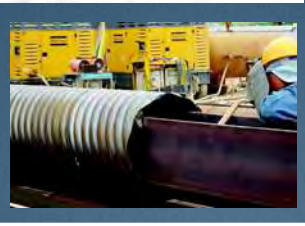
Risks / Difficulties – Scheduled Areas (Cont'd)

- Area 2 NW NT / Area 4 Ma On Shan (Cont'd)
  - Foundation Design & Construction (Cont'd)
    - For high capacity bored piles
      - Effect of cavities to be considered (below both the plan & surrounding area)
    - Overcome underground obstruction / Karst Cobbles obstruction
      - Preboring
      - Minimize vibration effect
      - Backfill with sand after preboring

Risks / Difficulties – Scheduled Areas (Cont'd)







Risks / Difficulties – Scheduled Areas (Cont'd)

- Area 2 NW NT / Area 4 Ma On Shan (Cont'd)
  - Foundation Design & Construction (Cont'd)
    - Vibration assessment
      - During piling activities
      - Monitor / control effect on surrounding structures
  - Site Supervision for GI & Foundation Works
    - Be supervised full-time by a suitably experienced engineer/engineering geologist or technical supervisory personnel
    - Qualified geotechnical engineer to conduct periodic inspections

Risks / Difficulties – Scheduled Areas (Cont'd)

- Area 2 NW NT / Area 4 Ma On Shan (Cont'd)
  - Performance review
    - Ground conditions experienced
    - Assessment of pile driving or construction records
    - To demonstrate the foundation works have been adequately inspected & construction records adequately assessed - then, consent to commence superstructure works

Risks / Difficulties – Scheduled Areas (Cont'd)

- Area 3 - MTR Protection Area / Area 5 - Sewage Tunnel Protection Areas
  - Area 3 - PNAP APP-24/ PNAP 77
    - Protection boundary is about 30m outside the outer surface of the MTR structure
    - No pile, foundation, borehole, well, soil nail, horizontal drain or other geotechnical installation should be driven or constructed within a distance of 3m from the underground railway structures
    - When required by the MTRCL, to monitor any movement and vibration on the railway structures by AP/RSE/RGE

Risks / Difficulties – Scheduled Areas (Cont'd)

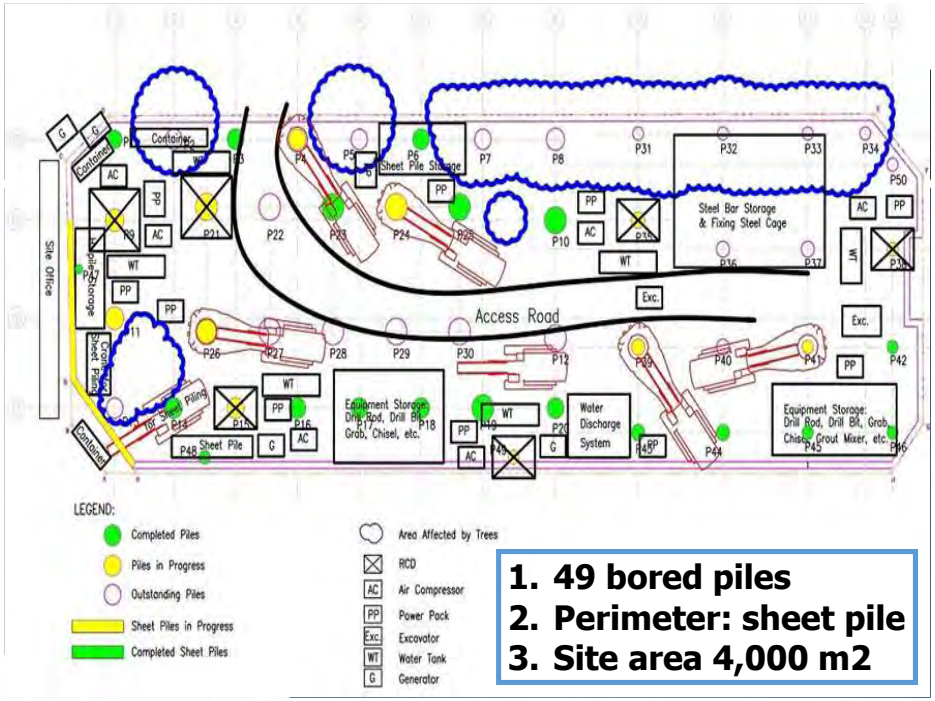
- Area 3 - MTR / Area 5 Sewage Protection (Cont'd)
  - Area 5 - PNAP APP-62 / PNAP 165
    - New building within 100 m from centreline of the route of sewage tunnels shall be subject to scrutiny by Government Departments
    - No holes or excavations shall be sunk or excavated within a distance of 3m from sewage tunnel structure without prior approval by BA
    - No pile, foundation or well shall be driven or constructed within 3m of any sewage tunnel structure

Risks / Difficulties – Scheduled Areas (Cont'd)

- Area 3 - MTR / Area 5 Sewage Protection (Cont'd)
  - Area 5 (Cont'd)
    - If proposed works within 10m from any sewage tunnel structure
      - Detailed method statements submission for constructing the proposed works
      - Monitoring the alignment/depth of the proposed works
    - No holes should be sunk or excavated within a 3m from any point of any sewage tunnel
    - GI work - prior approval and consent from the Building Authority

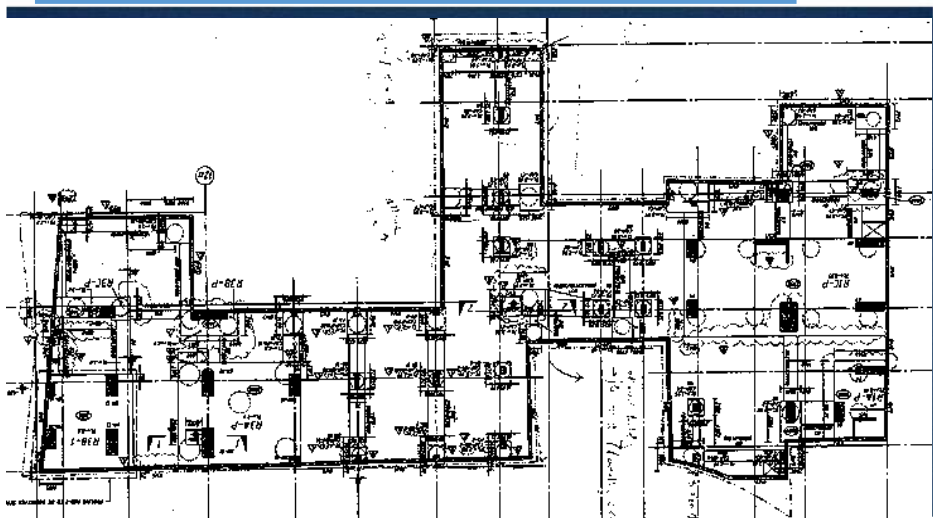
Risks / Difficulties – Site Access / Location / Condition

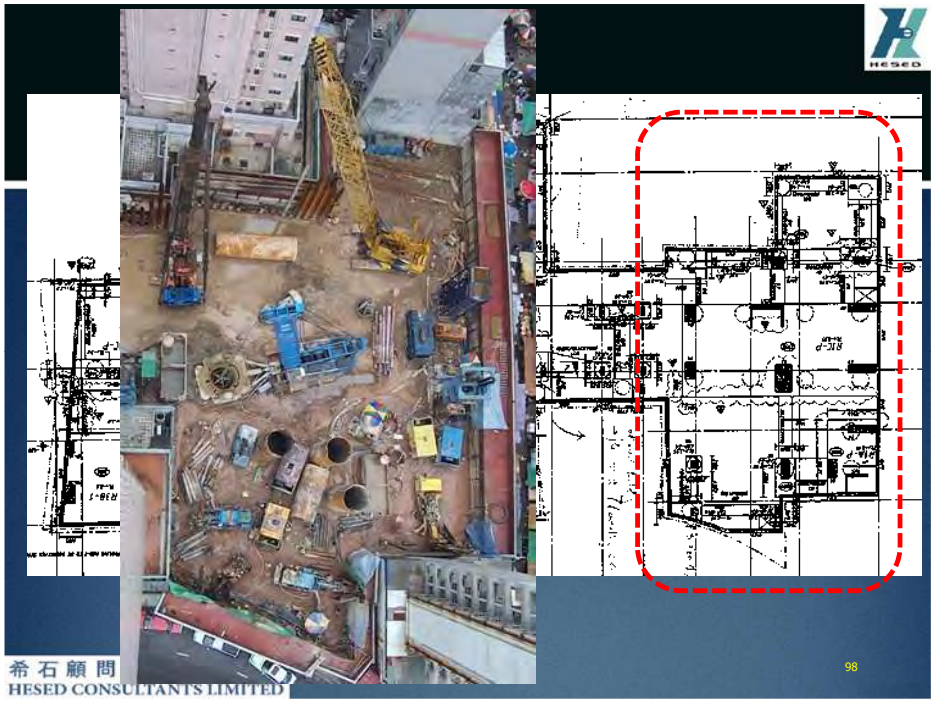
- Site area / shape
- Access
  - Number, width, location, headroom
  - Allowance for others to use
  - Through other contractor's access
  - Emergency access to be maintained
- Busy area / traffic
- Close to adjoining building / residential area

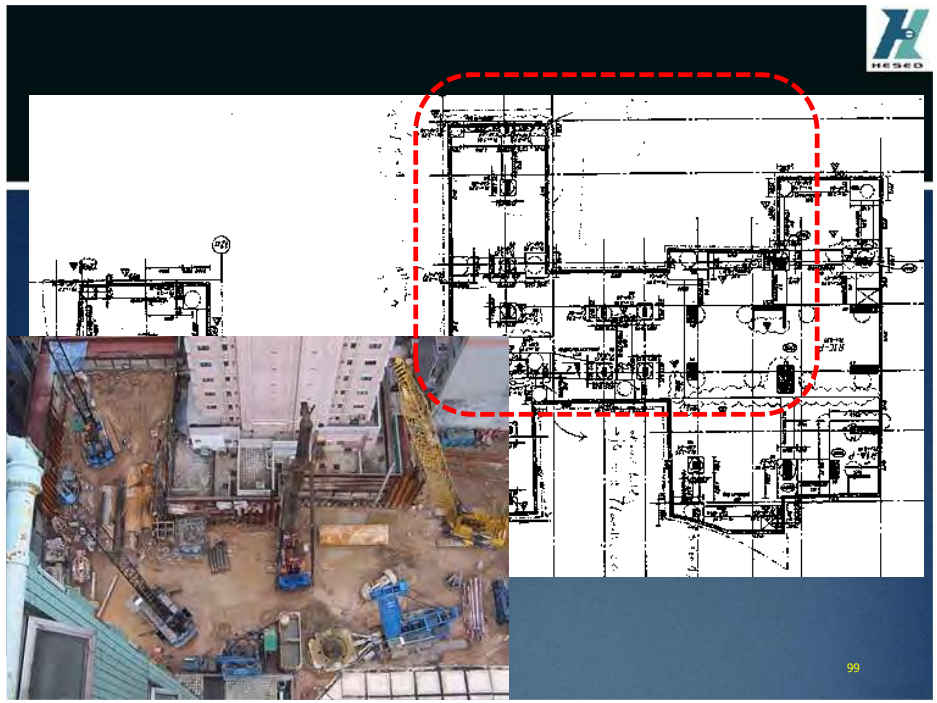


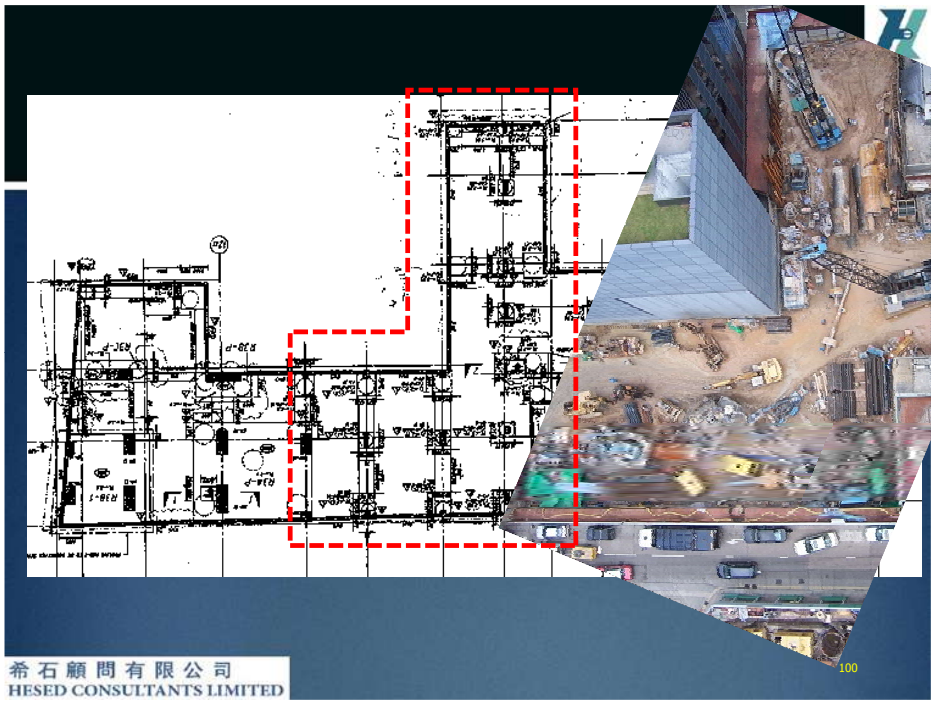
1. **49 bored piles**
2. **Perimeter: sheet pile**
3. **Site area 4,000 m2**

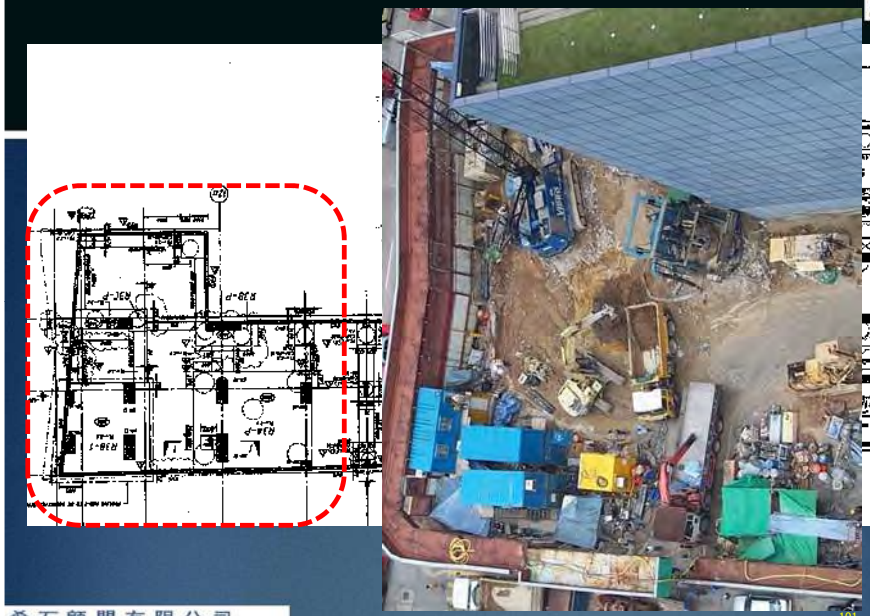
1. Congested Site with Irregular Shape
2. 54 bored piles
3. Perimeter: pipe/sheet piles
4. Site area 3,600 m2



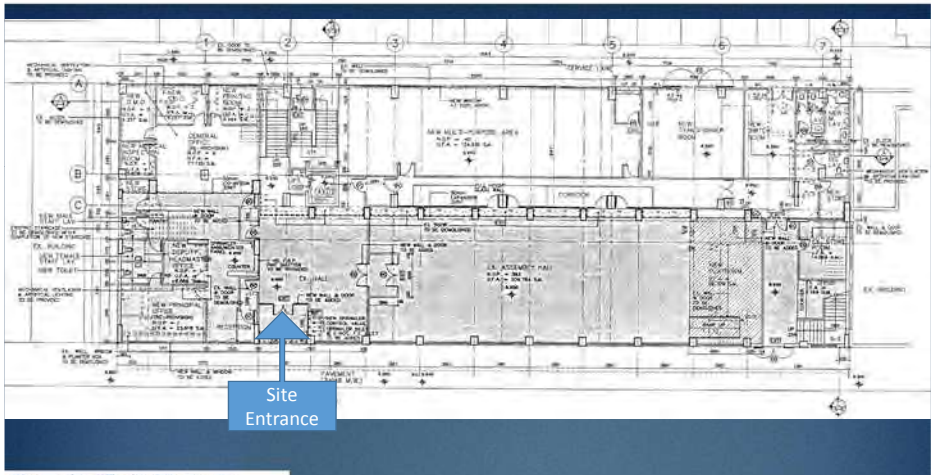




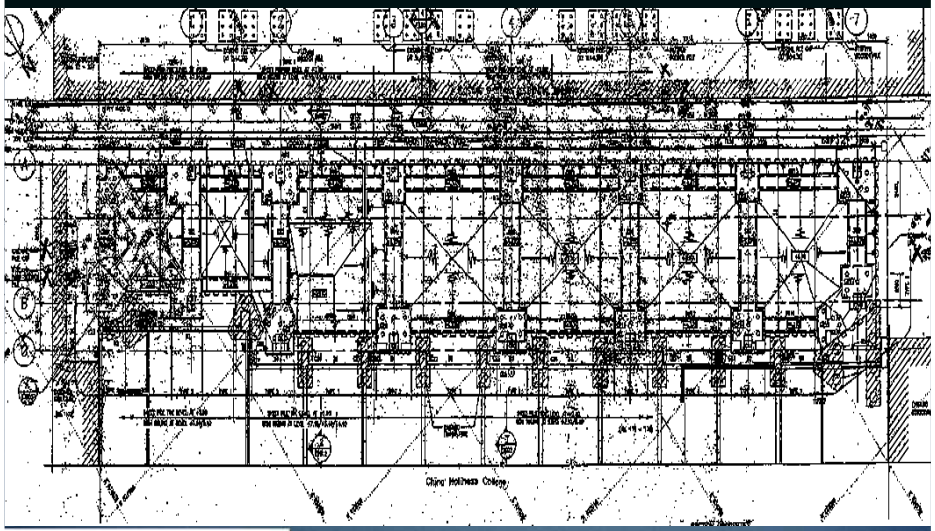


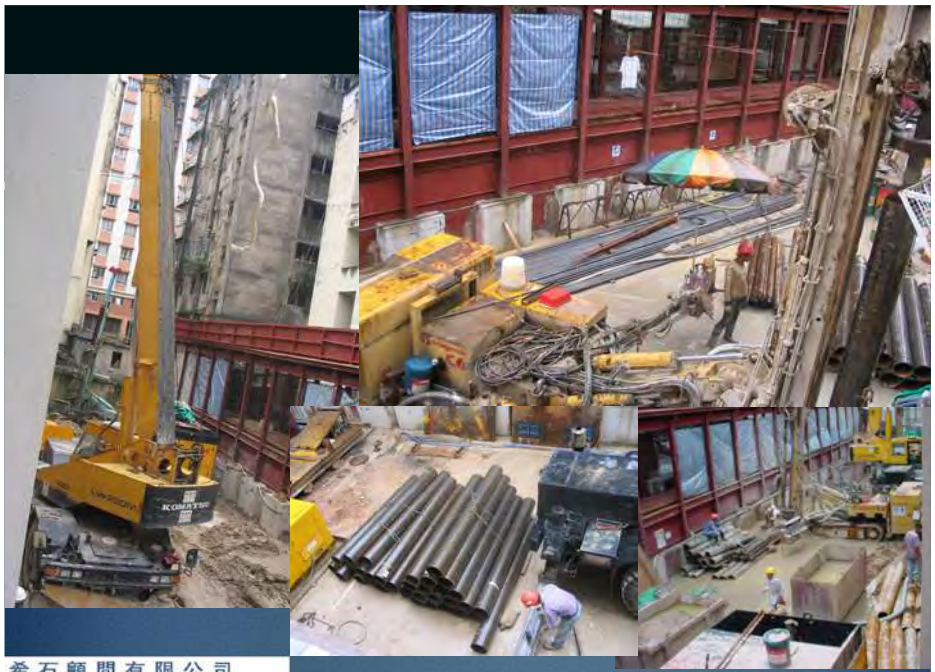


1. Narrow site
2. Site area 430 m2
3. Site entrance through existing building



1. 76 mini-piles
2. Difficulty in loading test





Risks / Difficulties – Site Access / Condition (Cont'd)

- Existing elements / structures affecting construction
  - Existing pile cap / piles
    - Re-access the capacity of existing pile for re-use
    - Select space for new pile location in particular the H-pile
  - Existing sea wall
  - Existing tree - Tree preservation & protection
  - Overhead cables
  - Presence of utilities
    - Utilities diversion
    - Temporary drainage / utilities, etc.

Risks / Difficulties – Site Access / Condition (Cont'd)

- Slope
- Temporary platform for piling work
  - Formed by soil / hardcore / concrete block
  - Bamboo / timber platform
  - Steel platform
  - Usually, it is "design & build" by contractor
- Reserve Area (drainage, tunnel protection area, etc.)
- Water source
- Ground water table

Risks / Difficulties - Underground Condition

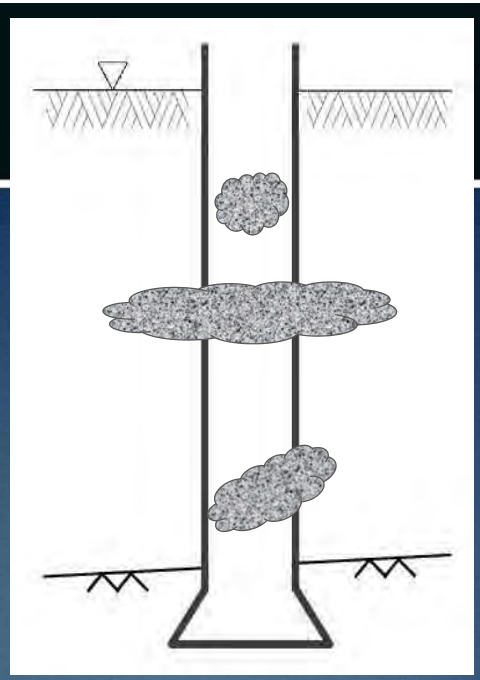
- Complicated geology
- Bedrock too low
- Found on Grade II rock (7500 kPa)
- Steep bedrock profile
  - Founding levels of adjacent piles should not differ by more than the clear distance between the pile bases
  - Unless the stability of rock under the piles are checked by considering existence of any adverse joints
  - Extra / Additional pile length

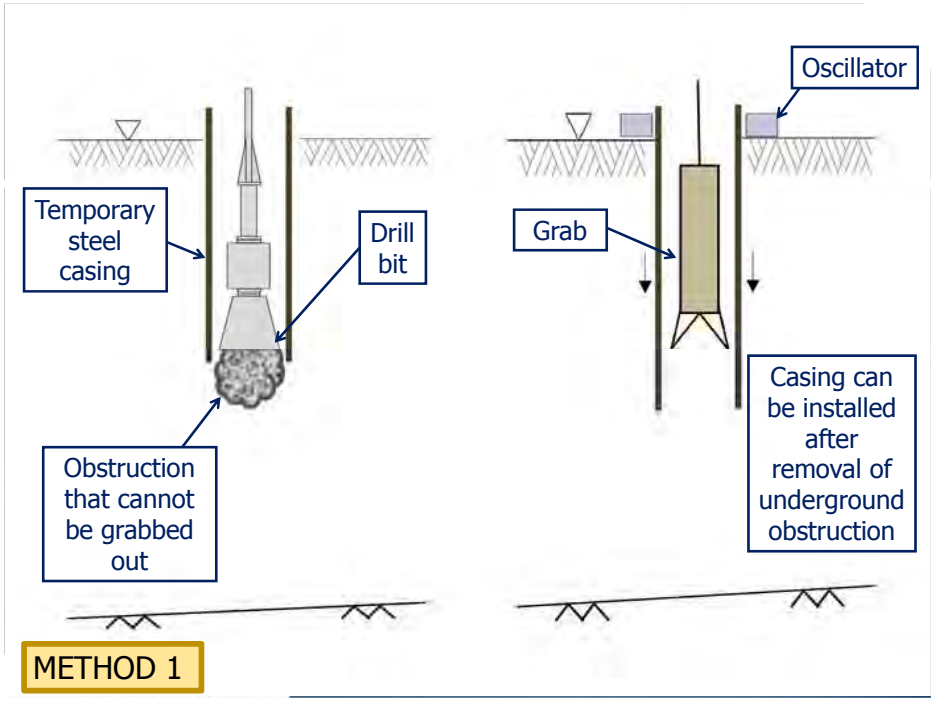
Risks / Difficulties - Underground Condition (Cont'd)

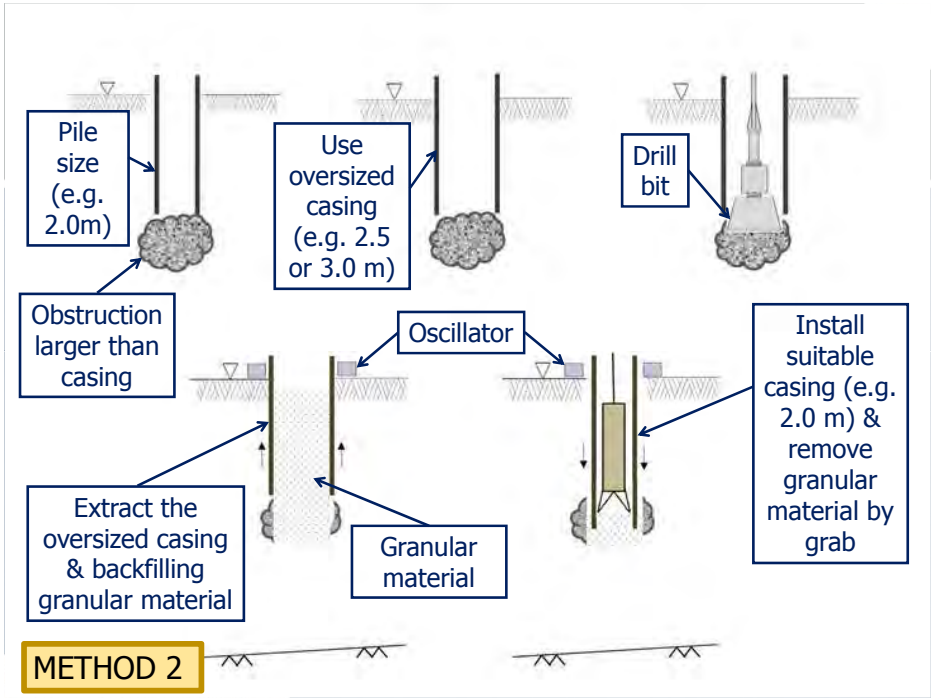
- Presence of boulders
  - Location / depth
  - Additional boulder removal cost / time by various methods (e.g. telescopic oversized casing method) for bored piling work
  - If driven pile (e.g. H-pile / PPC piles), allowance for damaged pile

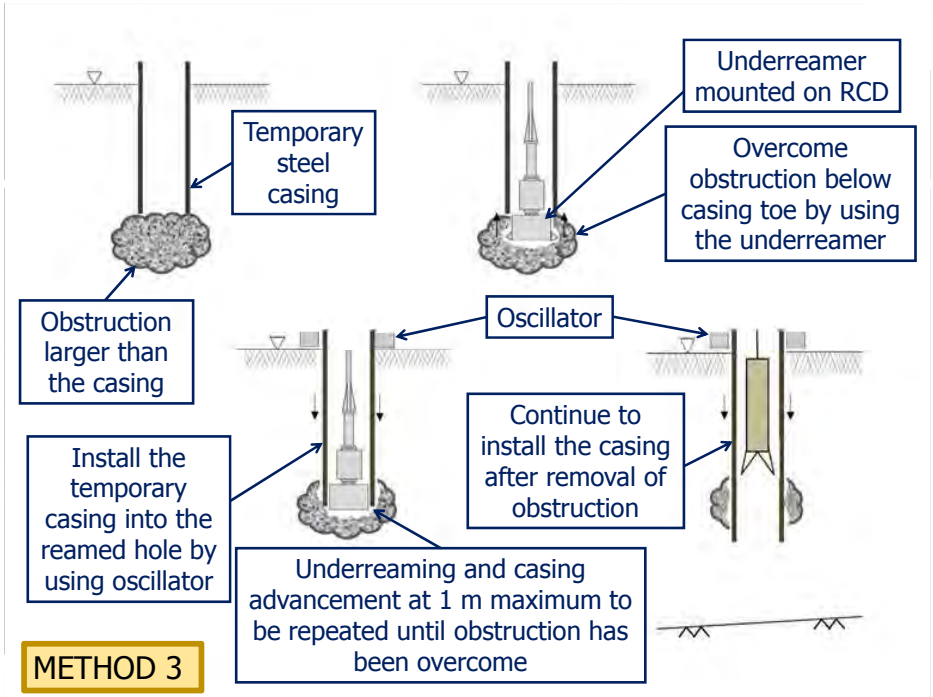
Bored Piling Work

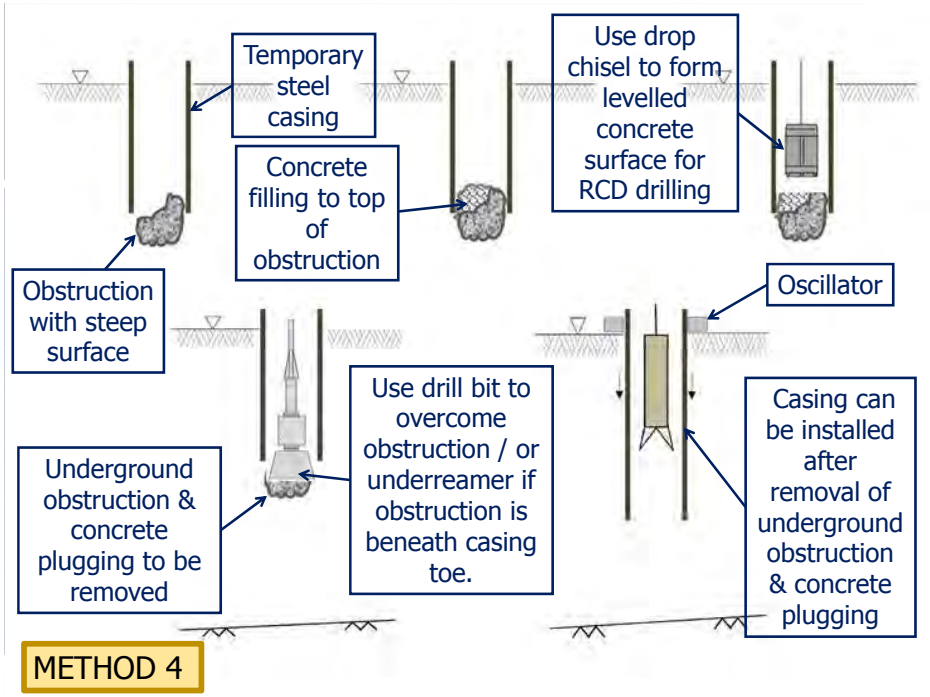
Methods for overcoming underground obstruction







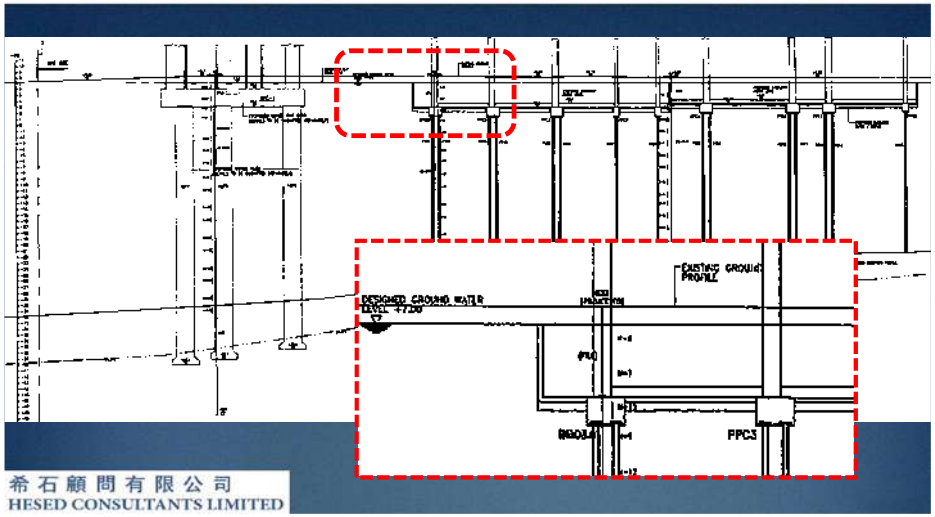




Risks / Difficulties - Construction Detail & Issue

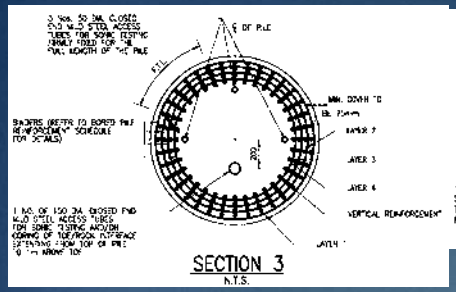
- Deep cut-off level (for basement)
  - Pile offset and verticality
  - Longer construction period
  - Higher costs of labour & plant (drive, weld, etc.)
  - Higher material cost / wastage
  - Extra work in loading test
  - Required further handling during pile cap construction period

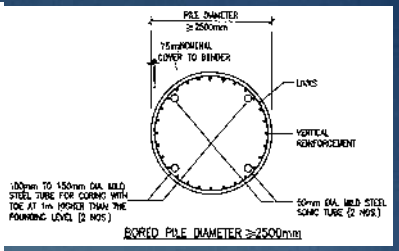
Risks / Difficulties - Construction Detail & Issue (Cont'd)



Risks / Difficulties - Construction Detail & Issue (Cont'd)

- Bored pile - heavy reinforcement
  - Increased difficulty in fixing & installation





Multi-layer Steel Cage

Single-layer Steel Cage

Risks / Difficulties - Construction Detail & Issue (Cont'd)

Risks / Difficulties - Contract Period & Market Condition

- Insufficient contract period
- High LD
- Fluctuation cost for long construction period
- Market condition – too busy of construction works
  - Extra cost to be incurred for further subletting, external plant hire, etc.

Risks / Difficulties - Other Constraint / Considerations

- High wastage of material, e.g. H-pile
- Historical feature to be protected
- Stringent EM&A requirement
- Comprising other trade of works
  - e.g. site formation, ELS, basement, waterproofing, etc.
- Phased handover of site to foundation contractor
- Partial area of site to be early handover to Employer
- Project scale - too large / small

5. Estimate of Foundation Cost

Estimate of Foundation Cost

Different stages & its Estimating Method

- Inception & Feasibility stages
  - Preliminary Cost Estimate - Project cost
  - Information : site location & area, project details (e.g. type, plot ratio, GFA/CFA, height limit)
  - Piling ratio
- Outline Proposal
  - Elemental Cost Estimate – Foundation / piling cost
  - Information: general layout, building shape, no. of storey, preliminary ground investigation information
  - Pile type and estimated number of piles

Estimate of Foundation Cost (Cont'd)

Different stages & its Estimating Method (Cont'd)

- Scheme Design
  - Cost Plan – Foundation / piling cost
  - Detailed foundation information and design
  - Pile type, scope, extent determined
  - Approximate quantity
- Tender
  - Pre-Tender Cost Estimate
  - Complete design
  - Detailed BQ / SOR

Estimate of Foundation Cost (Cont'd)

Estimating Method

- By area (CFA)
- By loading
- By measured items
- By furthering considering the above risks / difficulties factors from contractor's side
- Seeking advices from / collaboration with Engineer

Estimate of Foundation Cost (Cont'd)

Average Piling Ratio - Bored Piles

Building Type	m² CFA / m² cross section area of piles
Residential	200 - 300
Office / Commercial	200 - 250
Hotel	200 - 300

Average Piling Ratio - Driven H-Piles

Building Type	m² CFA / No. of piles
Residential	50 - 90
Office / Commercial	50 - 80
Hotel	50 - 90

Average Piling Ratio - Pre-Bored H-Piles

Building Type	m² CFA / No. of piles
Residential	70 - 120
Office / Commercial	70 - 110
Hotel	70 - 120

All pile ratios are for high-rise buildings with normal soil conditions.

- Source: Langdon & Seah, 2016

Estimate of Foundation Cost (Cont'd)

Pile Type	Size	Load Carrying Capacity
Large Diameter Bored Pile	2000 mm diameter 2300 mm diameter 2500 mm diameter 2750 mm diameter	35,300 KN 46,700 KN 55,200 KN 69,200 KN
Driven Steel H-pile	305 x 305 x 149 kg/m 305 x 305 x 180 kg/m 305 x 305 x 223 kg/m	2,450 KN 2,950 KN 3,650 KN
Socketed Steel H-pile	305 x 305 x 180 kg/m 305 x 305 x 223 kg/m	4,900 KN 6,100 KN
Mini-pile	219 mm diameter 273 mm diameter	1,370 KN 1,900 KN
PIP pile	610 mm diameter	1,460 KN

Estimate of Foundation Cost (Cont'd)

Pile Type	Size	Cost (HK$/m run) *
Large diameter bored pile	2000 mm to 3000 mm diameter	29,000 – 67,000
Driven steel H-pile	305 x 305 x 180 or 223kg/m	3,500 – 5,300
Socketed steel H-pile	305 x 305 x 180 or 223kg/m	5,500 – 8,900
Mini-pile	219/273 mm diameter	4,700 – 6,000
Pakt-in-place pile	610 mm diameter	2,000 – 2,500

* From developer's perspective; excluding preliminaries

Estimate of Foundation Cost (Cont'd) Illustrated Example 1

Commercial building:

- Site area 4,000 m2; Plot ratio 8;
- Bedrock: 50 m below existing ground level;
- 2.0 m diameter bored pile be used (cross sectional area = 3.1416 x 2.0 x 2.0 / 4 = 3.1416 m2)

GFA: 4,000 m2 x 8 = 32,000 m2

CFA: 32,000 m2 x 1.2 (say) = 38,400 m2 (approx.)

2.0 m dia. bored pile: 38,400 / 225 / 3.1416 = 55 Nos.

55 Nos. x 50 m x HK$ 30,000/m = HK$82.5 M

Estimate of Foundation Cost (Cont'd) Illustrated Example 2

Educational building (with an adjacent slope):

- CFA 25,000 m2; Total load (D+L) 800,000 kN
- Bedrock: 25 m below existing ground level;
- 610 mm diameter Socket H-pile be used

No. of pile: 800,000 kN / 6,100 (pile capacity) / 50% efficiency = 263 No. (load bearing pile) [piling ratio 95]

263 Nos. x 25 m x HK$ 7,000/m = HK$46.025 M

Adjacent Slope?? Actually, 125 Nos. shear piles req'd!!!

Educational Building		CFA:	25,000	m2		
		Qty	Unit	Weight *	Total kN	
Dead loads	R.C. structure	14,000	m3	24.5	343,000	
	Window / cladding	3,100	m2	3	9,300	
	Partition	7,000	m2	2.2	15,400	
	Finishes	86,000	m2	0.875	75,250	
	Permanent equipment		Say		12,500	
	Fixtures, etc.	25,000	m2	0.5	12,500	
Imposed Loads		25,000	m2	4.5	112,500	
Increase of 1.25 (due to wind effect)			kN		145,113	
					725,563	
F.O.S.					1.1	
					798,119	
Then, say					800,000	kN
* kN/m3 or kN/m2						

6. Conclusions

Conclusions

1. **No hard and fast rules**
2. **Understand construction methods for different piling / foundation works**
3. **Observe plant and equipment used for various piling works during site visit**
4. **Consider and quantify the risks factors one by one in terms of money and time**
5. **Other issues / factors (such as contractual, procurement, measurement, etc.) should also be considered**

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Practical Considerations in Estimating the Foundation Cost in HK

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18 February 2016

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