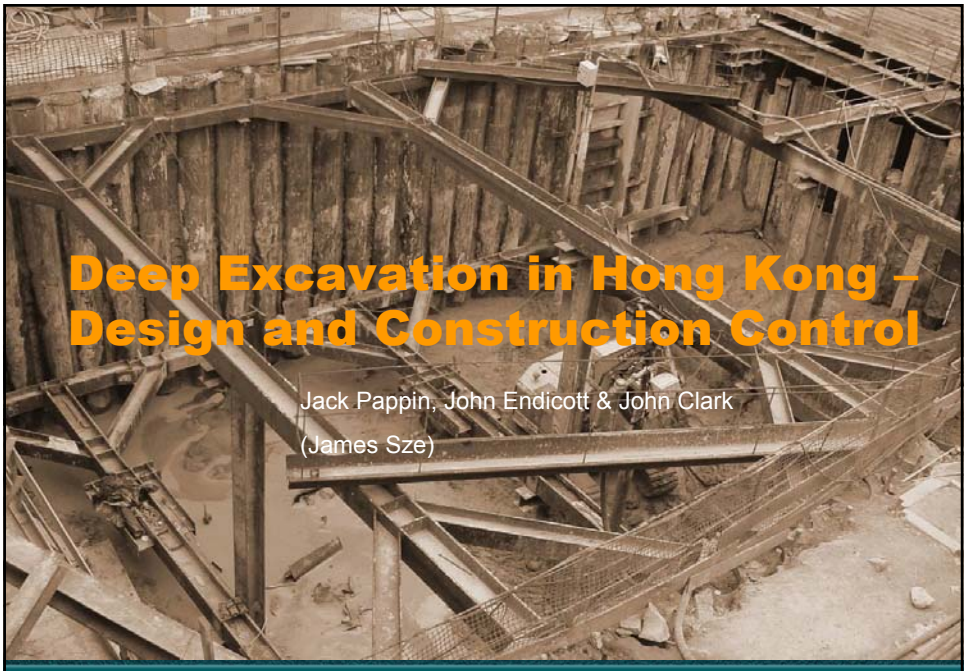


Deep Excavation in Hong Kong – Design and Construction Control

Jack Pappin, John Endicott & John Clark

(James Sze)

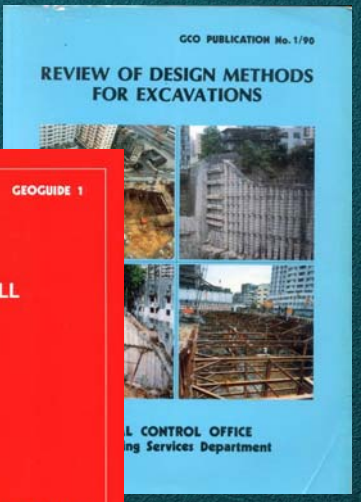
Content of the Presentation

- Part I – Design Considerations
- Part II – Numerical Modelling
- Part III – Observational Method

Part I – DESIGN CONSIDERATIONS

Design Codes and Guides

- CIRIA 104
- BS 8002
- DD ENV
- BD 42/00
- Piling handbook
- CIRIA R185
- CIRIA C517
- CIRIA SP95
- GEOGUIDE 1 2nd Ed.
- GCO Publication No. 1/90



Conventional Retaining System Design Approach

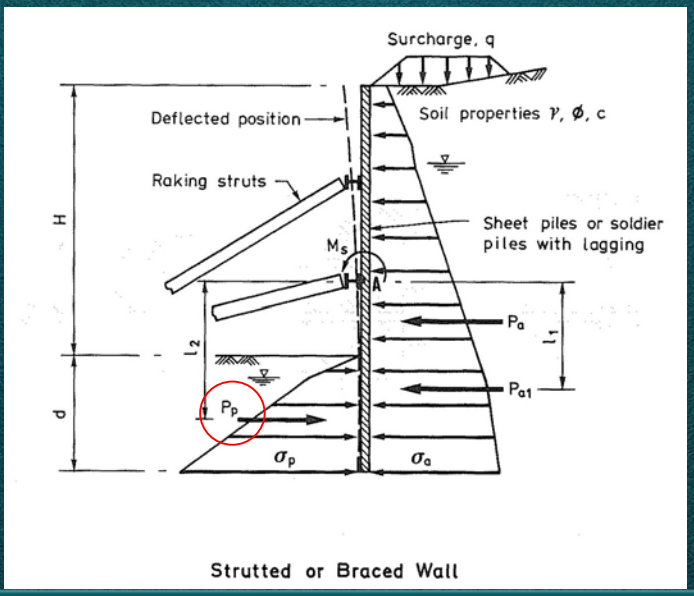
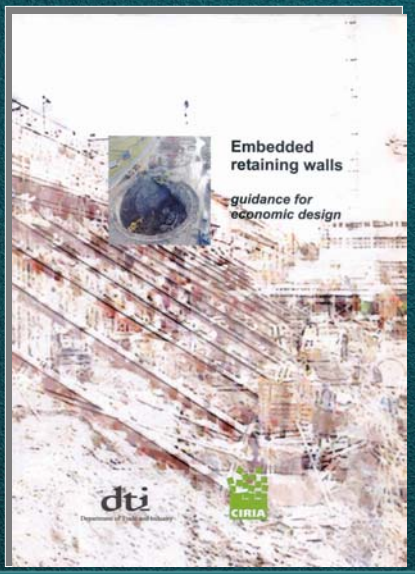
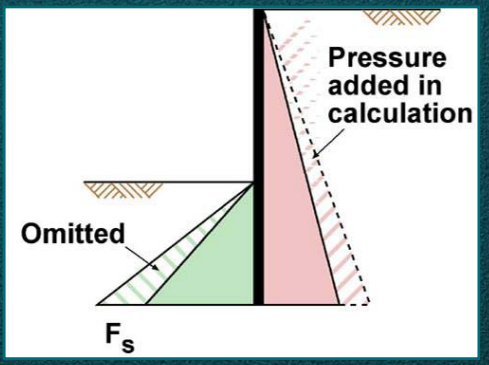


Figure 29, GCO 1/90 (Navfac, 1982b)

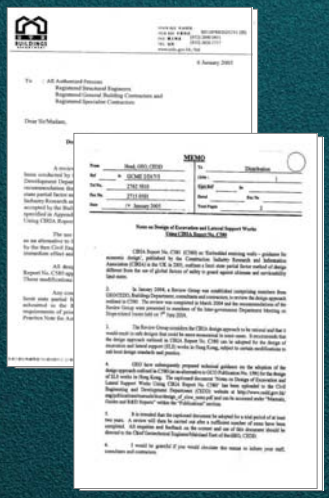
CIRIA Report C580 Design



- Aim - holistic, consistently reliable & economic ELS design
- Limit states design
- Maintain simplicity over different uncertainties – adopt partial factor of safety on soil strength only

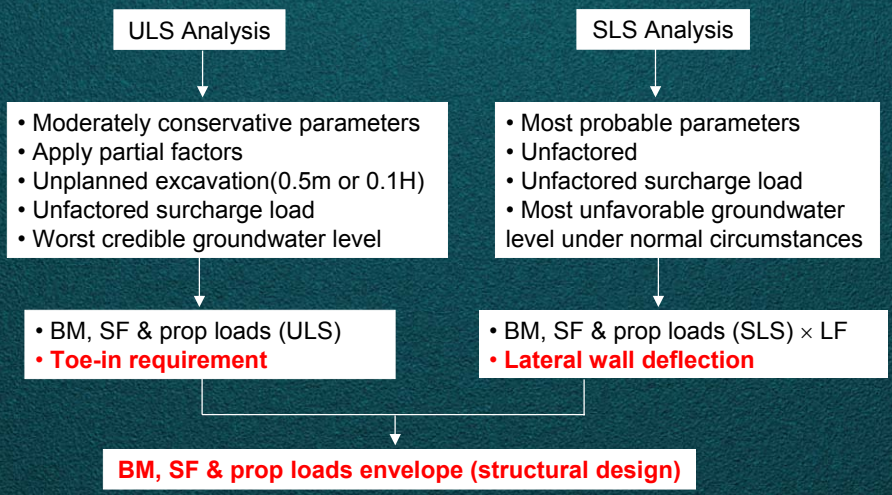


Use of C580 in Hong Kong

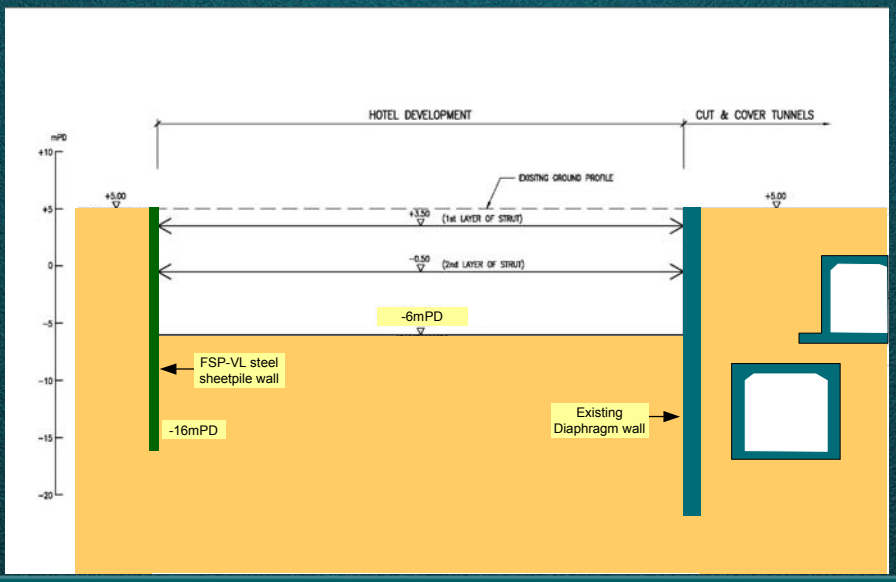


- **Review Group** set up by Geotechnical Engineering Office in 2004
- Recommendation concluded in "**Notes on Design of Excavation and Lateral Support Works Using the Limited State Partial Factor Method in the CIRIA Report No. C580**"
- Promulgated by BD/GEO in early 2005
- **alternative** to global factor of safety approach in GCO Publication No. 1/90
- review in **2 years** before long-term implementation

Simplified Flowchart of C580 Design Approach (SSI)

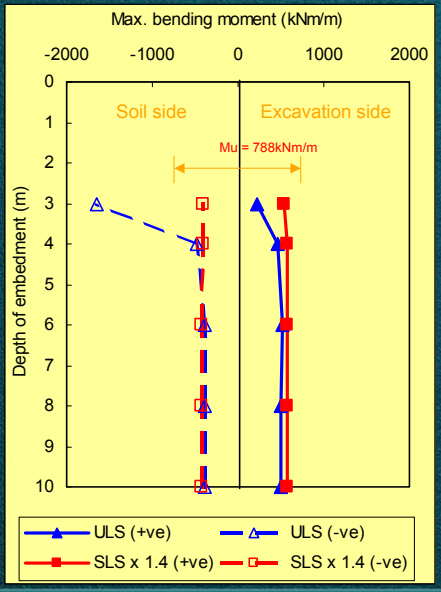


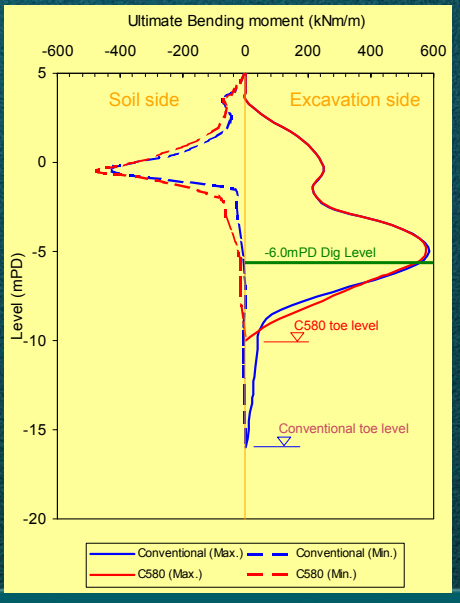
Conventional vs C580 Design Approach - Example



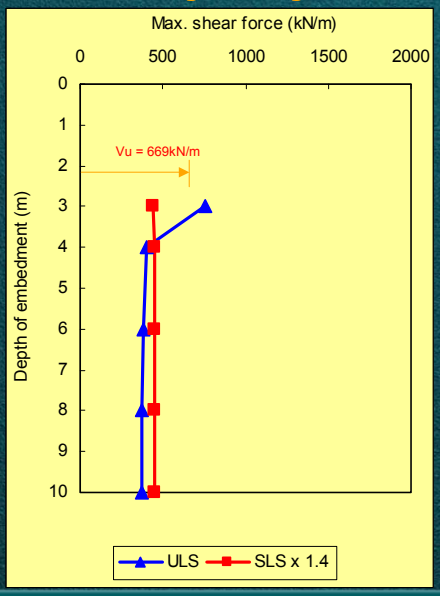
Sze & Lo (2005)

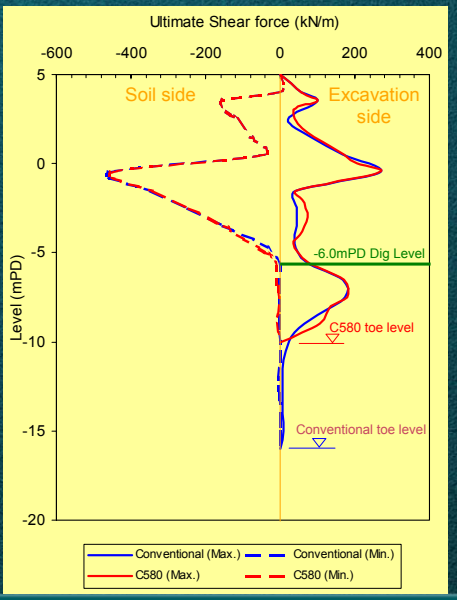
Sensitivity analyses – Wall Bending Moment



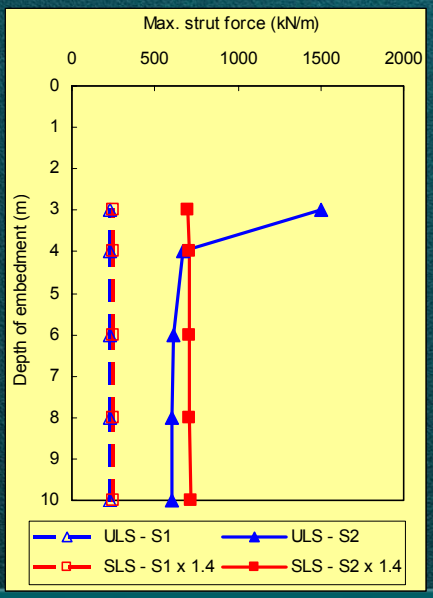


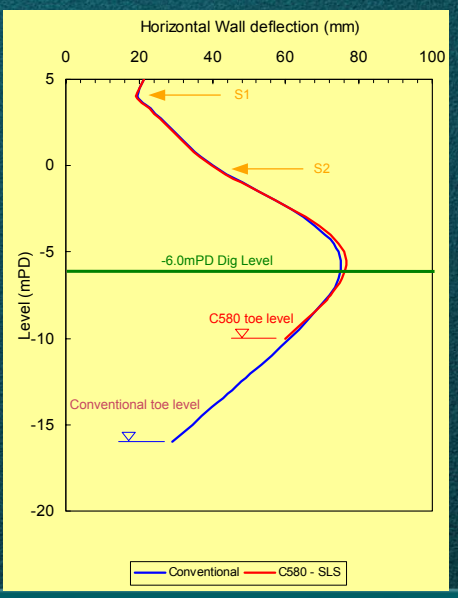
Sensitivity analyses – Wall Shear Force



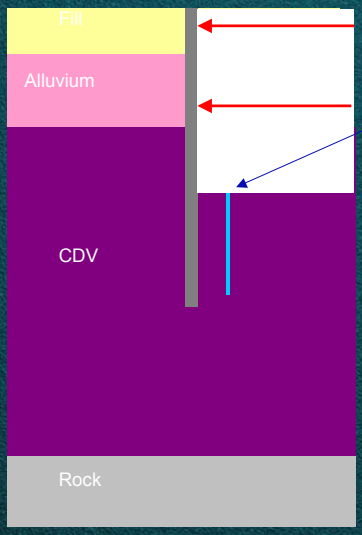


Sensitivity analyses – Strut Force & Wall Deflection





Control of Groundwater at Passive Zone



Pump well

E.g. KCRC Spurline Kwu Tung Station

Buildability

- Difficult in constructing
- Unrealistic movement criteria

Buildable Design

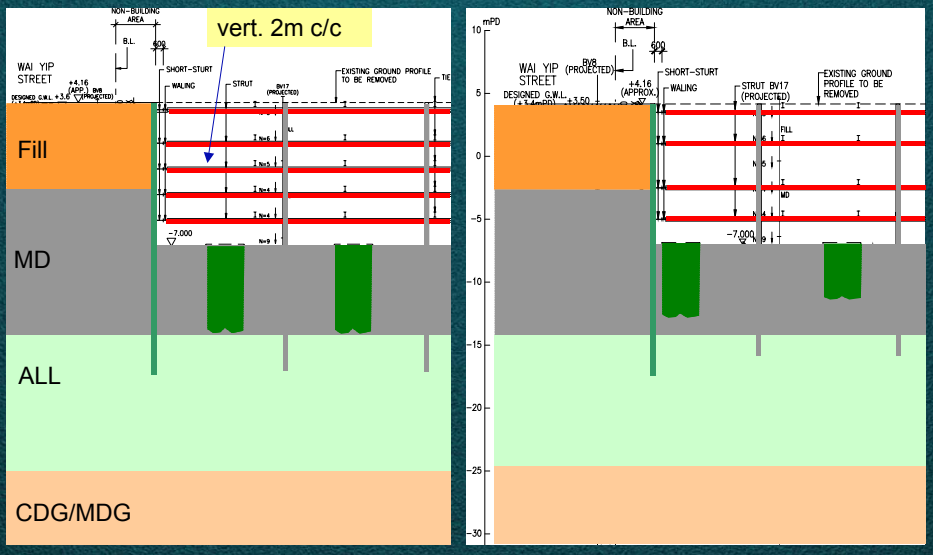
- Easy and fast construction
- Less risks
- Safer working environment
- Could be more cost effective

E.g. KCRC Tsuen Wan West Station

Over-excavation

Unworkable sequence vs Opportunistic contractor

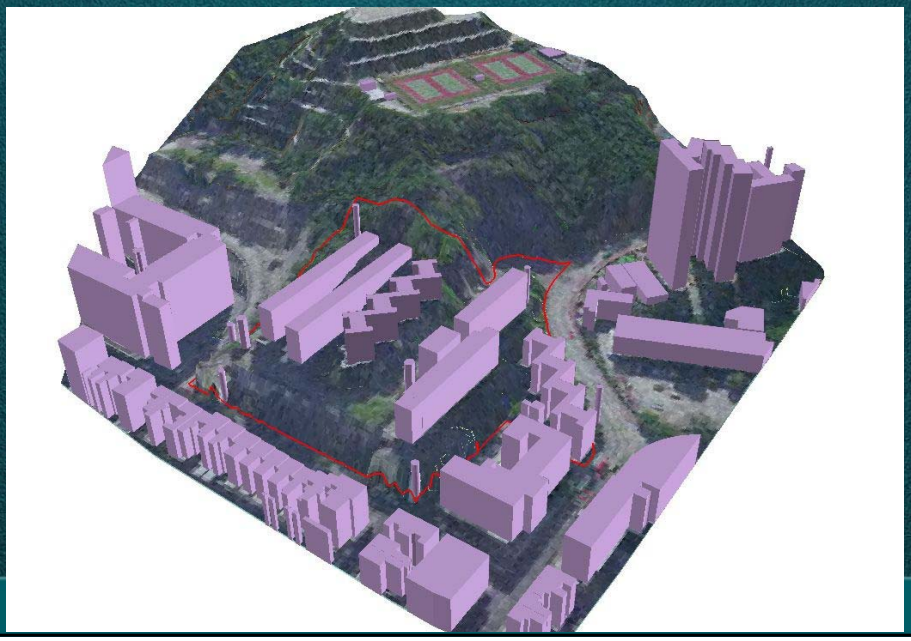
Optimization of ELS Design at Kowloon Bay



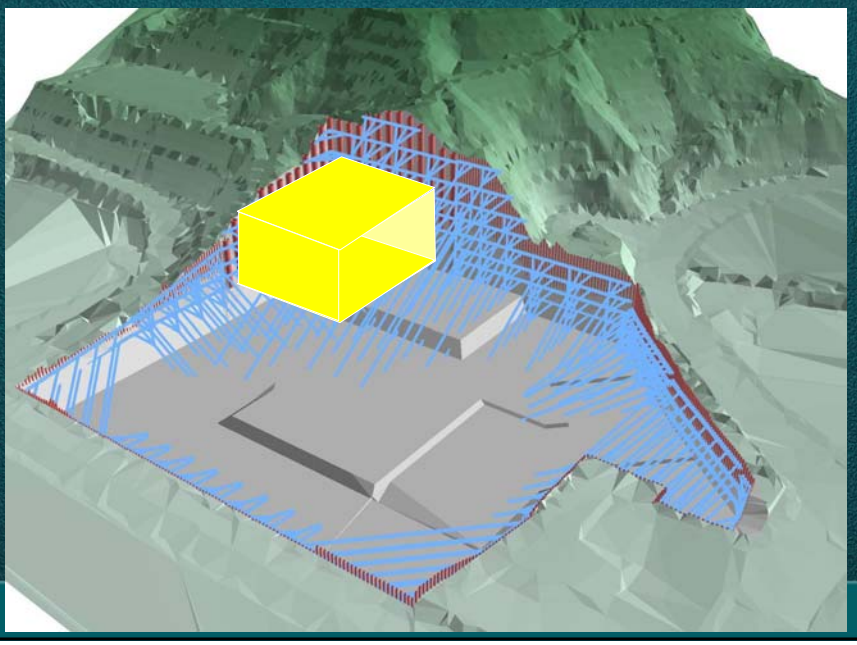
Original Design

Optimized

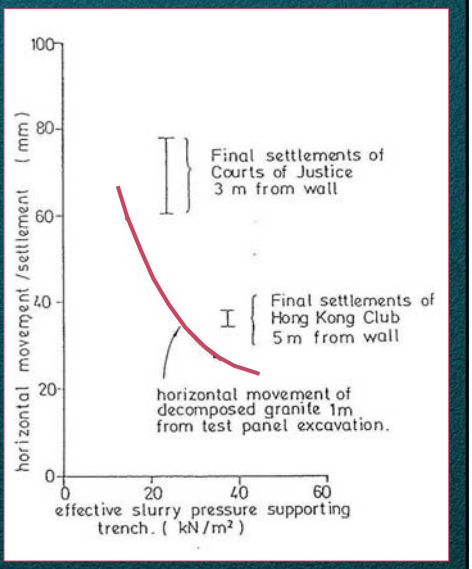
Development at Sheung Shing Street, KLN



Bottom-up with Raking Strut Option

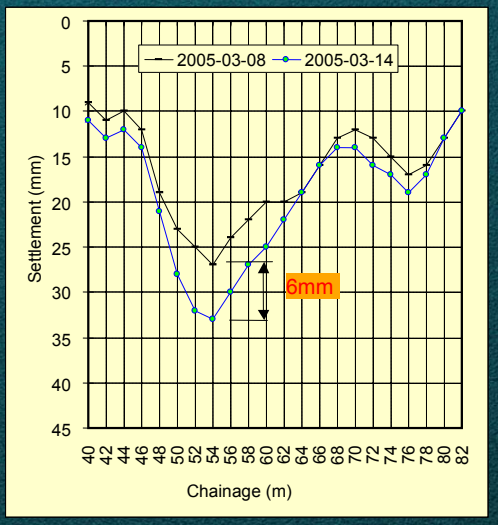


Unrealistic Movement Criteria - Diaphragm Wall



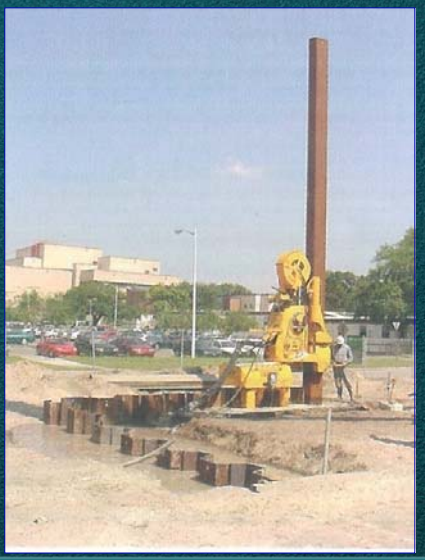
Settlement measured at Chater Station in mid 70s

How about Sheetpile Wall Installation ?



Installation may attribute a substantial part of induced movements

Sheet piling – Giken (Silent) piling



E.g. East Rail TSTE Mody Road Subway, CLP Cable Tunnel TWS access shaft

Conclusions of Part I

- C580 design approach would result in consistently reliable design.
- Shortest Toe-in might not be most economic.
- Buildability - one of key factors for successful execution of ELS works.
- Get Contractor's involvement at earlier stage if possible.

Part II – NUMERICAL MODELLING

Numerical Modelling

- Earth pressure Coulomb 1776Sub-title

Numerical Modelling

- Earth pressure Coulomb 1776
- Applied Pressure Diagram Terzaghi & Peck 1948

Numerical Modelling

• Earth pressure	Coulomb	1776
• Applied Pressure Diagram	Terzaghi & Peck	1948
• Beam on Springs		1976

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• Finite Elements/Differences		1986

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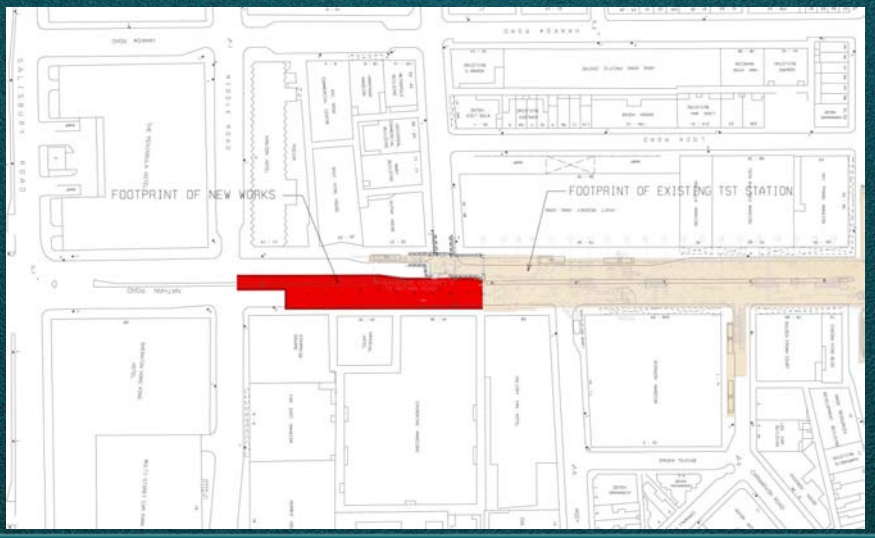
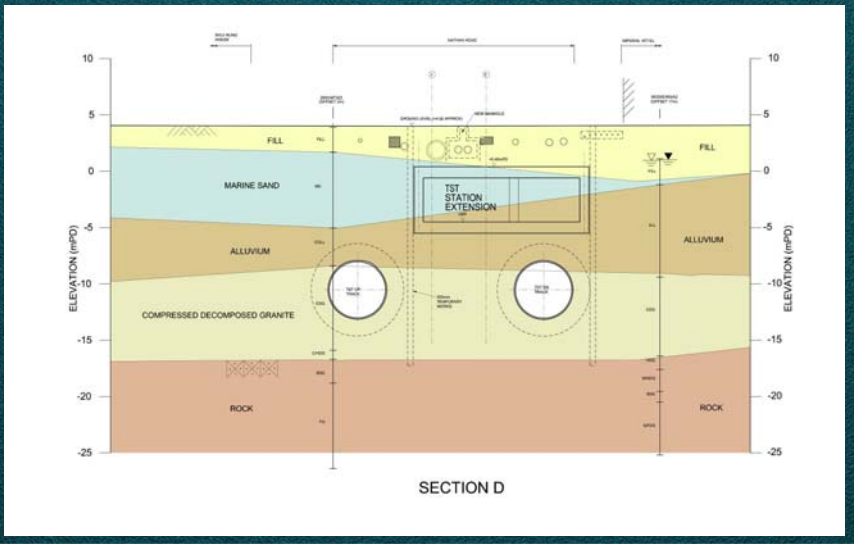
• 3D Applications in practice		2002 - 2005

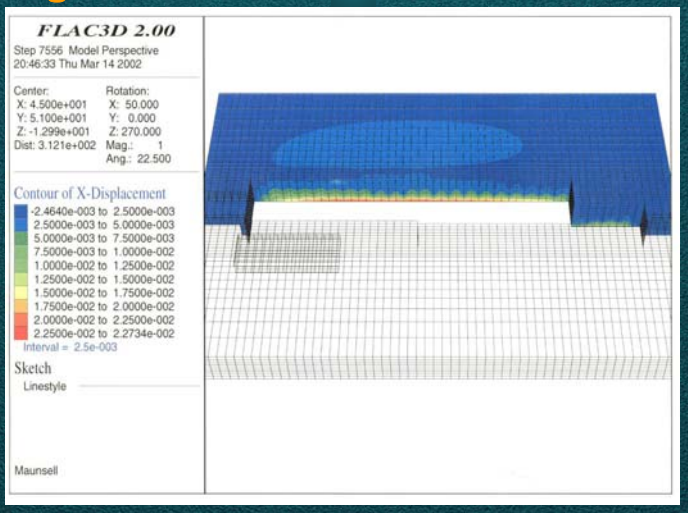
Layout Plan of Extension to the Tsim Sha Tsui Station Concourse



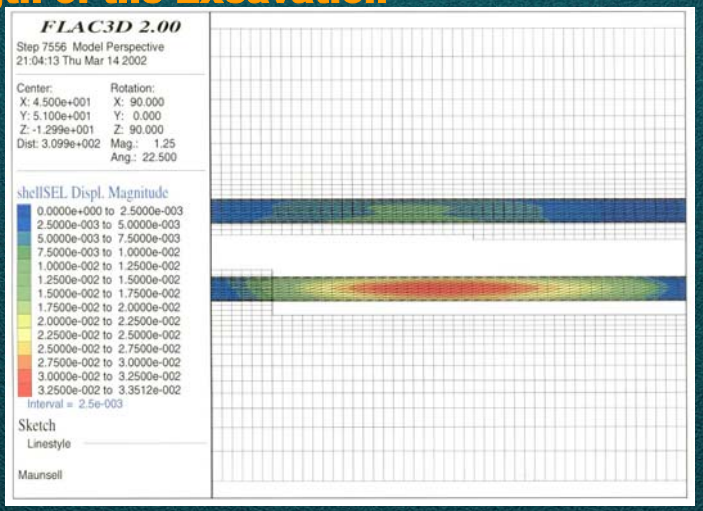
Typical Cross Section showing Ground Conditions and the Proposed Works



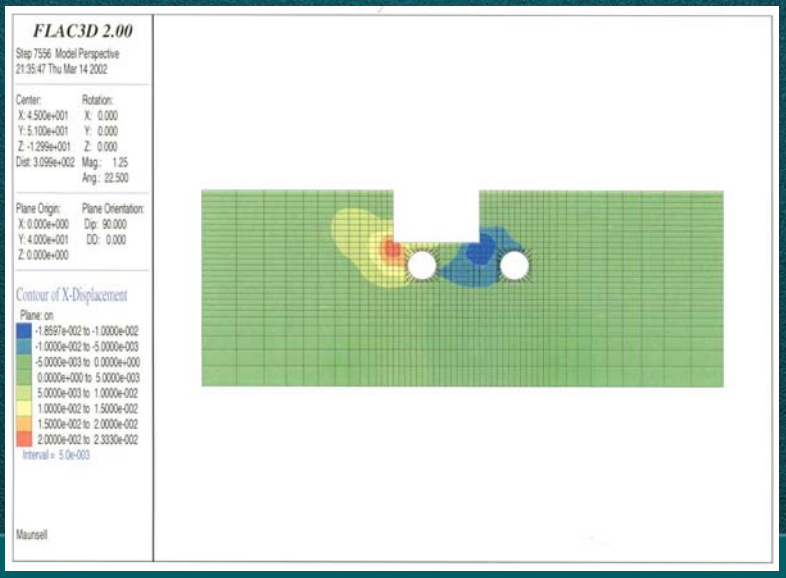
View of the 3D FLAC Model Developed showing the Lateral Wall Deflections along the length of the Excavation

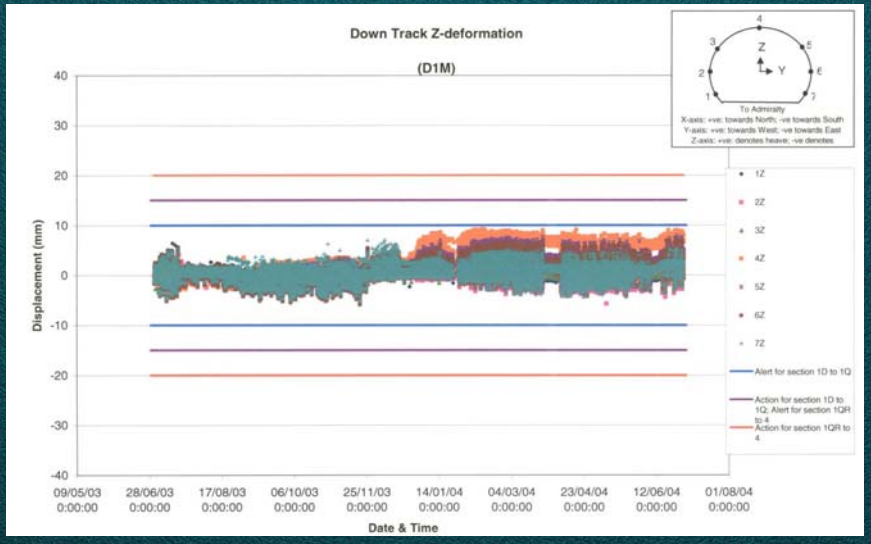


Plan view from FLAC 3D Model Showing the Displacement of the Tunnel Linings along the length of the Excavation

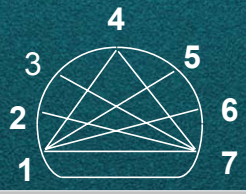


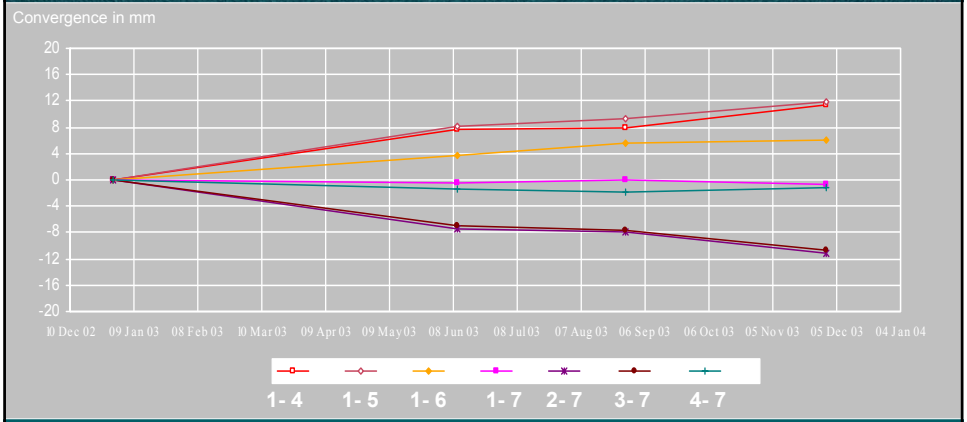
Wall Deflections and Tunnel Deformations from FLAC 3D at a Section about 40 m from the southern end



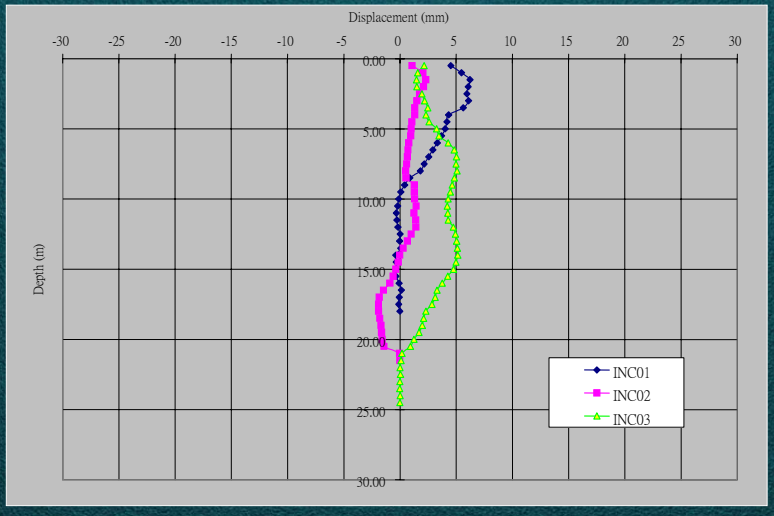


Monitoring of Tunnel Convergence – Downtrack Tunnel





Measured Deformation of Excavation Lateral Support Wall



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- **Often variations in ground conditions or construction procedure render sophisticated constitutive models redundant**
- **KIS = Keep It Simple**

  - Less likely to get a plausible result based on wrong reasons
  - Easy to check for approval
  - Easy to compare with monitoring results
  - Easy to back analyse

Part III - USE OF OBSERVATIONS MADE DURING EXCAVATION

What Constitutes a Well Performing Excavation?

- Common Objectives of Client and Contractor

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  - totally safe against collapse

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    - cost as low as possible after considering the above

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    - adequate protection to nearby structures and roads etc.
    - makes provisions for a safe working environment
  - **Commercial Factors**
    - permits reasonably rapid progress of work
    - cost as low as possible after considering the above

Dominating Factor… Ground Conditions Uncertainty

- **The state-of-the-art in modern geotechnics gives us…**
  - increasingly powerful design tools
  - easy access to information on the outcome of many past projects

- **But still views diverge on the correct balance between protective and commercial aspects.**
  - variance between analytical tools
  - significance of disturbance to field samples
  - use of average values or more conservative
  - whether soil properties may change during the excavation process

The Only Sure Way is the Observational Way

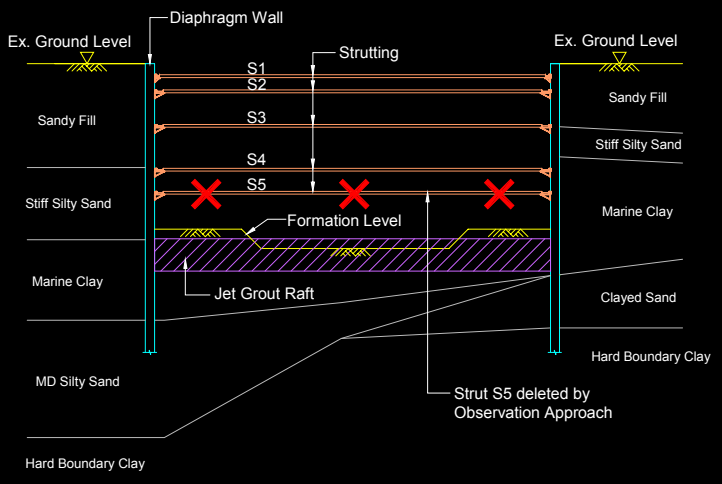
The Observational Method in ground engineering is the continuous review and refinement of a design based on observations of field behaviour

Examples

- **Tseung Kwan O Station**
  - observational method was used to justify omission of a layer of props and a buried prop at later stages of the project
  - otherwise it seems that use of observational design is the exception in Hong Kong

Example of Observational Method

Typical Section of Excavation



Why Use Observational Design?

Direct Alteration of Soil Properties

Heating / Dessication due to Jet Grout Hydration

Why isn't OM used for every excavation?

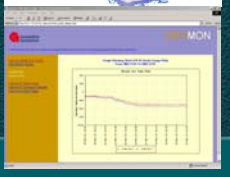
- time lag between measurement and reporting and interpretation
- reliability of reported measurements
- authority approval for change in sequence of work

Web Based Real Time Reporting

Instruments (eg.strain gauges on struts)

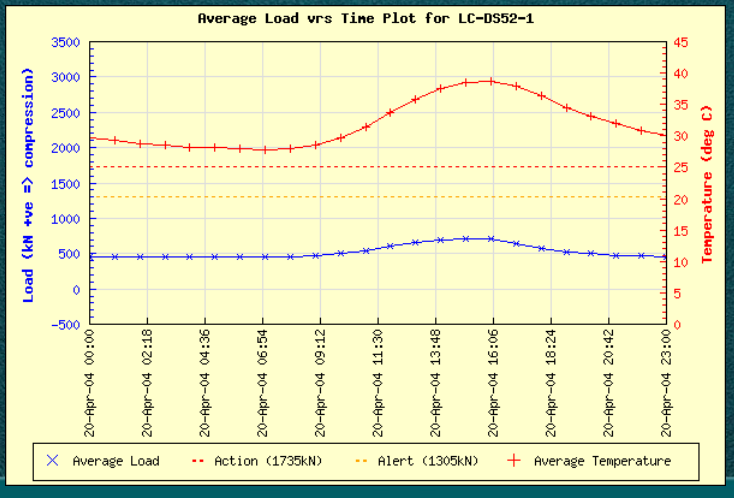
dataloggers with solar panel

Users connected over the Internet



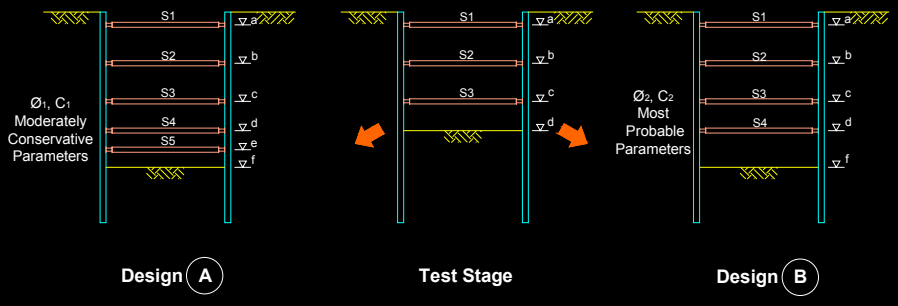
Server

Instrument Reliability



Authority Approvals Strategy

- **Submit two designs for approval**
  - Design A – Adopts "moderately conservative" parameters agreeable to the authority (i.e. normal practice)
  - Design B – Targets more favourable parameters
    - Proponent (probably the contractor) decides how much better performance is expected to be... could be "most probable" or even more optimistic
- **Identify a Test Stage in the Excavation**
  - Up to the test stage, A and B follow the same path, but diverge thereafter
  - Identify test conditions to verify that more favourable parameters are safe
  - At design approval stage, the authority approves only the test conditions, not the target parameters



Test Condition –

Strut load, deflection

Issues to Address in adopting the Observational Method

- **Most critical is to avoid a delay of say one month waiting for consent after submission of a report on reaching the test stage, therefore...**
  - make consistently up-to-date archive of observations available to the authority and the supervising engineer
  - build a simple control framework into the web based real time reporting system so that compliance with test stage conditions can be instantly verified
  - adopt a "self-regulation" process whereby the Supervising Engineer (RSE) certifies the compliance with the test stage conditions

Summary

- **Limit State Design**
  - for consistency and economy
- **Buildability**
  - most problems are the result of buildability not being properly considered in the design, the leanest solution may not be the best
- **Sophisticated 3D modeling**
  - invaluable for unusual, complex analysis, esp. for effects on existing sensitive structures, *but requires specialist expertise in its application*
- **Observational Method**
  - viable tool for reducing cost and improving safety that can and should be integrated into existing procedures for authority control

Thank you