A Short Course on

DEEP EXCAVATIONS

By

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Brisbane, Australia

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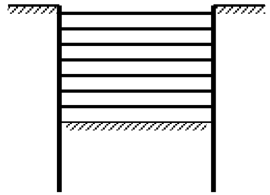
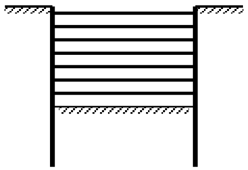


A robust design is the most important step towards a successful excavation.

2



A poor design brings…

Headache

Trouble

Disaster !!!

The end result is **cost over-run** and **time delay**!

3

Potential consequence of a poor design!

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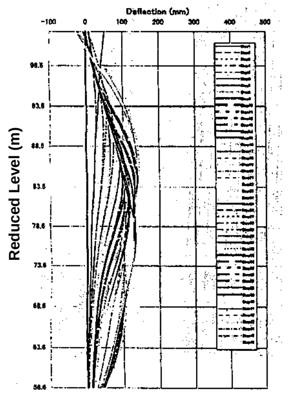
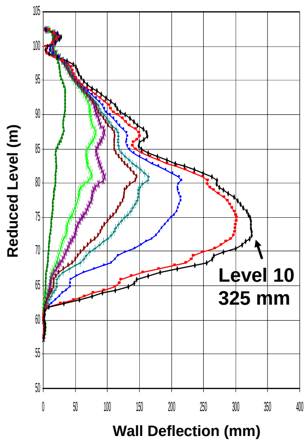
Comparison of Computed & Measured Wall Deflections

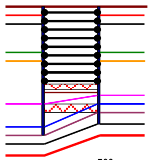
Computed using Method A



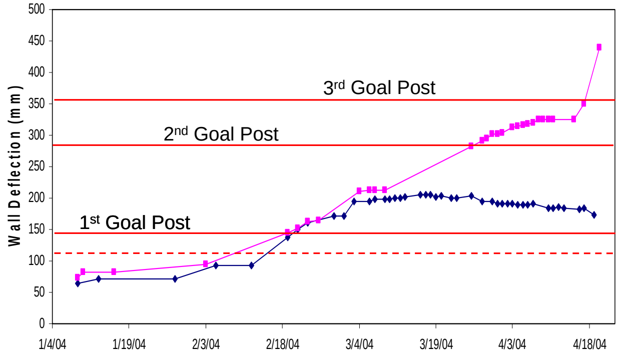
Measured



Formation = 118 mm
Final = 145 mm



Poor initial design resulted in many rounds of redesign and resetting of new goal posts



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Here is a quote from a local "authority" figure:

> "At least half of the FE analyses reviewed in Singapore contained major, fundamental errors."
>
> -- UGS2005

No wonder why we have so many failures and near failures in excavation related incidents in recent years!

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Lectures on Braced Excavation

- Overview
- Basal heave stability
- Uplift & toe stability
- Strut forces
- Bending moment
- Wall deflection and ground settlement
- Numerical modeling
- Mohr-Coulomb soil model
- Design issues
- Observational method
- Case Studies

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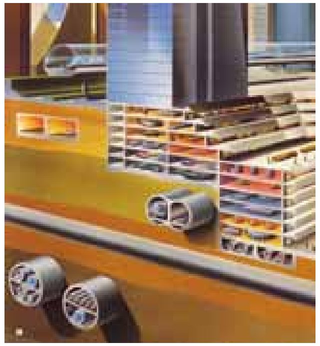

Overview of Braced Excavation

- Types of walls
- Methods of excavation
- Modes of failure

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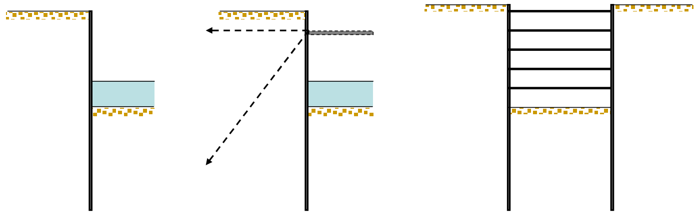
Types of Retaining Walls for Excavation



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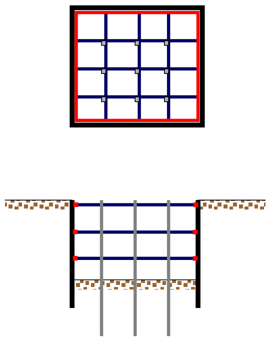
Wall Types of Deep Excavations



- ➢ Diaphragm Wall
- ➢ Sheetpile Wall
- ➢ Bored Pile Wall
- ➢ Soldier Pile Wall
- ➢ DCM or Grout Mixed Pile Wall

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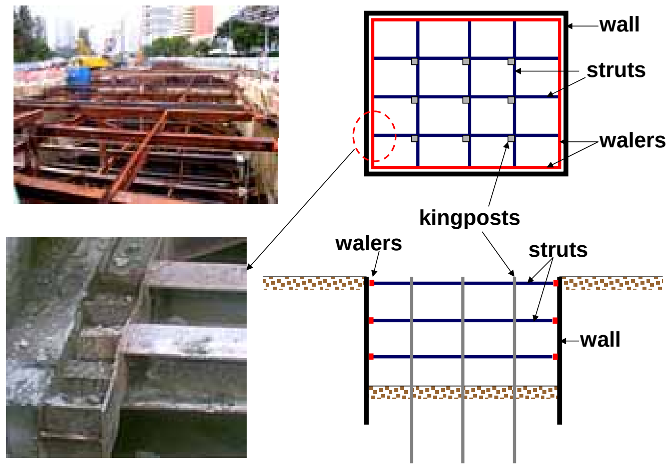
Braced Excavation with Diaphragm Wall



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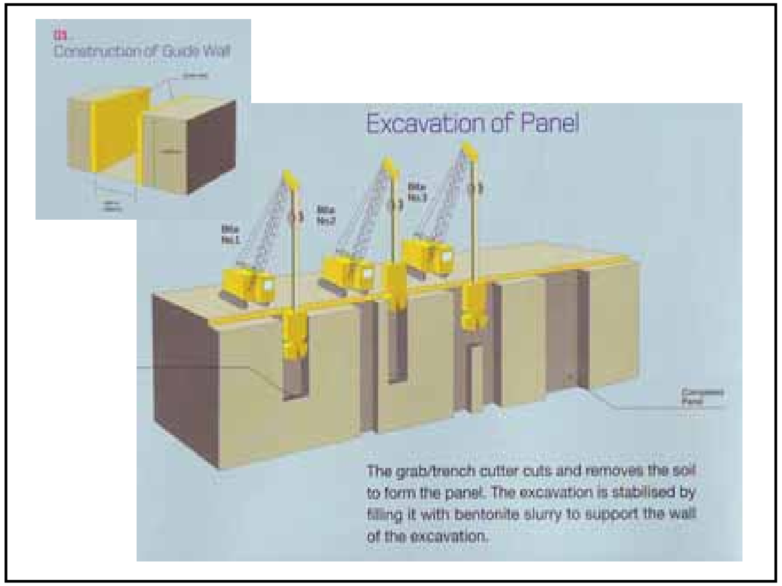

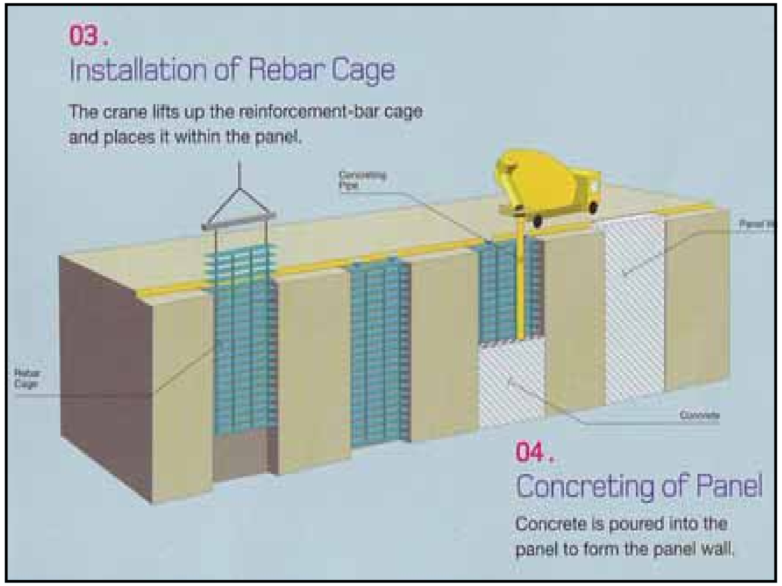

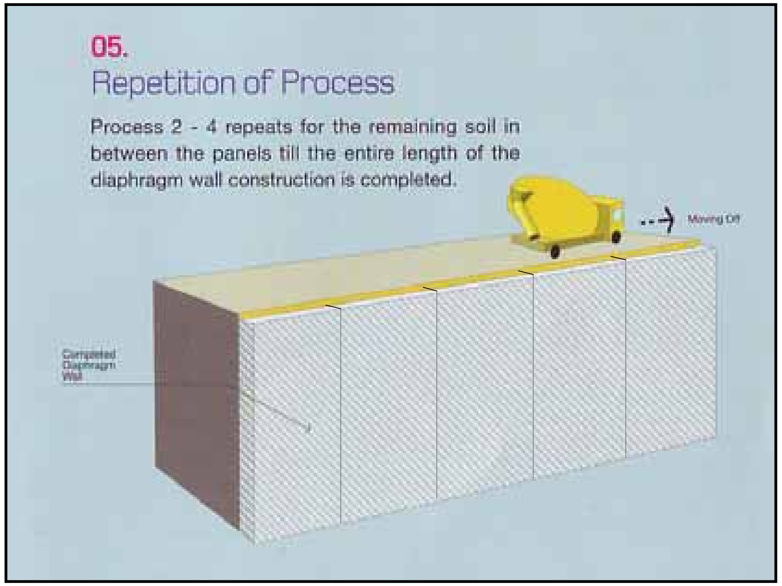

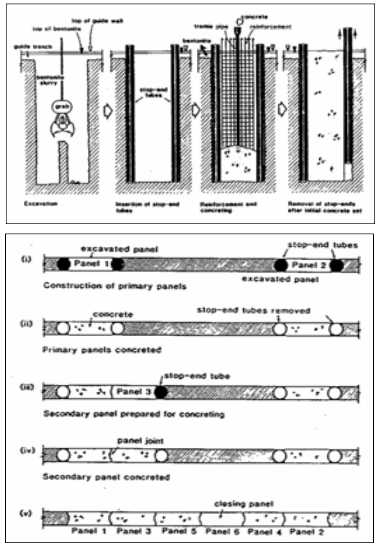

Concrete Diaphragm Wall

Stop-ends & water-proofs

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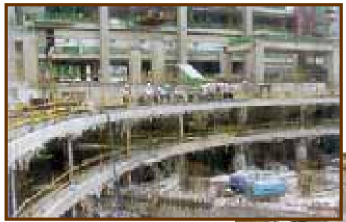
Ring Beam System



Central at Clarke Quay in Singapore

The Sail *at Marina Bay in Singapore*

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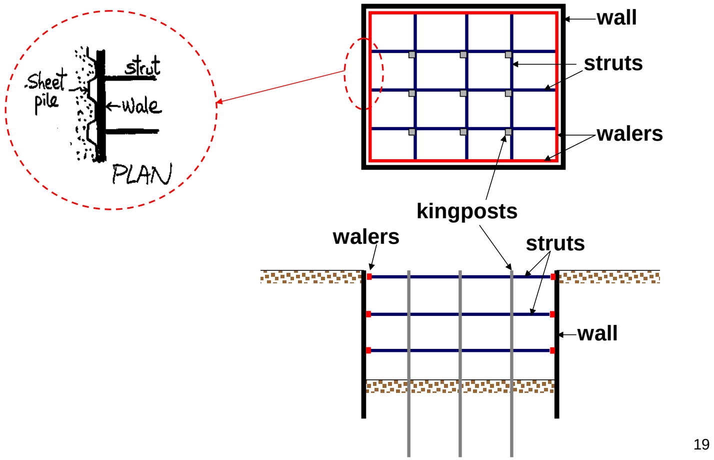
Braced Excavation with Sheetpile Wall



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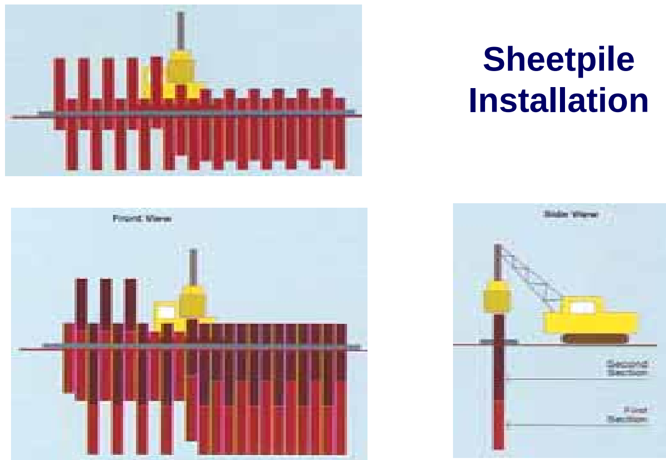

Sheetpile Installation

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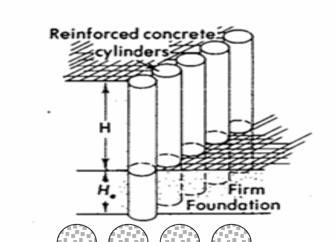
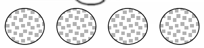
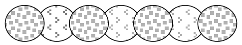
Bored Pile Walls







Contiguous Bored Pile Wall

Secant Bored Pile Wall

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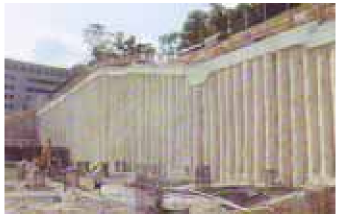
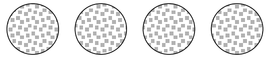
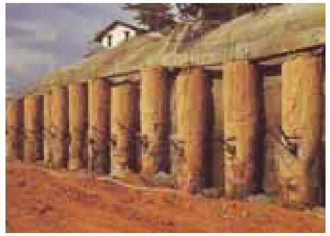
18.5m Cantilever CBP wall at NUS



Contiguous Bored Pile Wall





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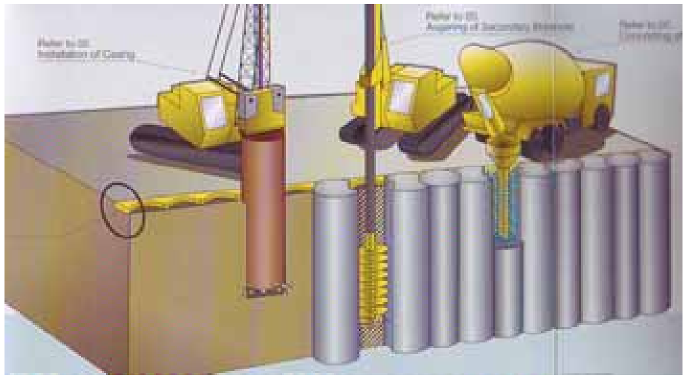
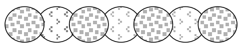
Construction of Secant Bored Pile Wall





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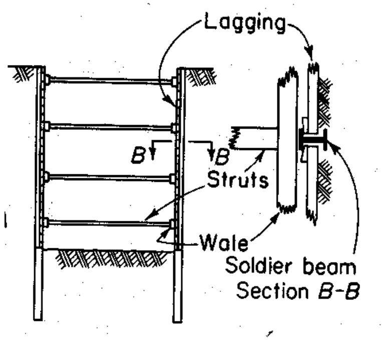
Braced Excavation with Soldier Pile Wall



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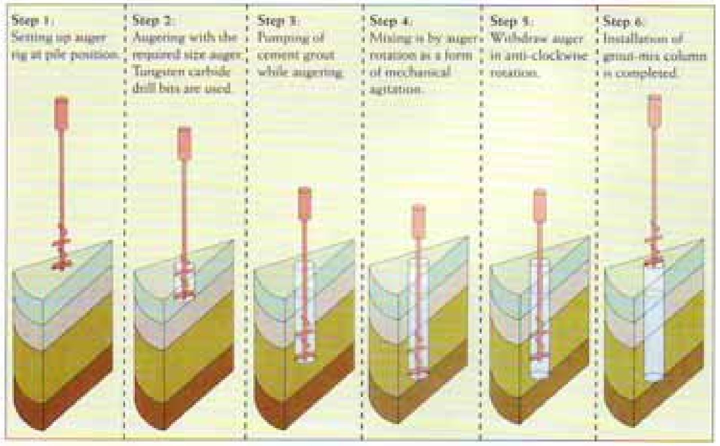
Construction of DCM or Grout Mixed Pile Wall



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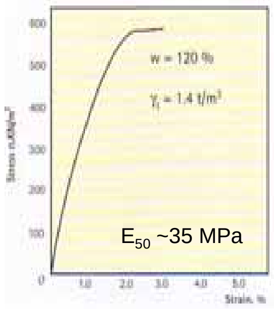
Properties of DCM or Grout Mixed Pile Wall



Soil Type	Amount of Cement (kg/m³)	q_u (kPa)
Peaty Clay	250 - 500	400 - 700
Sandy Clay	200 - 350	700 -1000
Marine Clay	100 - 250	200 - 700

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Grout Mixed Pile Wall

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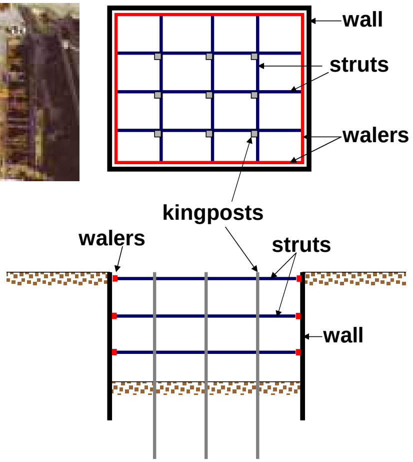

Conventional Bottom-Up Excavation Method

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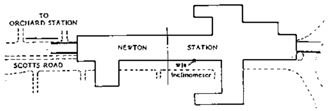
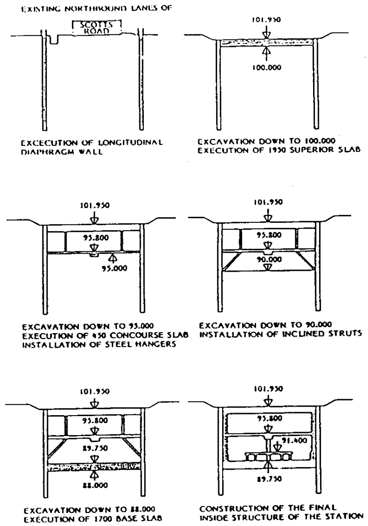
Top-Down Excavation





Top-Down Excavation at Boon Keng Station

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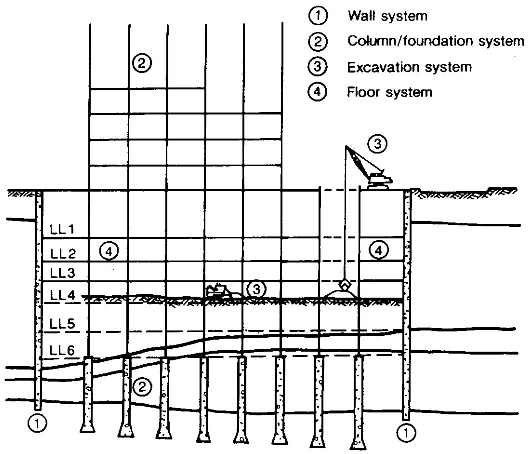
Up-Down Construction Method



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Up-Down Construction Method

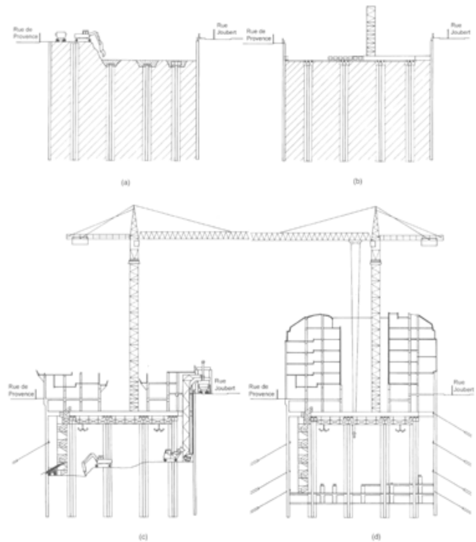
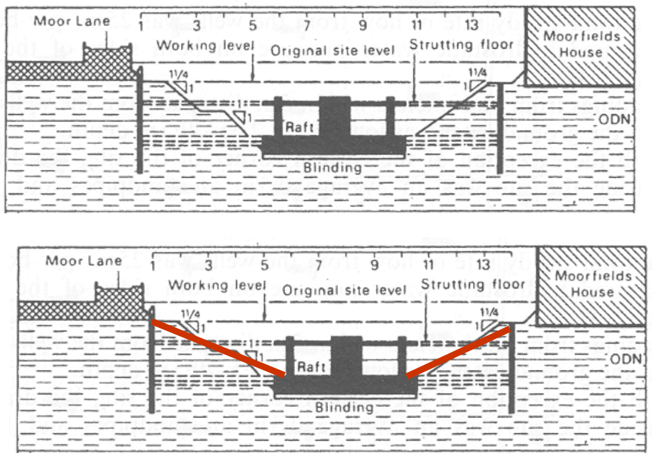


Fig. 8.16. Paris basement construction sequence, Provence Opera, Paris: (a) barrette sections installed; (b) ground floor construction; (c) superstructure construction and excavation below ground floor slab; (d) superstructure and substructure

Island Method of Excavation



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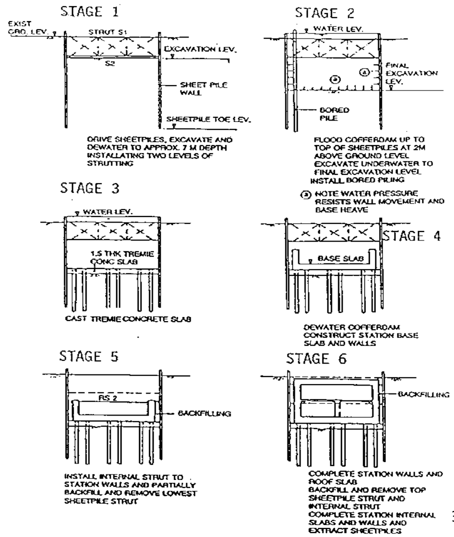
Under Water Excavation at Marina South



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Can this be avoided?

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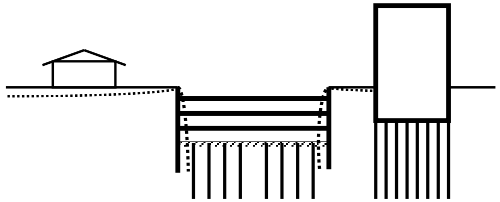
Major Design Considerations in Deep Excavations



Total collapse

- Overall stability
- Basal heave
- Uplift or blow-out failure
- Toe stability
- Strutting system failure

Excessive movements

- Wall deflections
- Ground settlement
- Effect on adjacent structures

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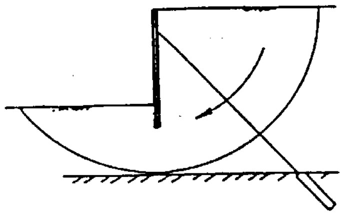
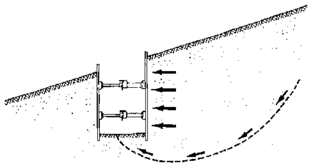
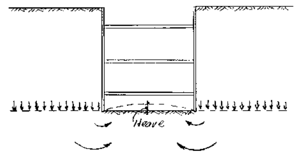
Overall Stability



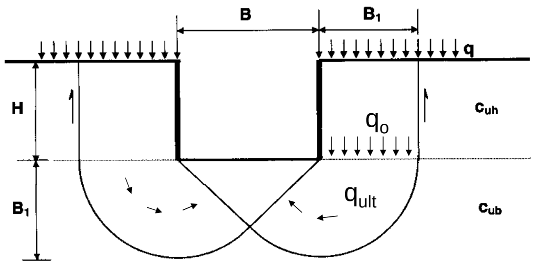


Bottom Heave Stability



- Bottom heave is usually associated with deep excavations in soft clay.
- A small portion of the heave comes from rebound due to removal of soil. This heave has no effect on the stability of the system.
- The heave that is of major concern arises from the soil behind the wall that acts as a surcharge. When the surcharge approaches the bearing capacity of the, large heave will occur.

Basal Heave Stability

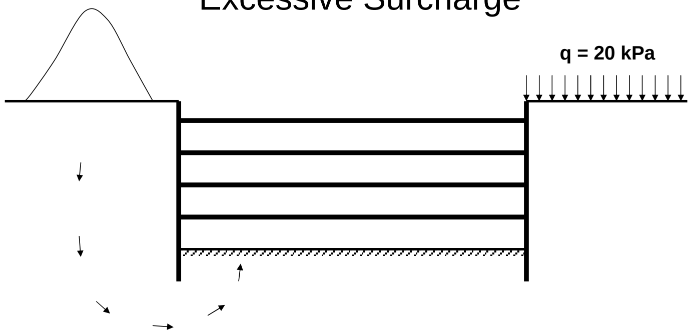


When $q_o > q_{ult}$, failure in imminent.

Basal Heave Failure in Taipei

Basal Heave Failure due to Stockpiling

Excessive Surcharge



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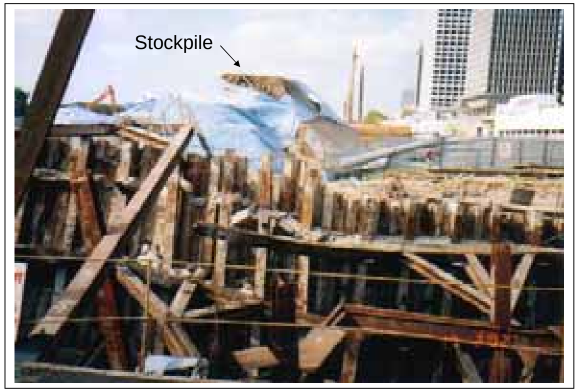
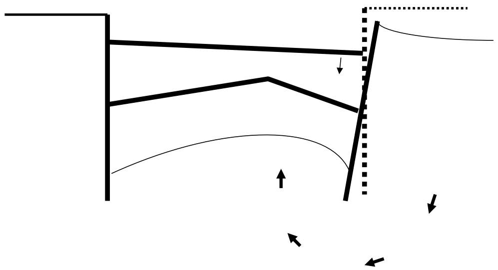
Basal Heave Failure due to Stockpiling



Courtesy of Dr Lim PC 42

Basal Heave Stability

Wall Rotation



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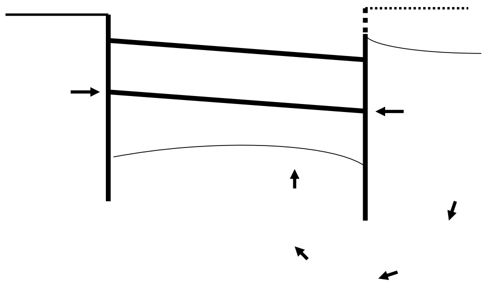
Basal Heave Stability

Wall Raking



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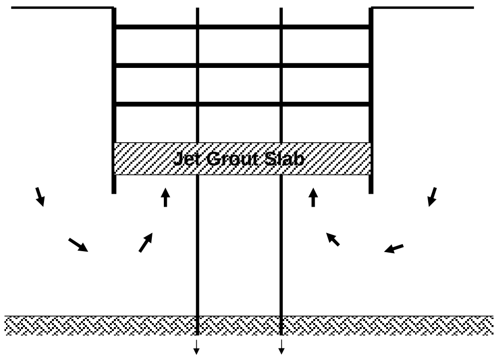
Basal Heave Stability

Lifting of King Posts



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Lifting of Kingpost due to Bottom Heave

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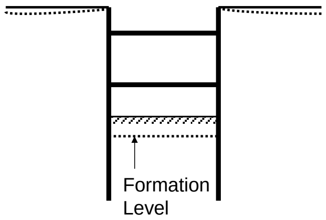
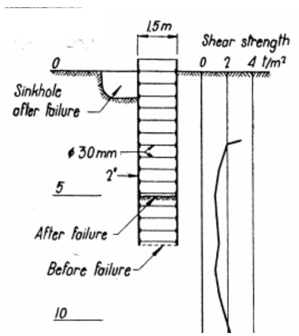
Basal Heave Stability

Not all basal heave instability lead to catastrophic failures





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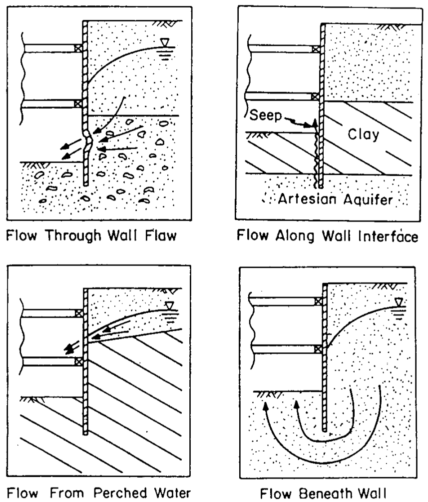
Piping & Loss of Fines



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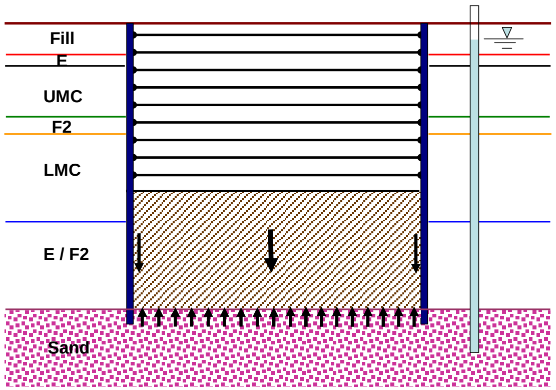
Uplift Instability or Blowout Failure



1. What is the permeability of the sand?
2. Is there a free supply of water?

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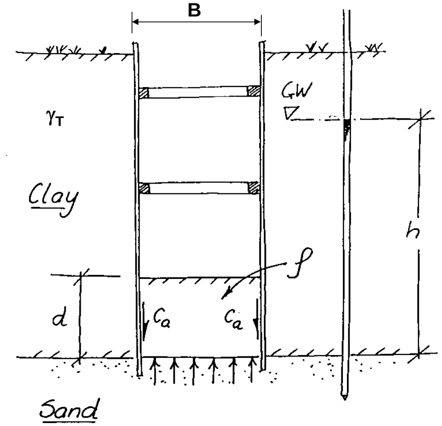
Blowout Failure

$$Fs = \frac{\gamma_T\ B\ d + 2\ C_a\ d}{\gamma_w\ h\ B}$$



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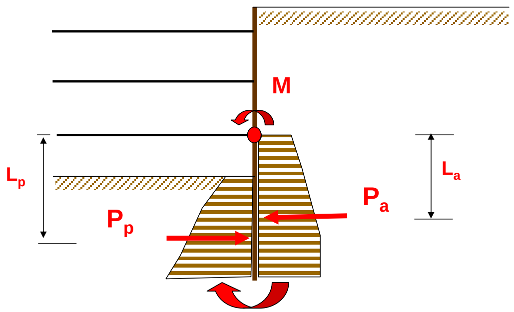
Toe Kick-out Stability



Are there any reported failures due to toe instability?

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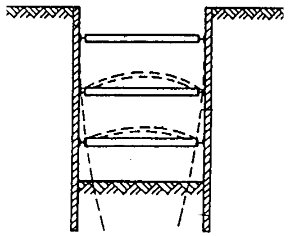
Strut Failure



The buckling of one strut will transfer the load to adjacent struts that may lead to progressive failure and eventually total collapse of the whole system.

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Strut Failures

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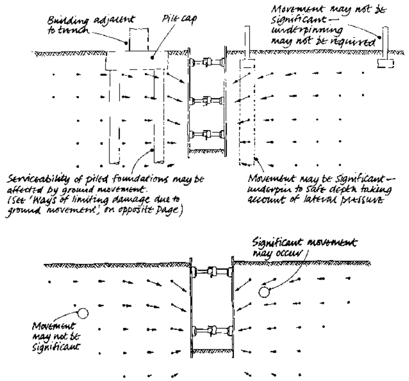
Effect on Adjacent Structures



Excessive wall deflections may induce adverse movements to adjacent foundations, cause large surface settlement, lead to cracking of pavement and underground utilities.

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Effect of Excessive Movements

Damaged Pavement

After Choong (2003)

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Buildings on Shallow Foundations

Race Course Road

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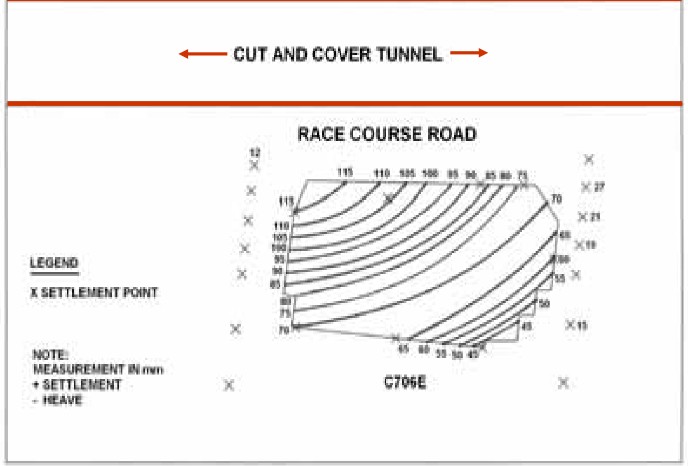
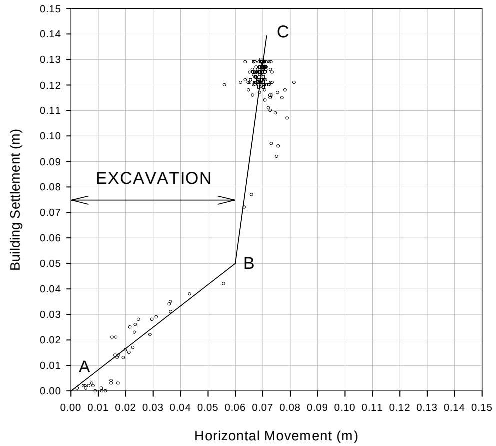
Buildings on Shallow Foundations



Post-excavation Settlement



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Building on Mixed Foundations

(Shirlaw et al., 2003)

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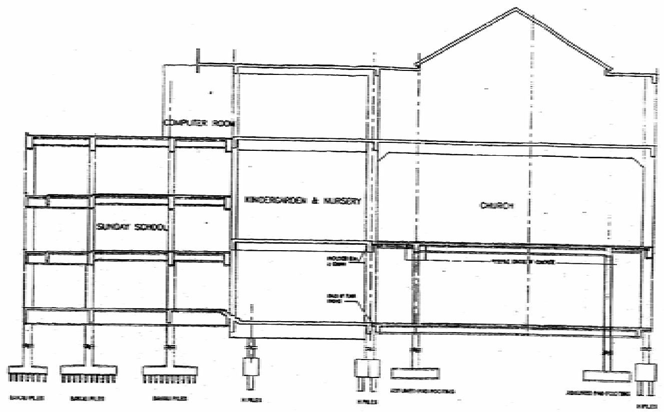
Building on Mixed Foundations



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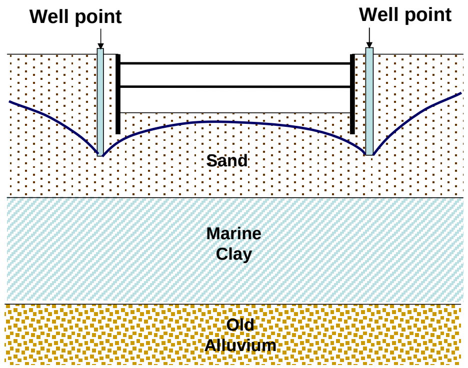
Lowering of Ground Water Table



Causes:
- Pumping
- Wall leakage

Lowering of ground water table will increase the effective stress in soft clay and result in consolidation settlement. 61

Effect of Lowering of Groundwater Table


FROM A SPACIOUS BUNGALOW TO A WRECK IN 2½ YEARS

Developer: It's a private dispute

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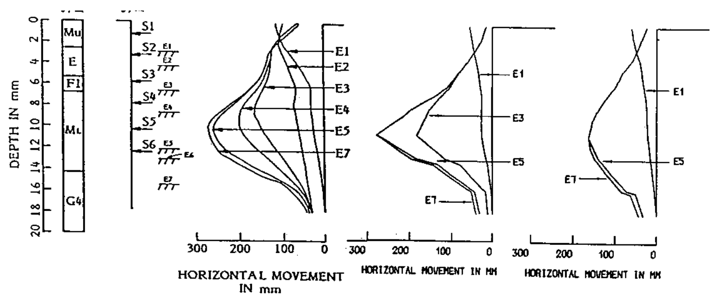
Yielding of Sheetpile Wall



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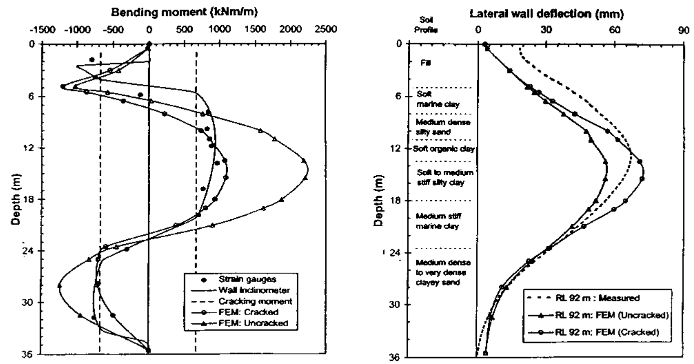
Excessive Cracking of Diaphragm Wall



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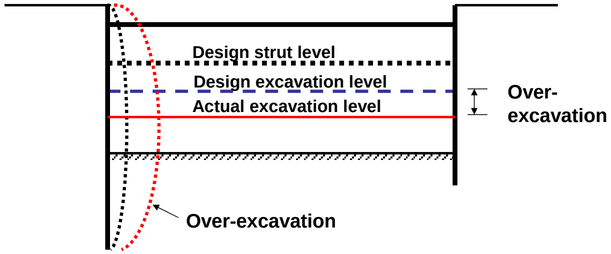
Over-Excavation



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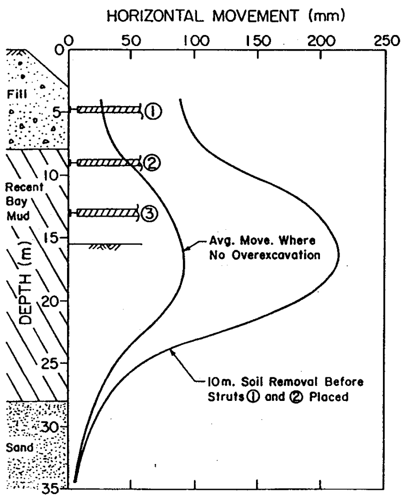
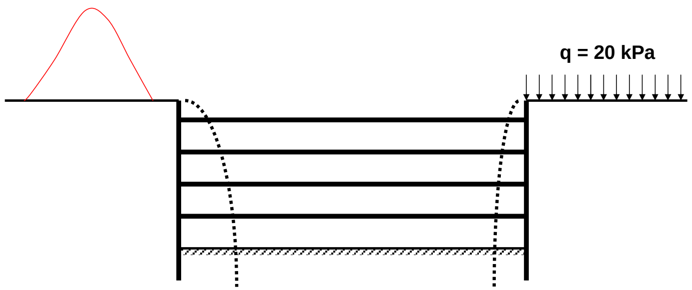
Over-Excavation

(Clough & O'Rouke, 1990)



Excessive Surcharge



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Sequence of Construction