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CSIC Cambridge Centre for Smart Infrastructure and Construction

地盤工事におけるOMの国際的動向

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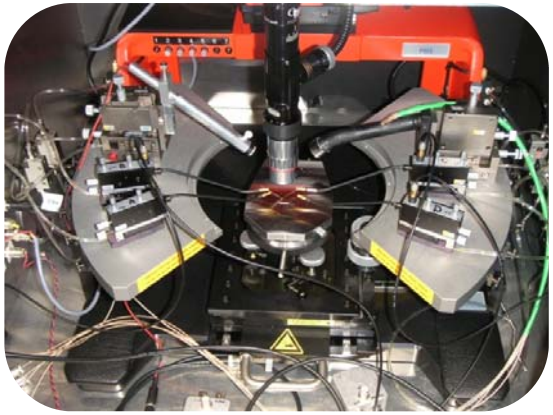
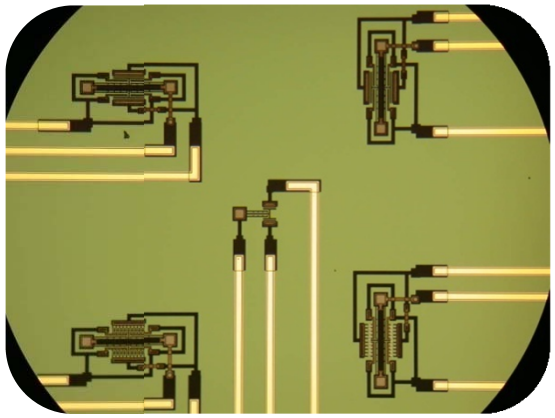
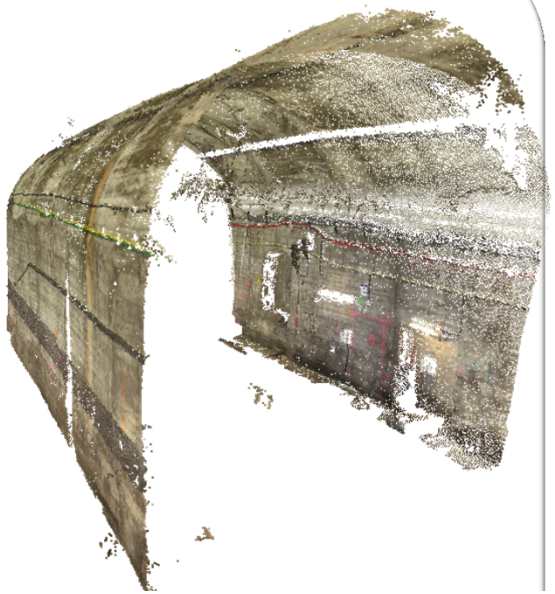
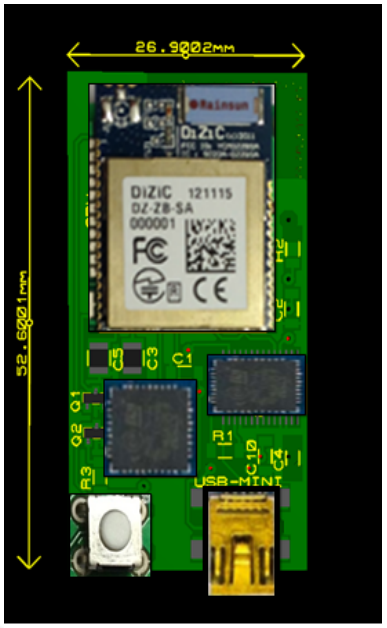
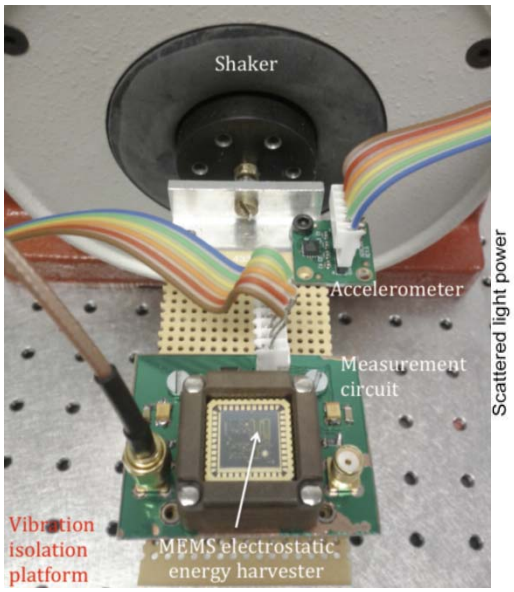
- Fibre optics distributed sensors
- Micro-Electro-Mechanical Sensors
- Wireless Sensor Network
- Computer Vision
- Power Harvesting
- Active RFID

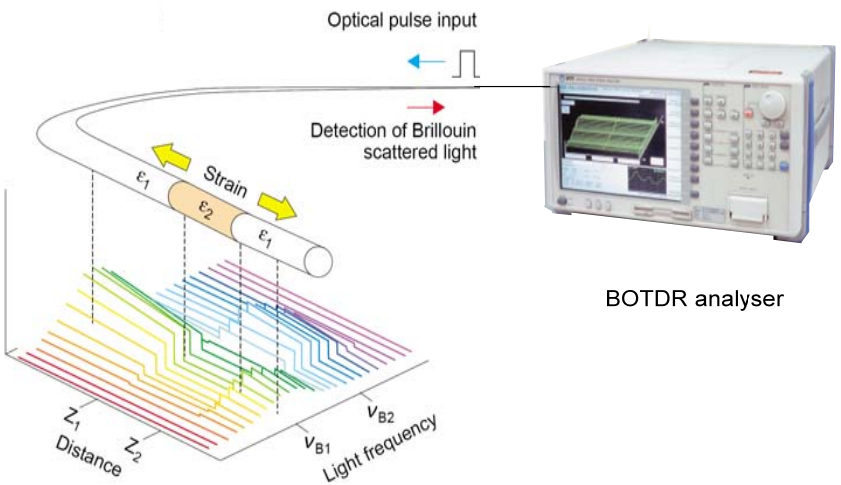








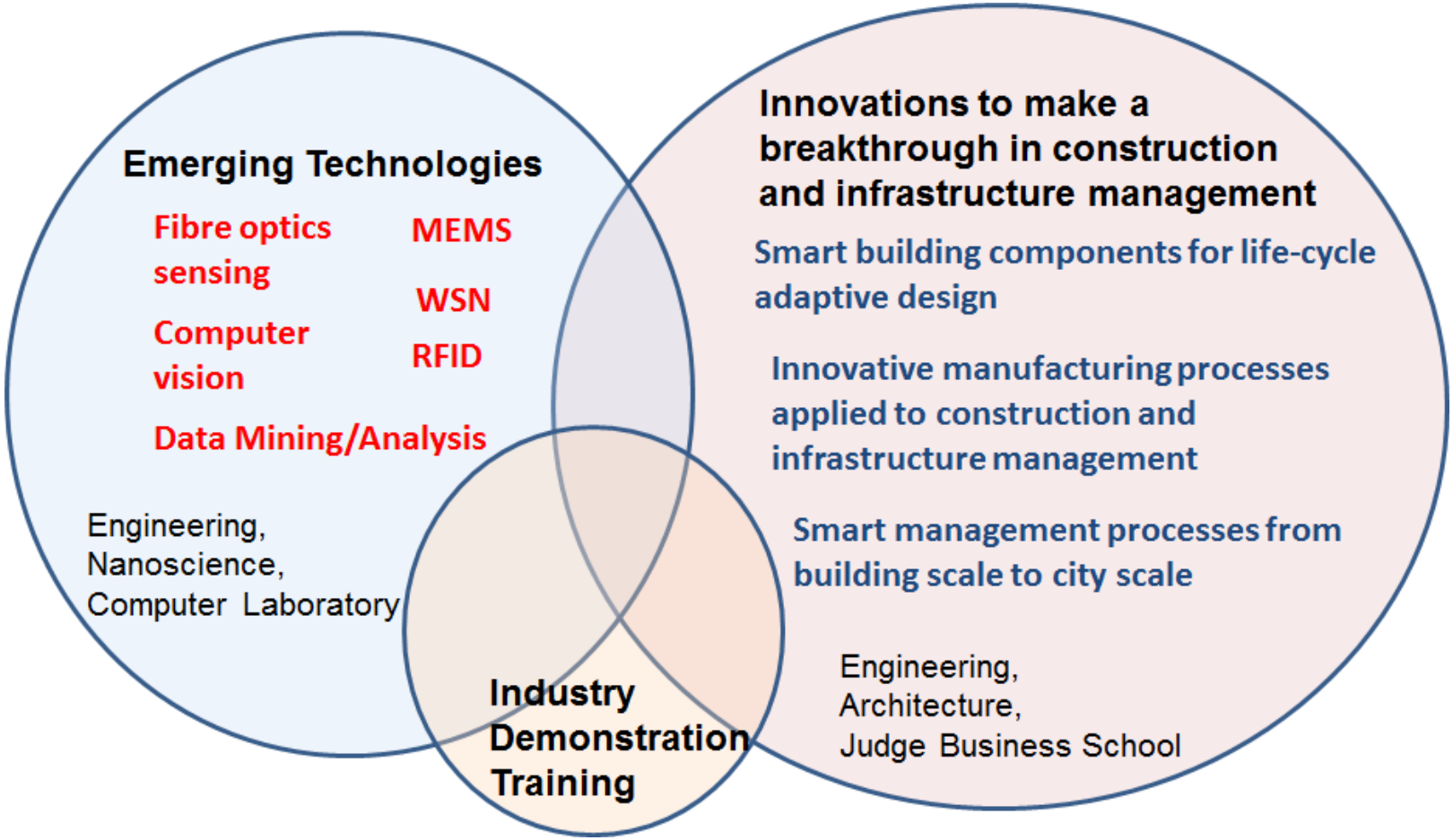




BOTDR analyser

The frequency shift of the Brillouin scattered light is proportional to the strain.

CSIC Cambridge Centre for **Smart Infrastructure and Construction**



EPSRC Engineering and Physical Sciences Research Council

Technology Strategy Board Driving Innovation

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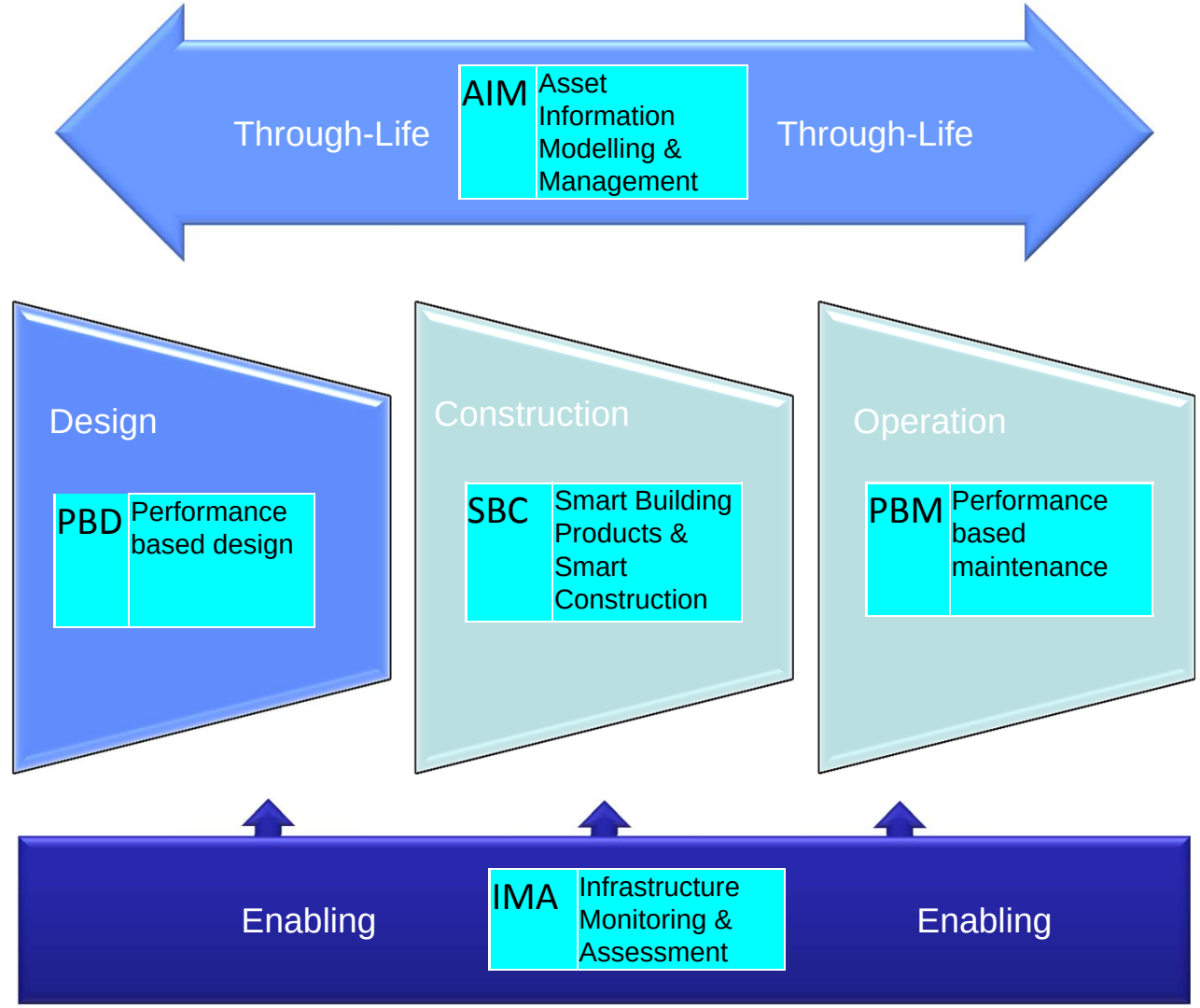
UK Government £10m + Industrial support - £7m

Construction Sector

Infrastructure Sector

Manufacturing, Electrical & Information Sectors


Through-Life
AIM
Asset Information Modelling & Management
Through-Life
Design
PBD
Performance based design
Construction
SBC
Smart Building Products & Smart Construction
Operation
PBM
Performance based maintenance
Enabling
IMA
Infrastructure Monitoring & Assessment
Enabling

History

- **1969 - Peck's Rankine Lecture**
- Early 1990's- Channel Tunnel, Limehouse Link Projects
- **1994 - Geotechnique Symposium in Print**
- **1995 - EC7 OM Clause**
- 1996 - ICE and HSE - NATM publications
- **1999 - CIRIA - OM Report No 185**
- 2001 - ICE Managing Geotechnical Risk
- 2003 - CIRIA C580 – Embedded retaining Walls.
- 2006 - Geotechnet - www.geotechnet.org

Peck's (1969) Observational Method – Eight Ingredients

1. **Sufficent SI** to establish general nature / properties of deposits.
2. Assess **Most Probable** and **Most Unfavourable** conditions.
3. Establish **Design** based on **Most probable**.
4. Select **Monitoring parameters** and **calculate values**.
5. Calculate values for **most unfavourable** conditions.
6. Select design **modification options**.
7. **Monitor** and **evaluate** actual conditions.
8. **Modify** design to suit actual conditions.

Eurocode EC7 Cl 2.7 (1989 and1995)

- Recognised prediction is difficult in Geotechnics – OM used in these cases.

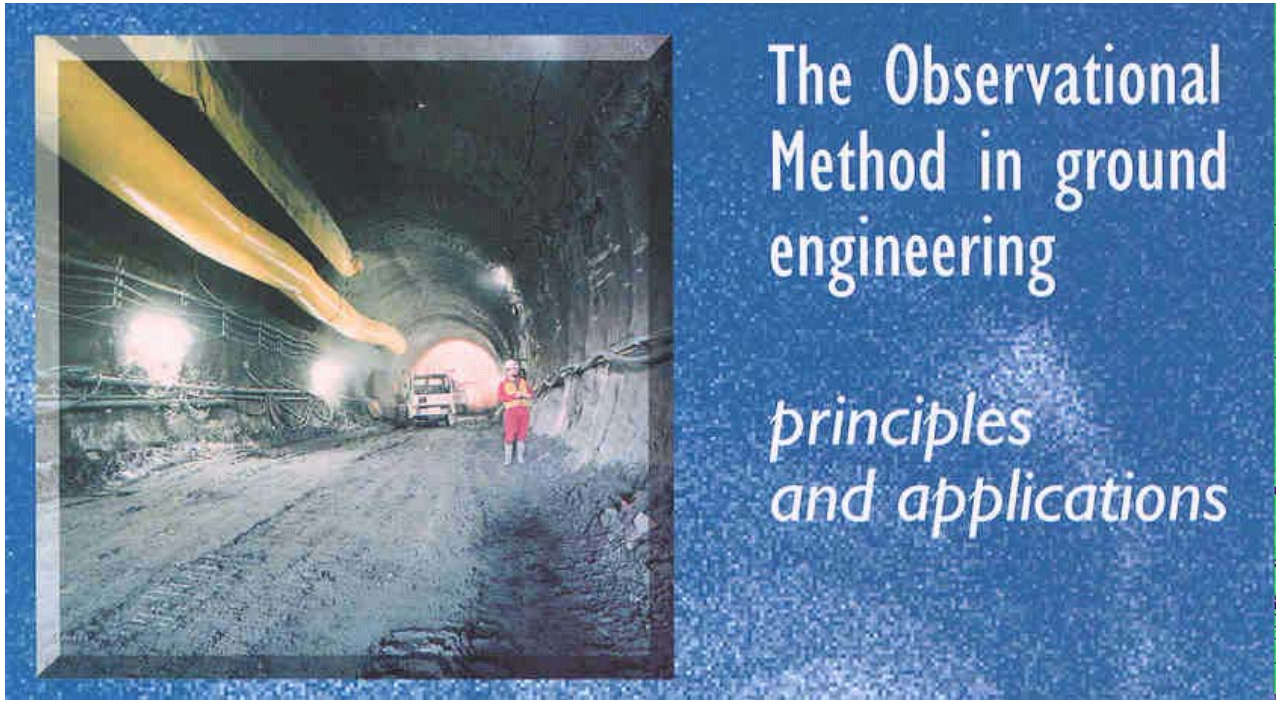
1) Establish limits of behaviour.

2) Acceptable probability actual behaviour within limits.

3) Monitoring plan, response times and contingencies.

4) Contingencies adopted if real outside acceptable range.

CIRIA (1999) Report 185 - Nicholson, Tse and Penny



Goals

- Clarify OM definition and process
- Integrate OM process into modern design
- Focus on “Ab Initio” applications – better planning

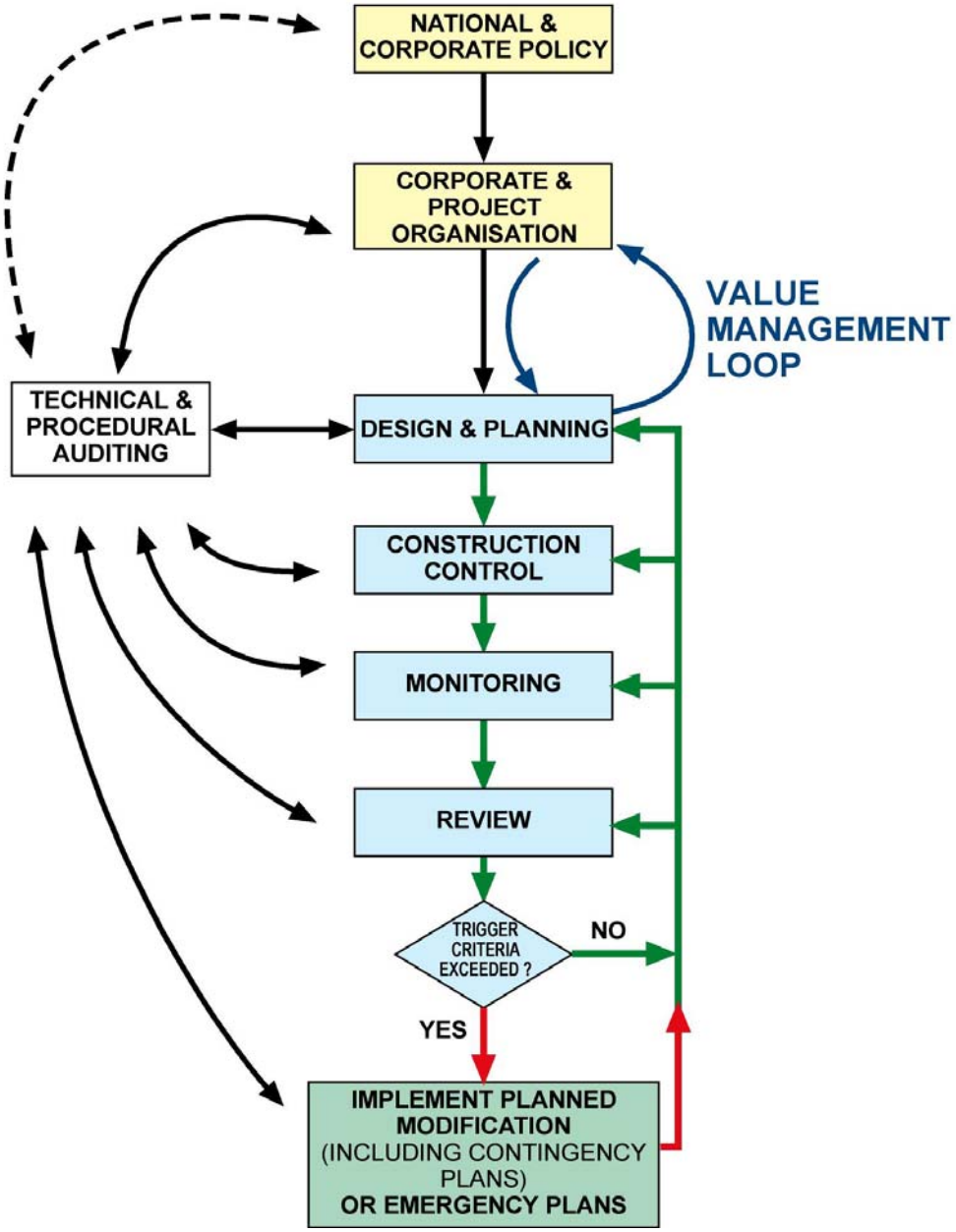
CIRIA (1999) - OM Definition

- The Observational Method in ground engineering is a **continuous, managed, integrated, process** of **design, construction control, monitoring and review** which enables **previously defined modifications** to be incorporated during or after construction as appropriate. All these aspects have to be **demonstrably robust**. The objective is to **achieve greater overall economy without compromising safety.**

- The Method can be adopted from the inception of a project or later if benefits are identified. However, the Method **should not be used where there is insufficient time** to implement fully and safely complete the **planned modification** or emergency plans.

CIRIA (1999) R185 Figure 1.2

The OM Process



Predefined Design Process

- Permanent works
- One set of parameters (MC)
- One design / predictions
- Outline construction method

- Trigger values

- Contractor's temp design /method statement

- Monitoring checks trigger values not exceeded
  - If exceeded, Back Analyse -
  - Introduce OM - Best Way Out

- Emergency plan

The OM Process - Ab Initio

- Temporary works (mainly)
- Two sets of parameters (MC +MP)
- Two designs / predictions
- Integrated design and construction methods
- Methods relate to triggers

- Comprehensive and robust monitoring system
- Review and modify process
  - Contingency plan
  - Improvement plan

- Emergency Plan

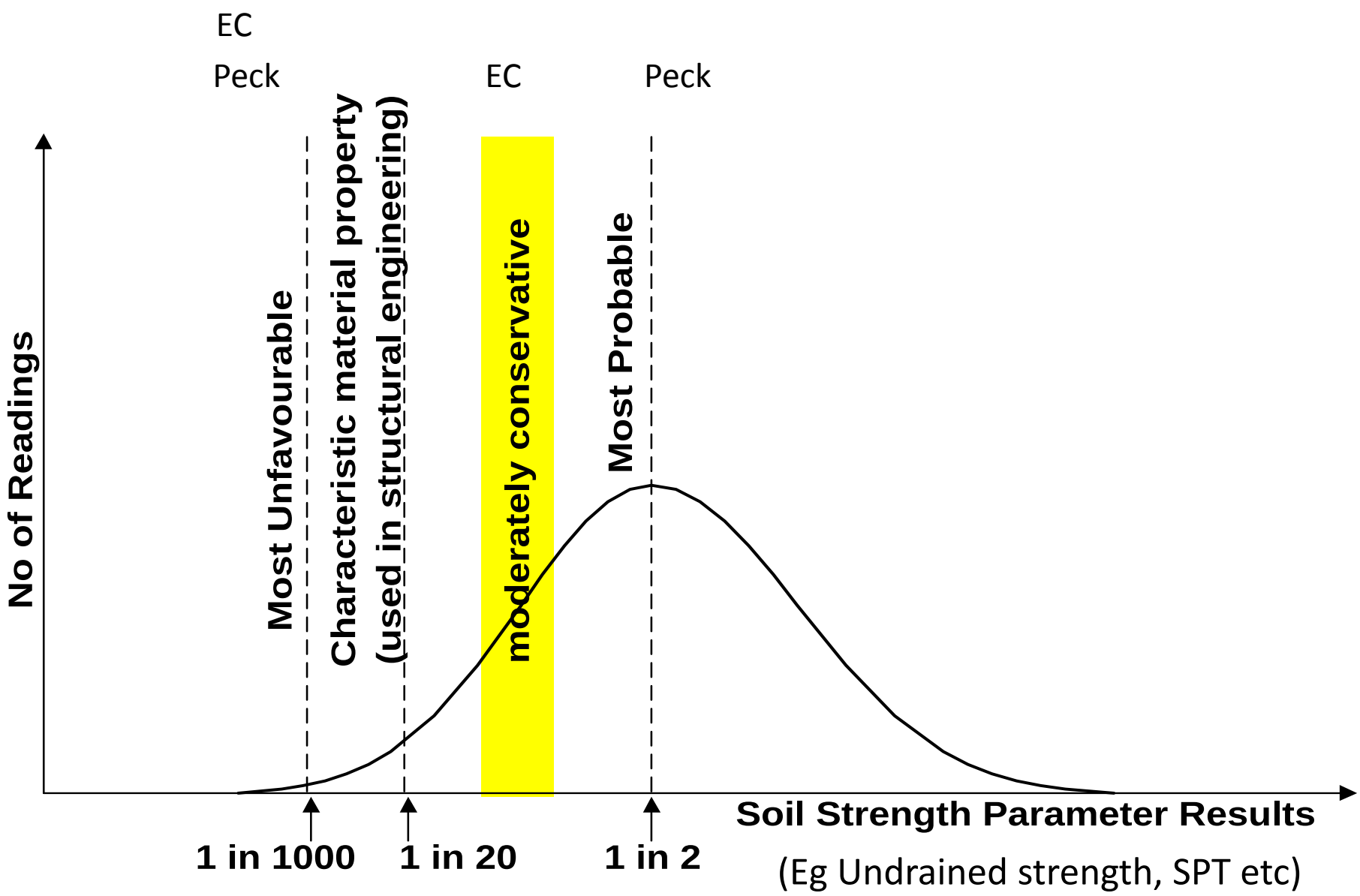
Design Parameters - Peck's (1969) OM and Current Codes

- **Peck (1969)**
  - **OM conditions/values**

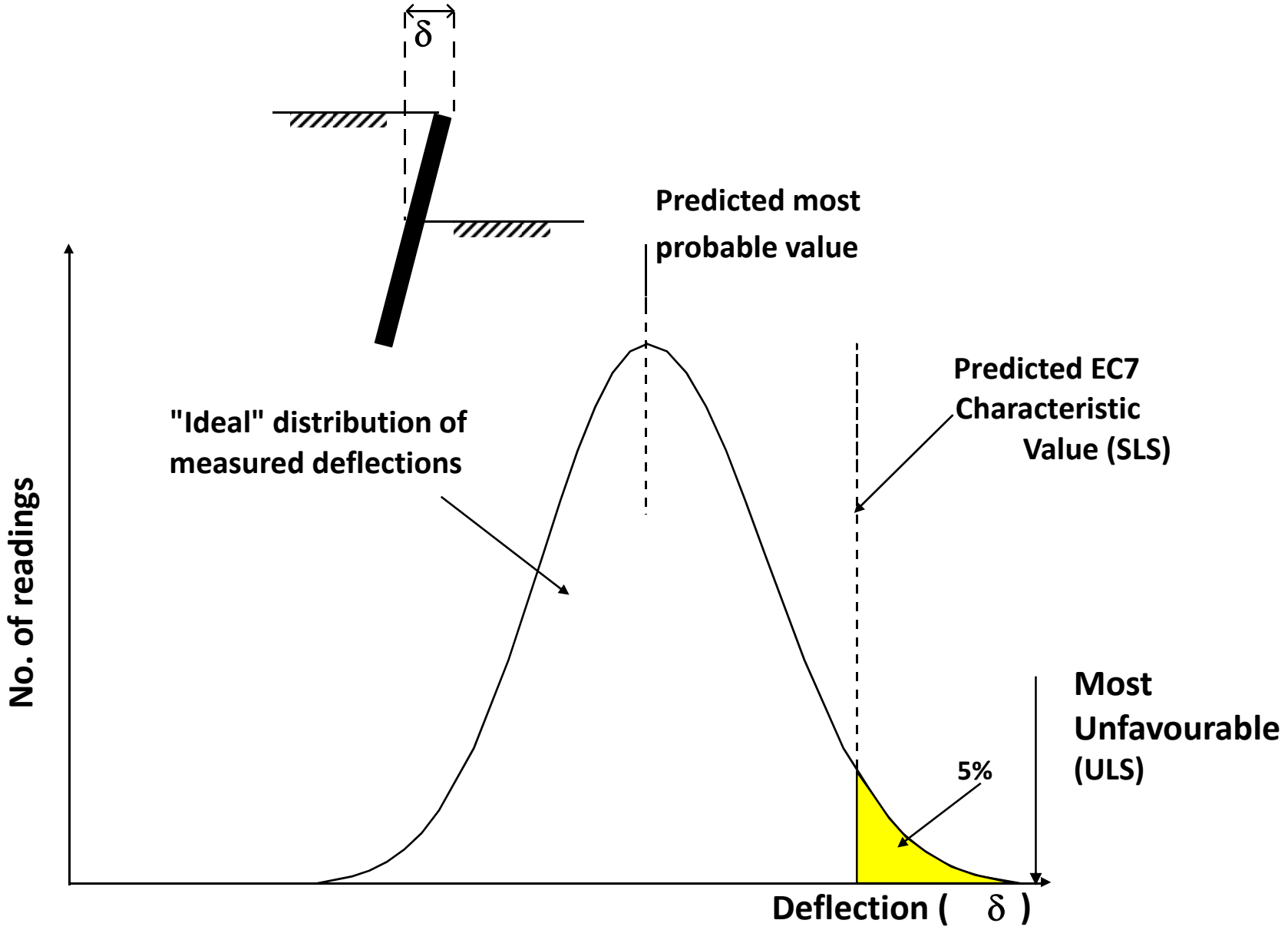
- **UK Current Codes**
  - **CIRIA C580**
  - **Eurocode – EC7**

Most Probable	**Not used**
Not used	Mod Conservative or Characteristic
Most Unfavourable	Worst credible

UK Design Codes - Soil Strength Parameters



Ideal EC7 Predicted versus Measured Performance



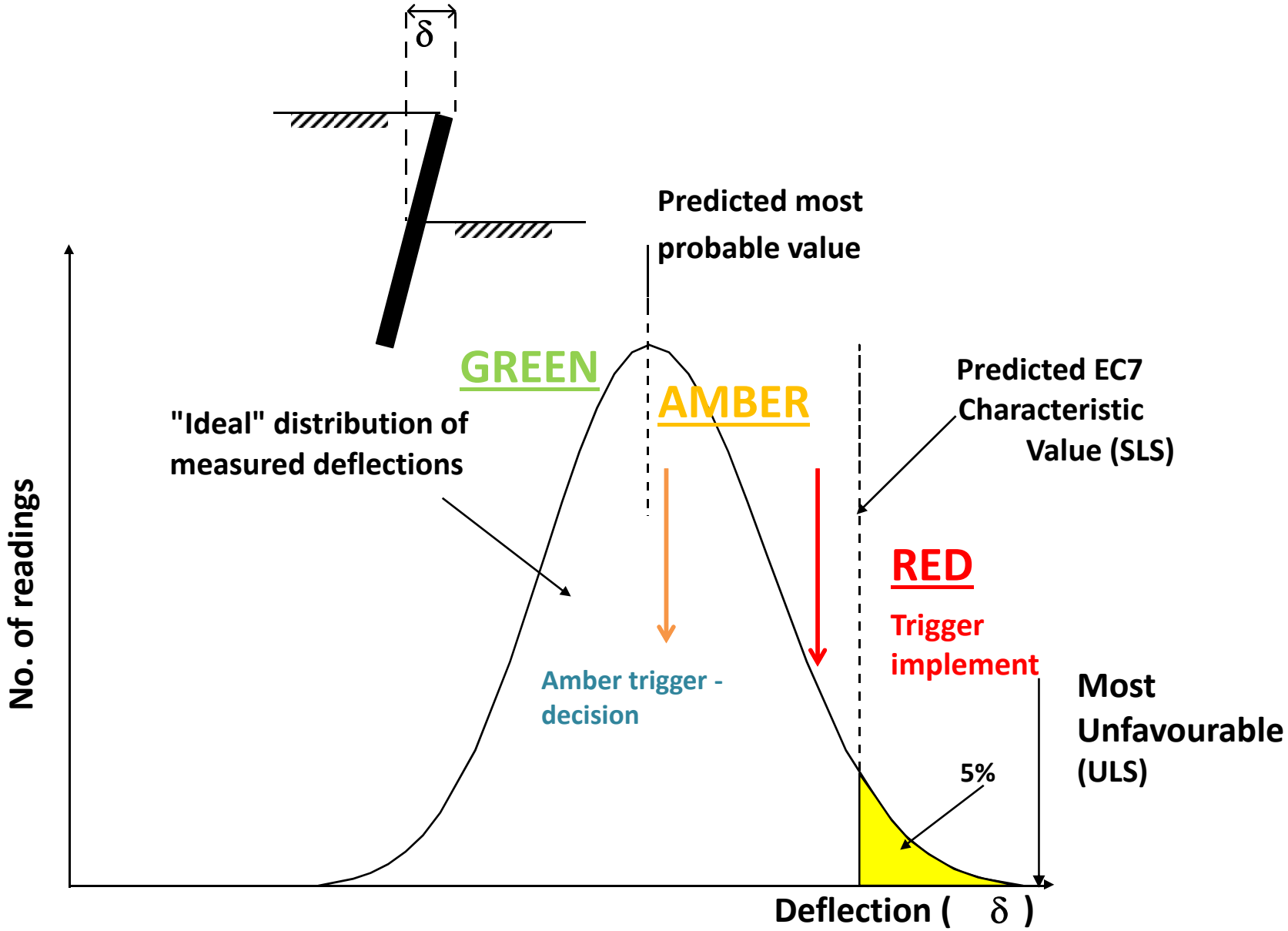
Trigger Criteria

Traffic light conditions include:-

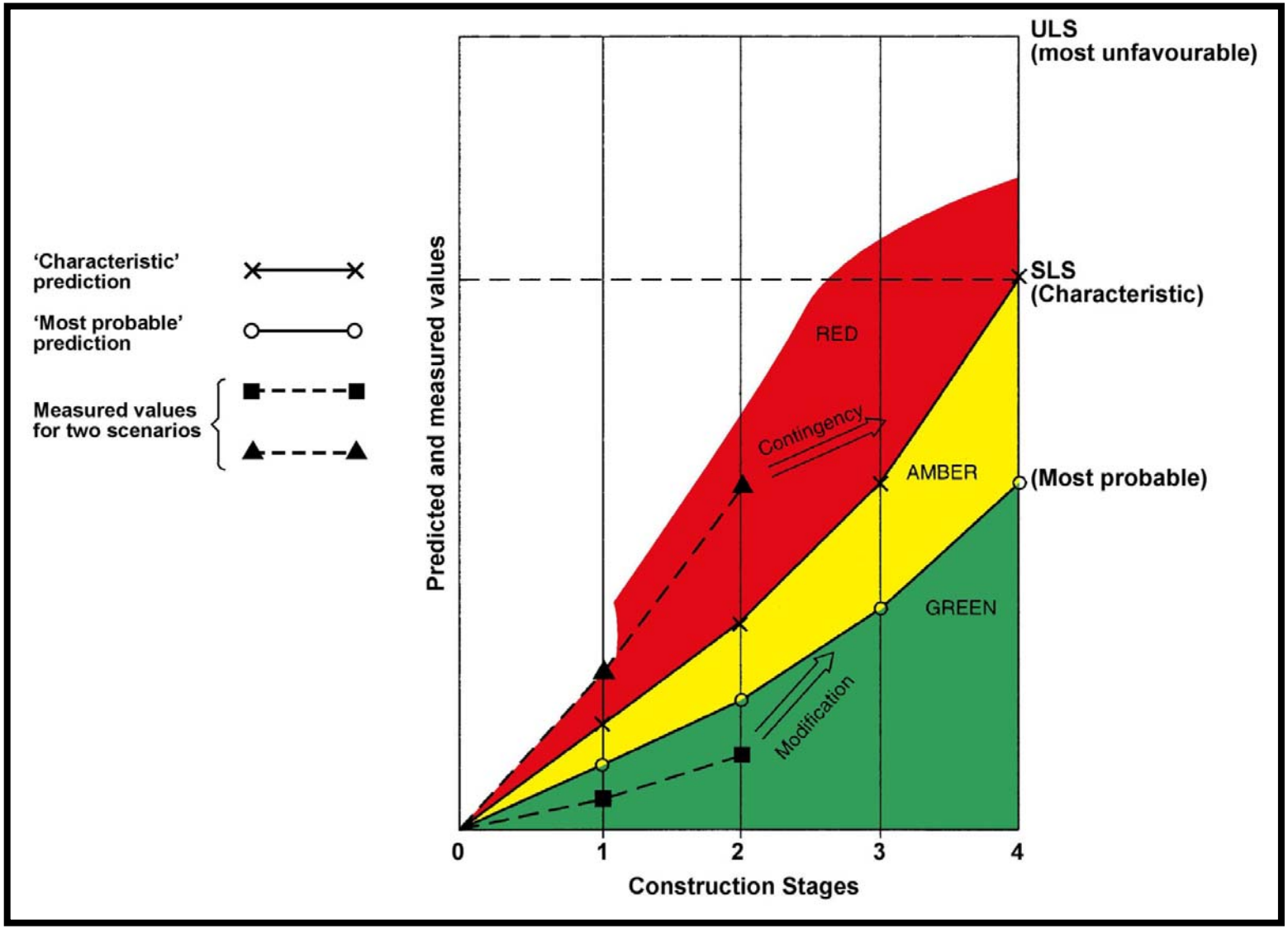
- **Green** = Safe site condition.
- **Amber** = Decision stage
- **Red** = Implement planned modifications
- **Emergency** = Evacuation

(Not normally part of OM. Required under CHSW Reg (1996). Relates to Ultimate Limit State.)

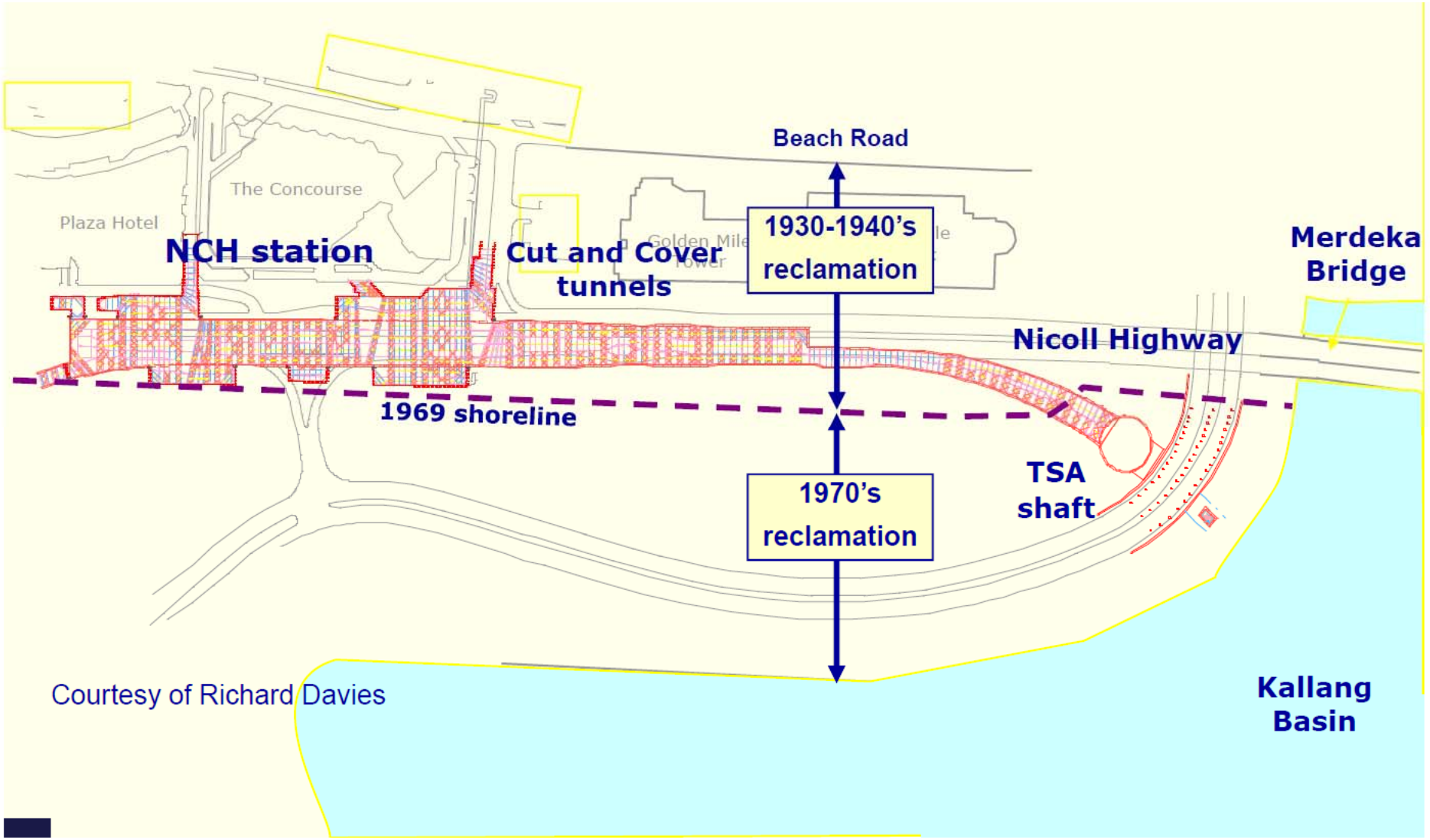
Ideal EC7 Predicted versus Measured Performance

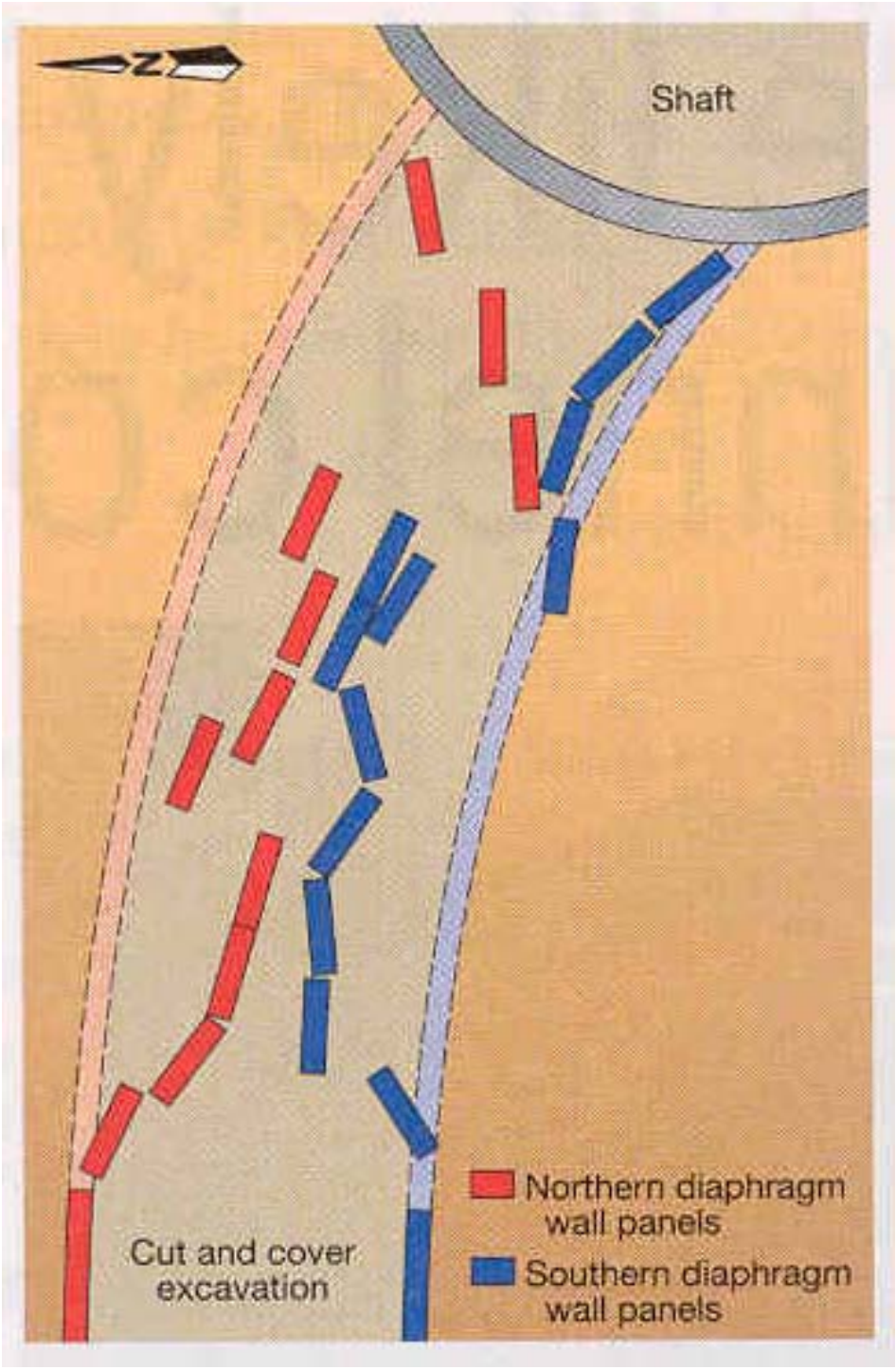


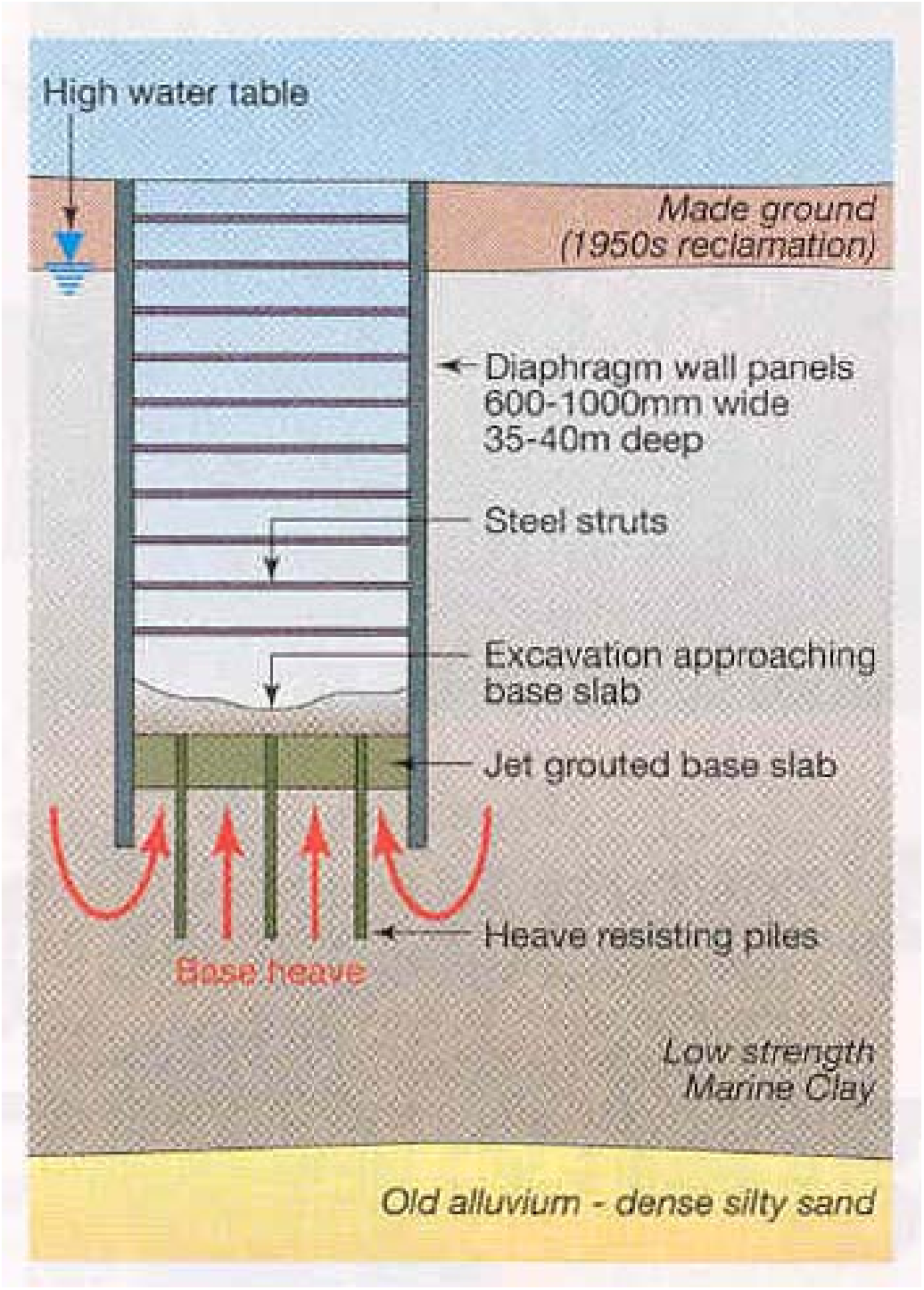
CIRIA (1999) Fig 3.13 Multi Stage Excavation

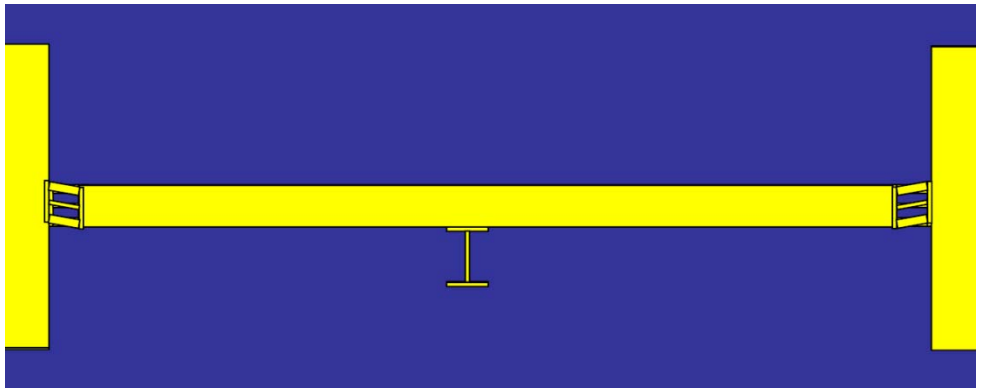



New Civil Engineer
nce
www.nceplus.co.uk
Magazine of the Institution of Civil Engineers
29 April 2004
Singapore cut and cover collapse

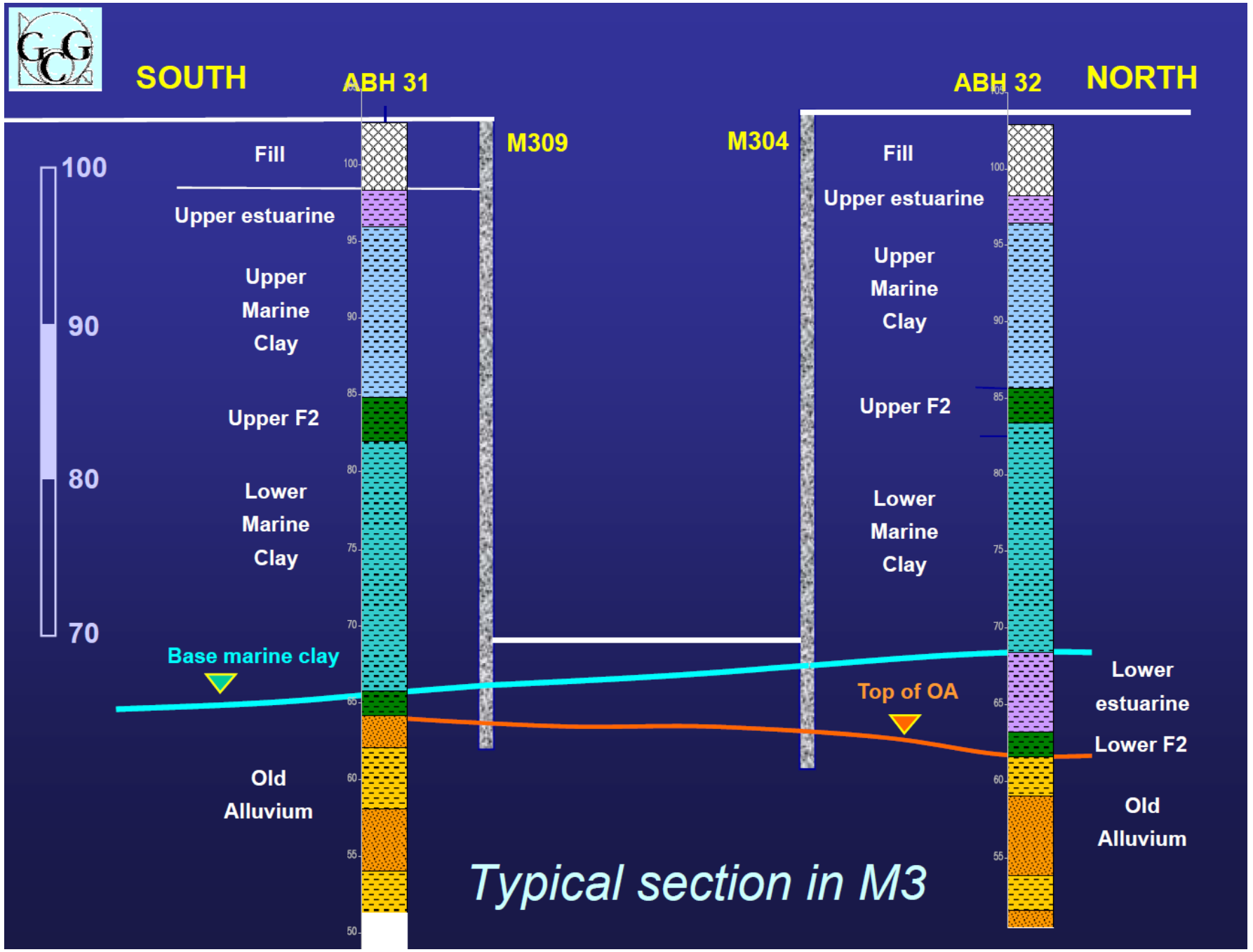

Beach Road
The Concourse
Plaza Hotel
NCH station
Cut and Cover tunnels
1930-1940's reclamation
Merdeka Bridge
Nicoll Highway
1969 shoreline
TSA shaft
1970's reclamation
Courtesy of Richard Davies
Kallang Basin


N
Shaft
Cut and cover excavation
Northern diaphragm wall panels
Southern diaphragm wall panels


High water table
Made ground
(1950s reclamation)
Diaphragm wall panels
600-1000mm wide
35-40m deep
Steel struts
Excavation approaching
base slab
Jet grouted base slab
Heave resisting piles
Base heave
Low strength
Marine Clay
Old alluvium - dense silty sand

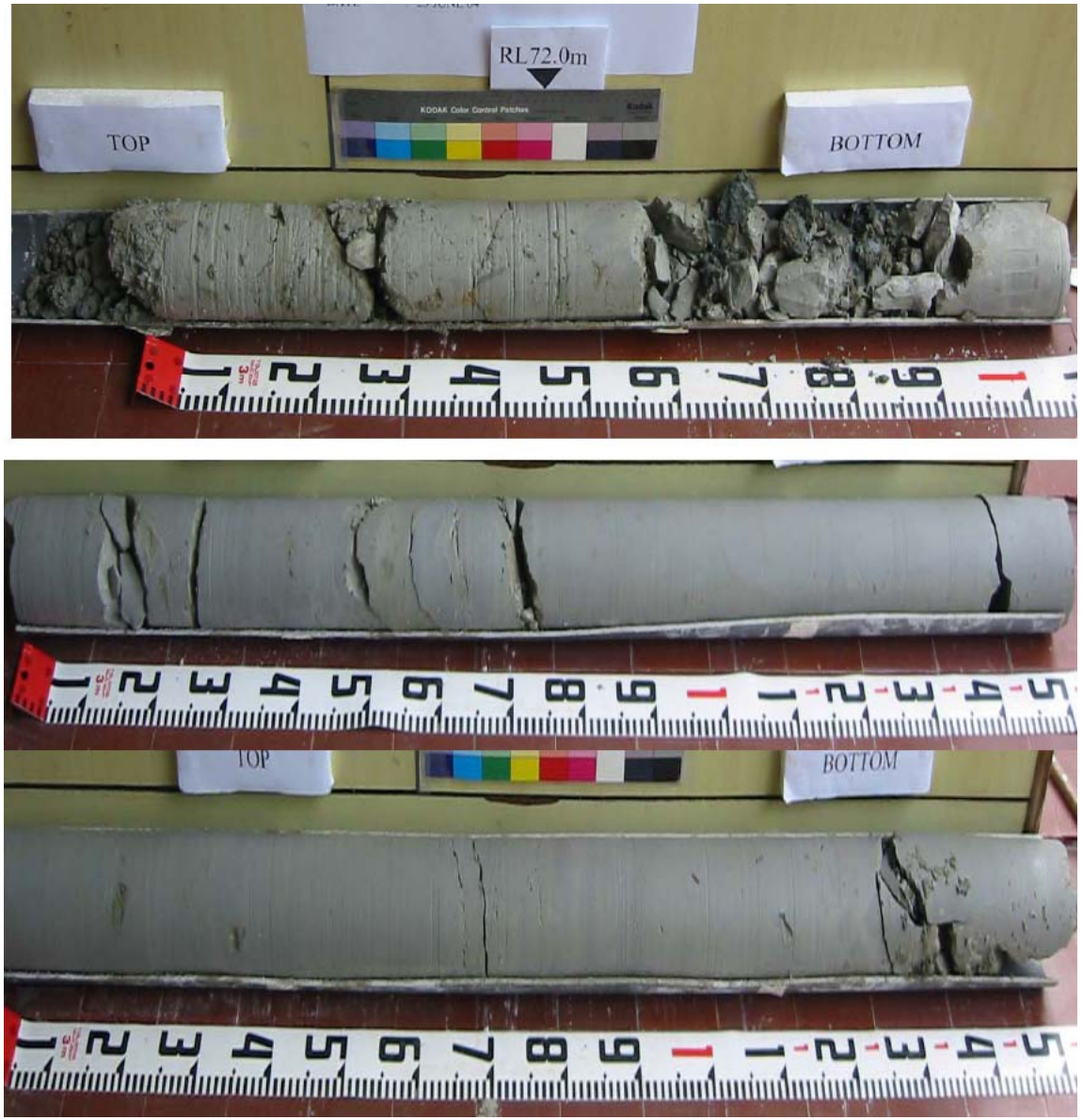


Hight, GCG


SOUTH
ABH 31
M309
M304
ABH 32
NORTH
100
90
80
70
Fill
Upper estuarine
Upper Marine Clay
Upper F2
Lower Marine Clay
Base marine clay
Old Alluvium
Top of OA
Lower estuarine
Lower F2
Old Alluvium
Typical section in M3

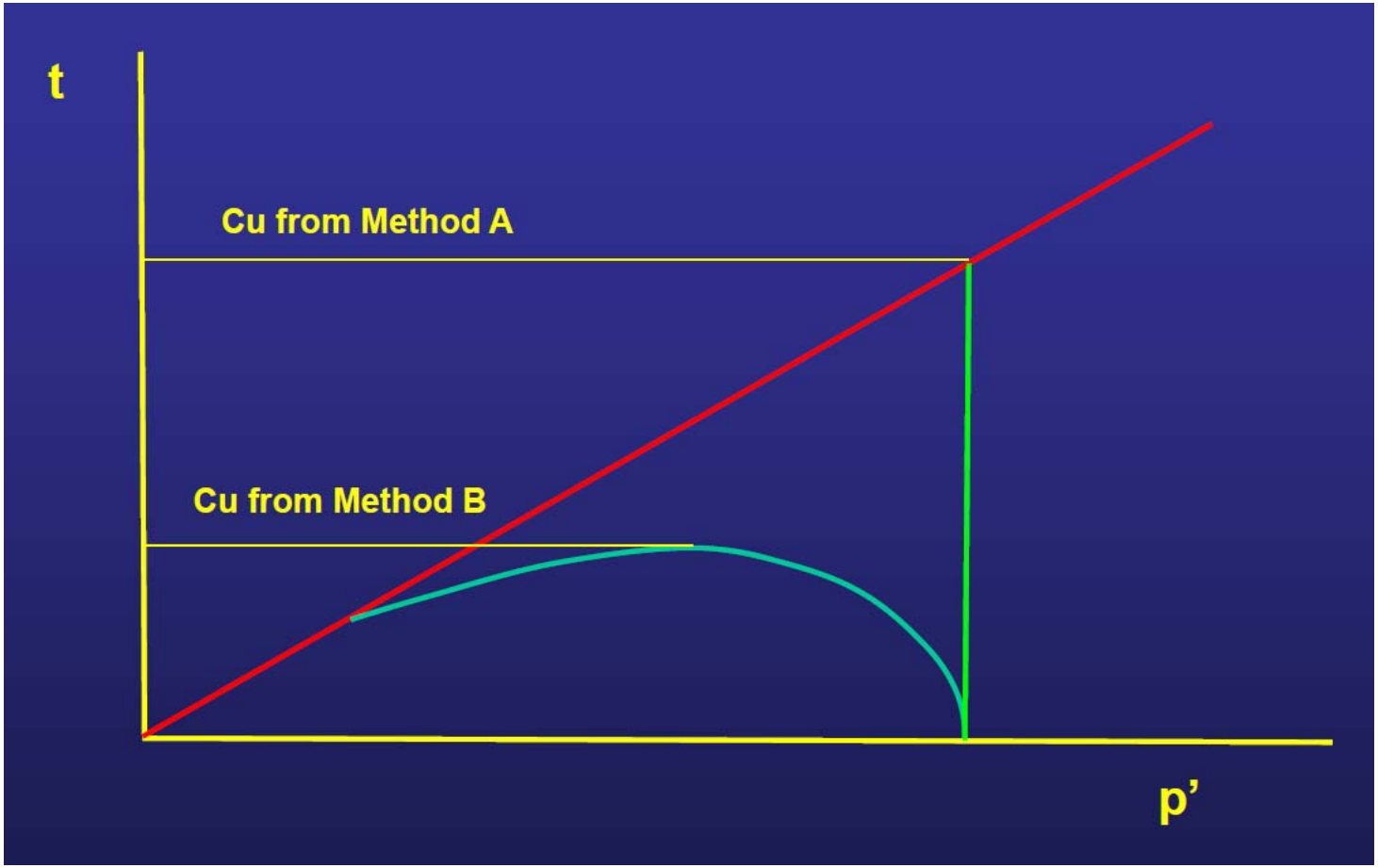
Hight, GCG

Quality of Jet Grouting

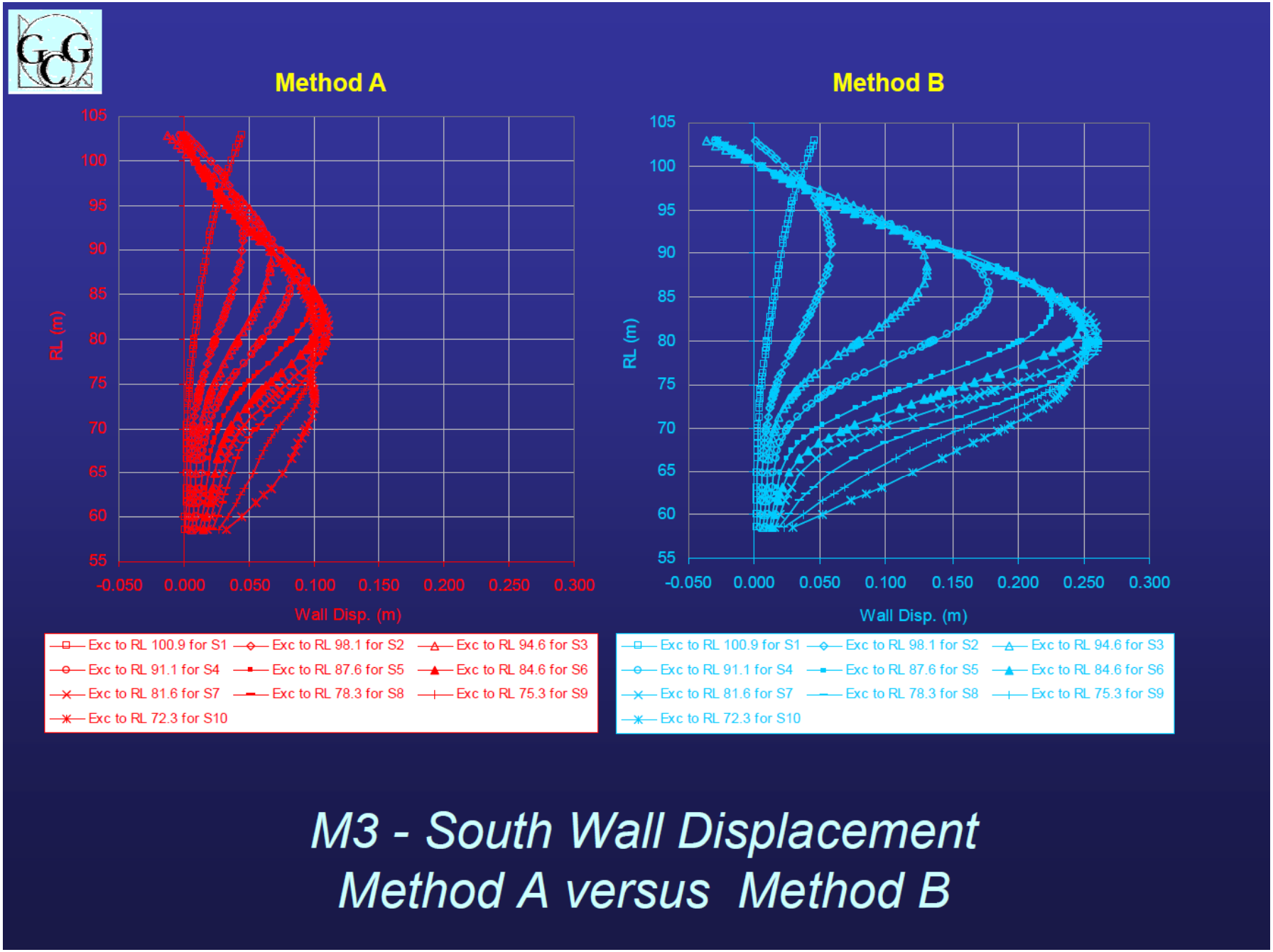


Hight, GCG

Grouted material (brittle) – Soft Clay (ductile)
Mass properties?



Hight, GCG



M3 - South Wall Displacement
Method A versus Method B

Back Analysis

(1) Develop a model of the events, leading up to the failure, using the available evidence.

(2) Make adjustments to parameters, design methodologies or assumptions within credible bounds until the model matches the actual behaviour observed in the field.

(3) Assess validity of the original design method and the development of subsequent design modifications with greater confidence.

(4) A vital tool in recovery of unexpected events or problems before failure occurs

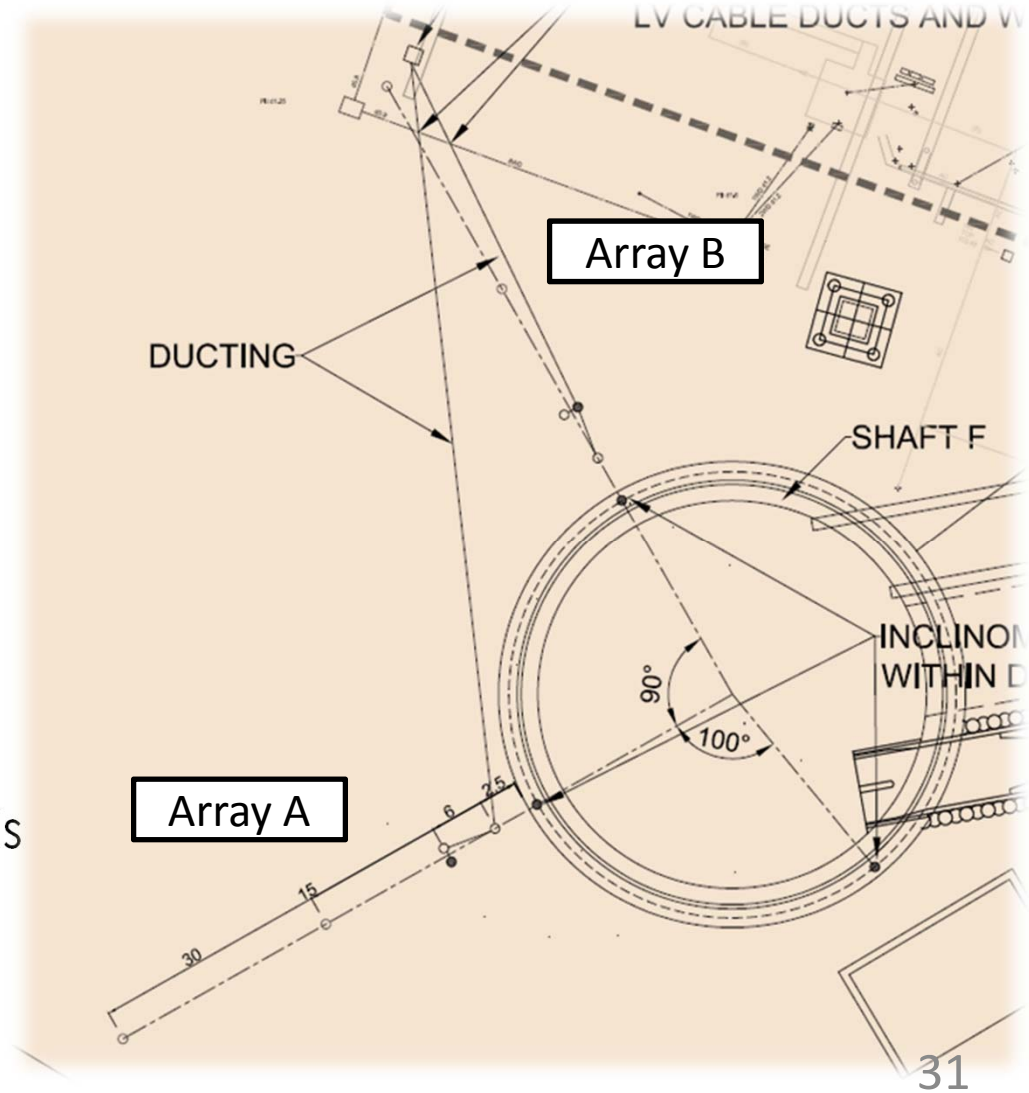
Construction Sequences

'I had …failed to examine all the available evidence with an open mind….pre-occupation with the wrong phenomenon created a blind spot to the significant phenomenon'. (Peck, 1969)

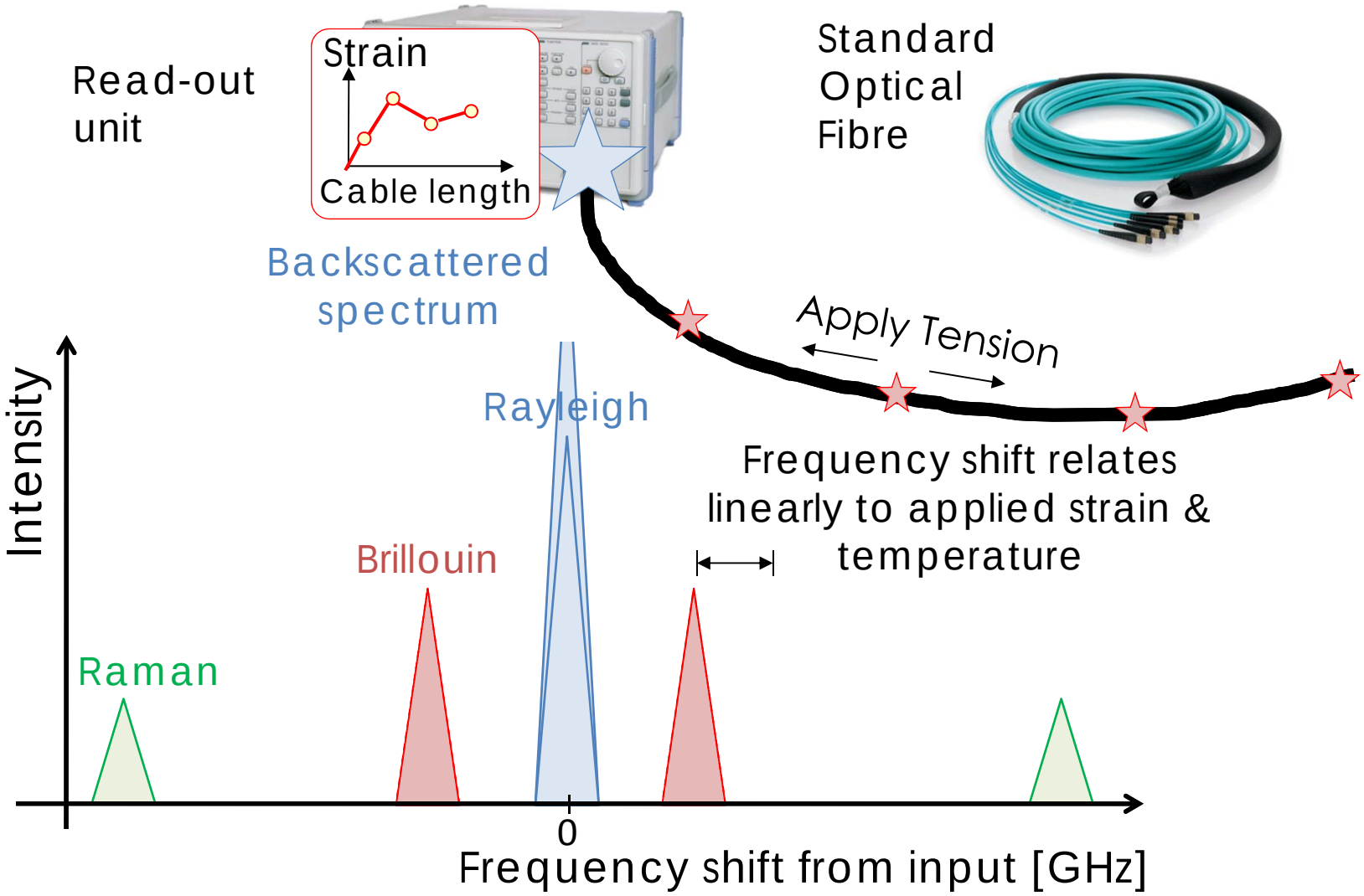
Understanding the actual conditions and behaviour operating in the field, rather than justifying the original design assumptions.

Overview

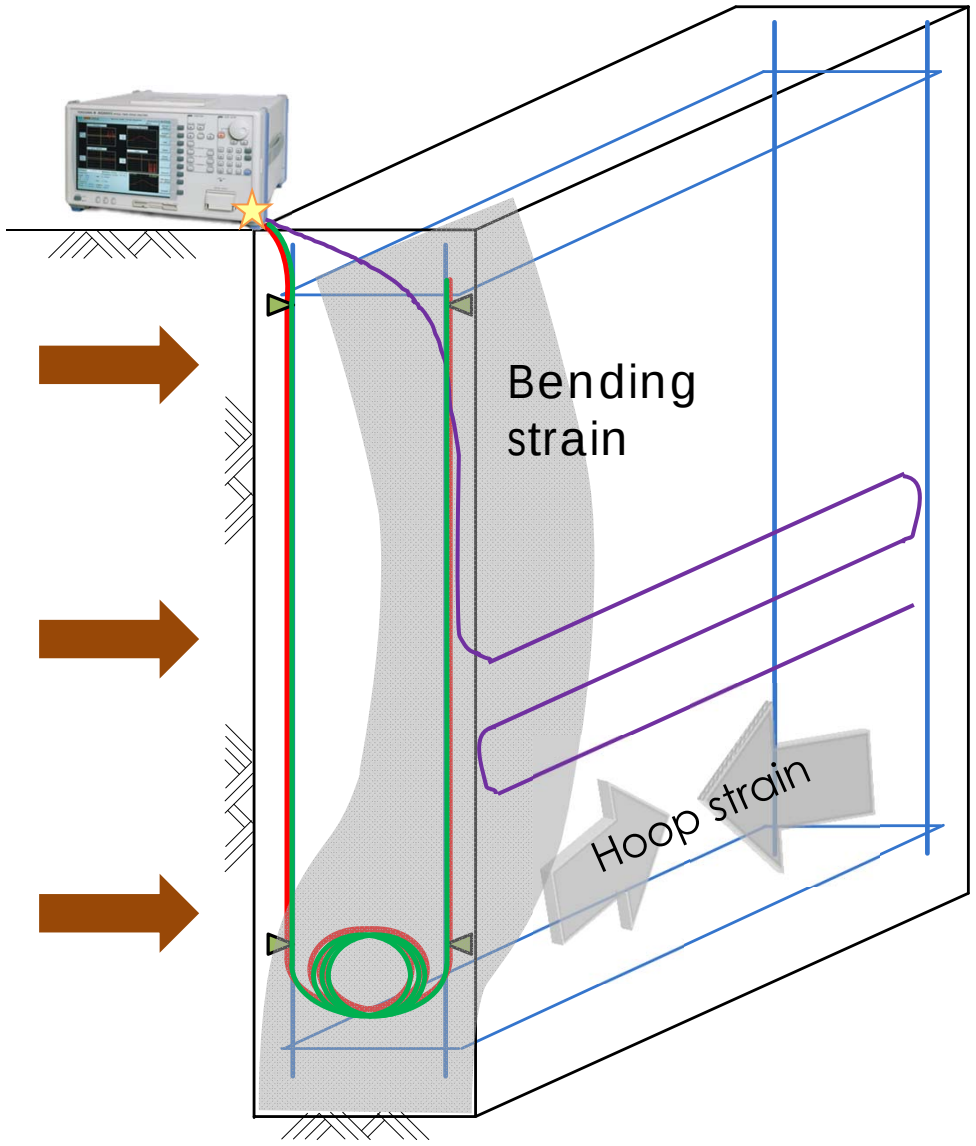
- Abbey Mills shaft:
  - 30m diameter
  - 73m deep
- Diaphragm walls:
  - 1.2m thick
  - 84m deep
- Monitoring:
  - Fibre optics in 3 panels
  - Inclinometers in 3 panels
  - Inclinometers & Extensometers in surrounding soil



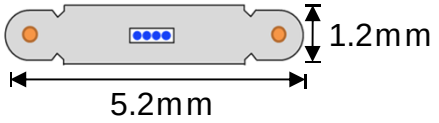
Fibre Optics Monitoring



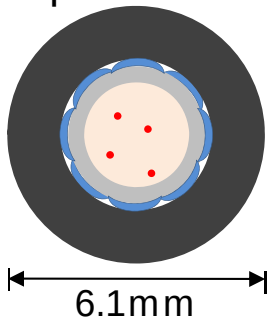
Fibre Optics Installation



Strain cable



Temperature cable



Monitoring

1. **Dewatering trial**

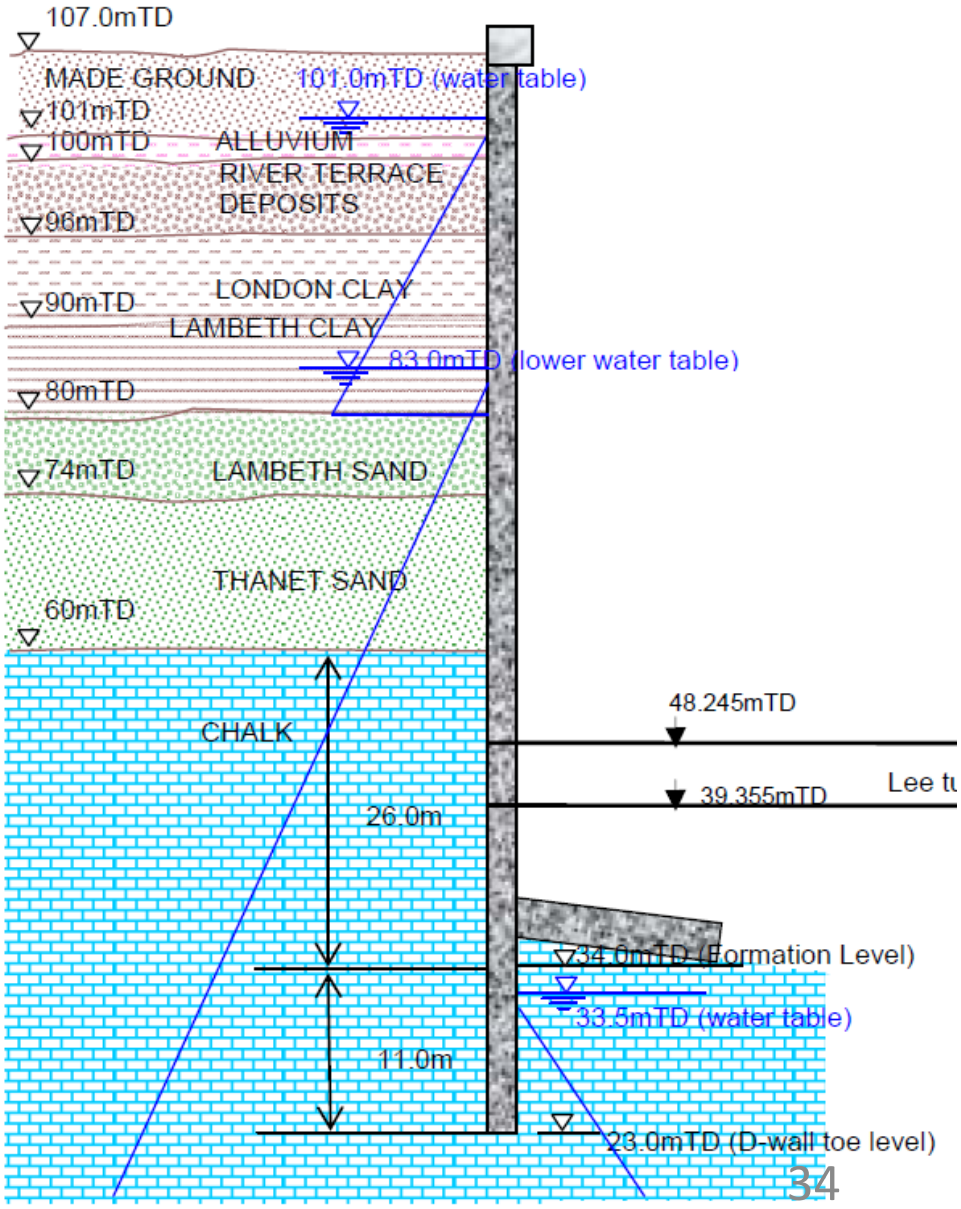
   Before shaft excavation

   Water table lowered to test if dwalls are waterproof

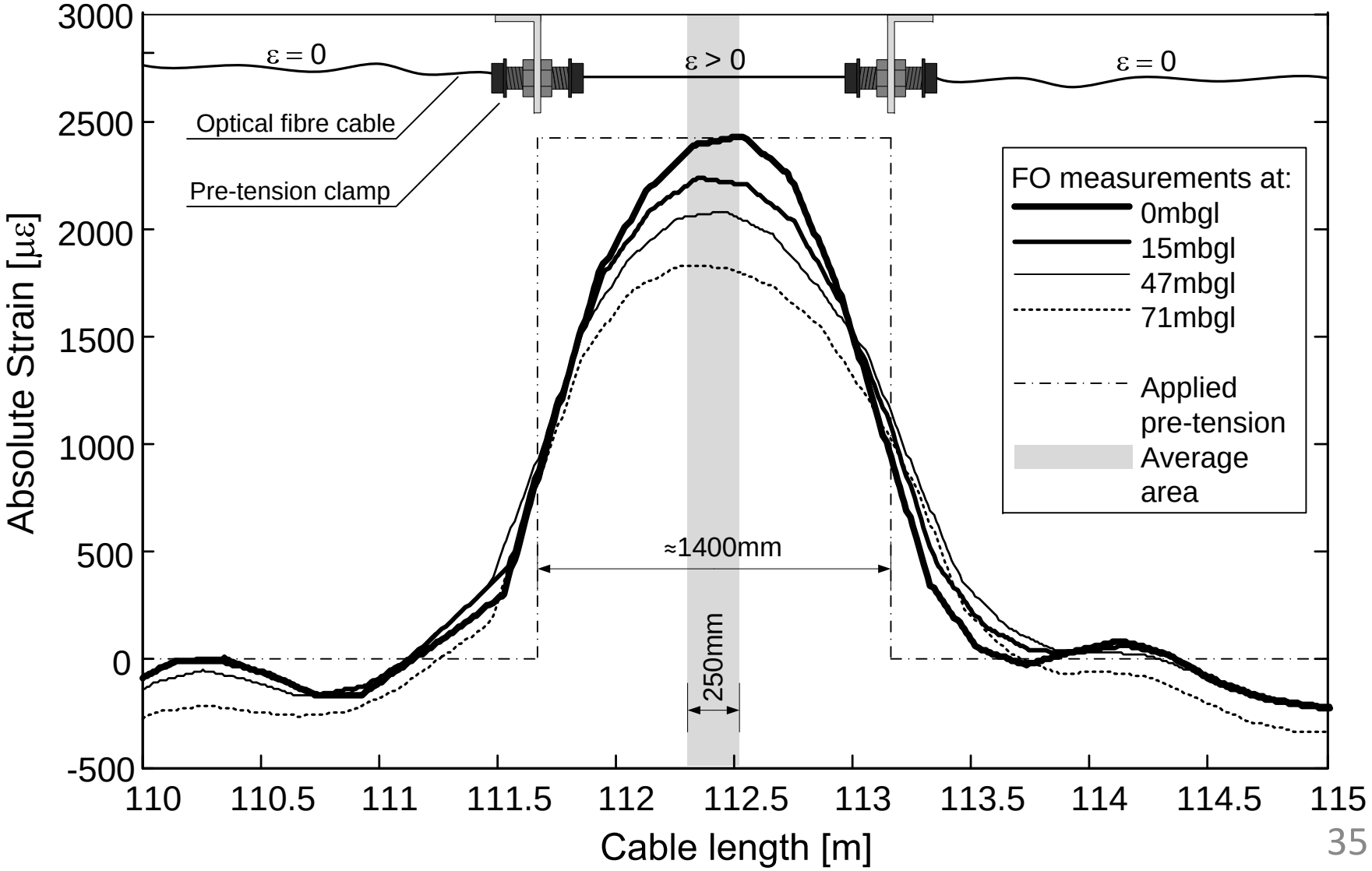
   Take reading before dewatering and after.

2. **Shaft excavation**

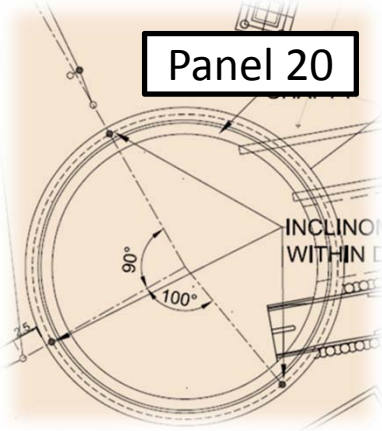
   Take readings at several excavation depths.

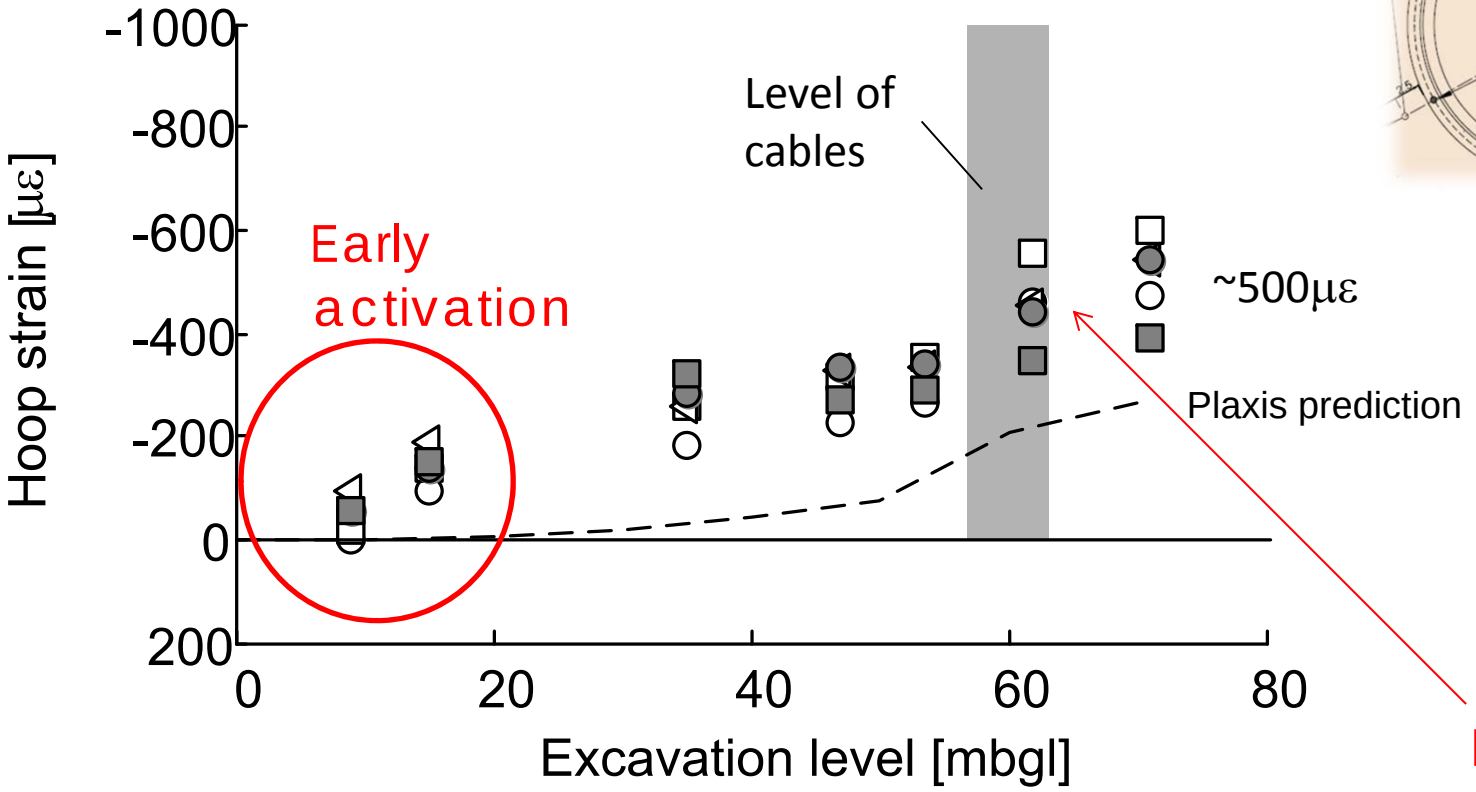


Analysis - Hoop



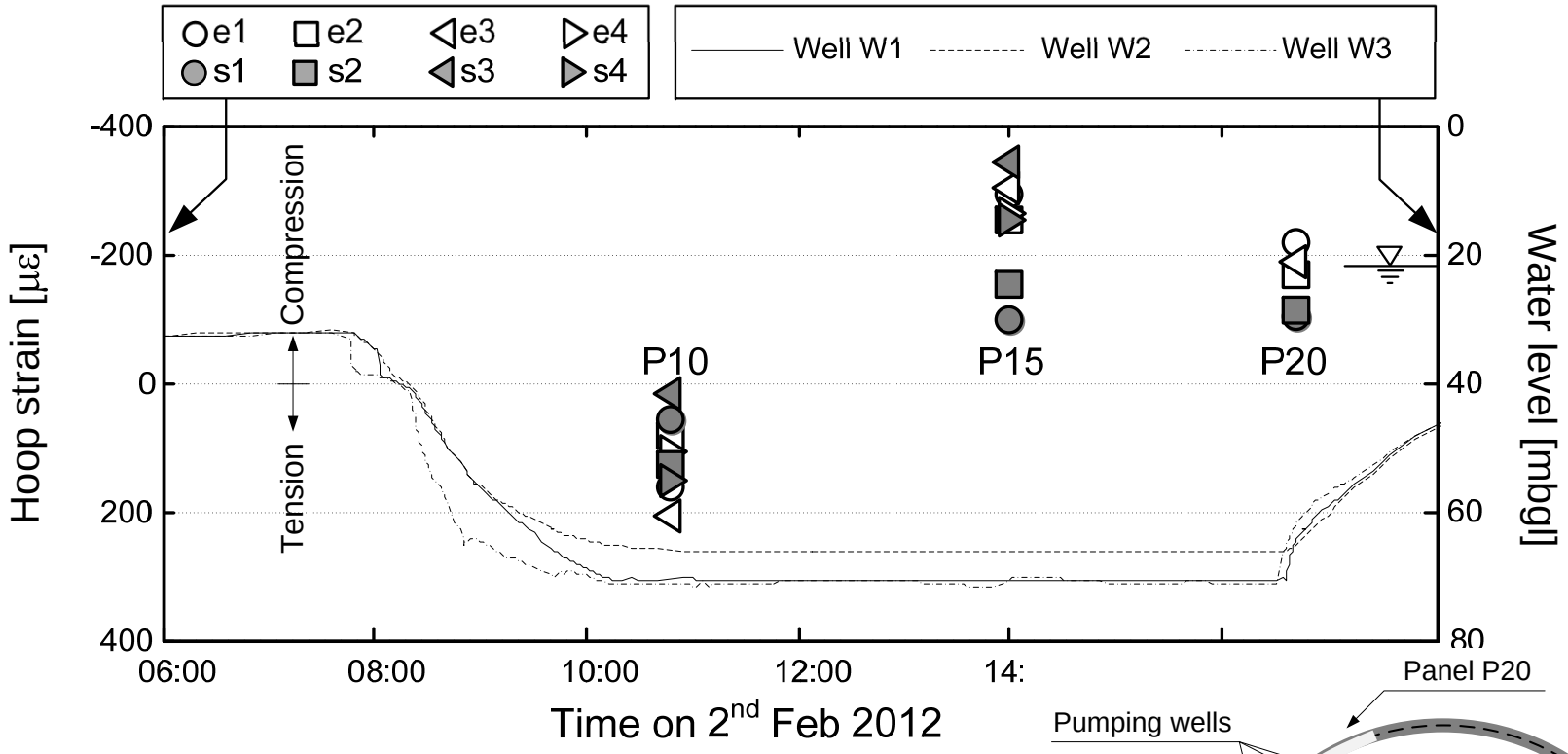
Results – Hoop Strain



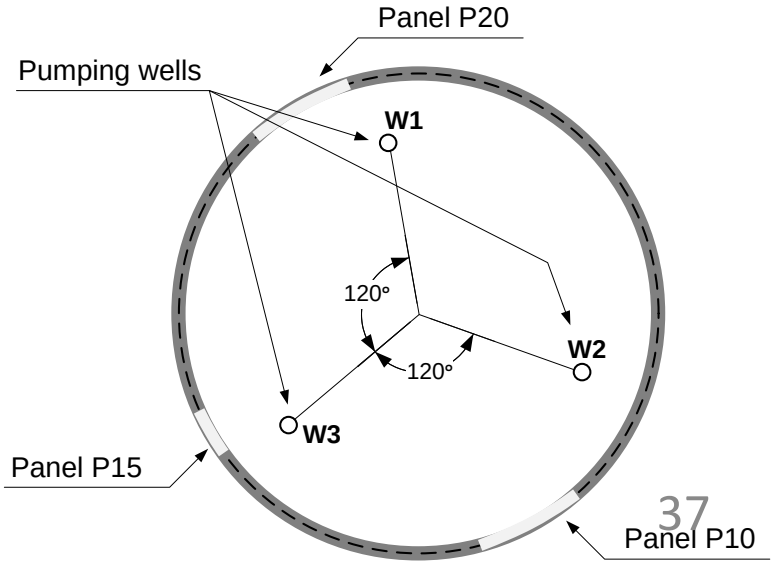


Larger than predicted

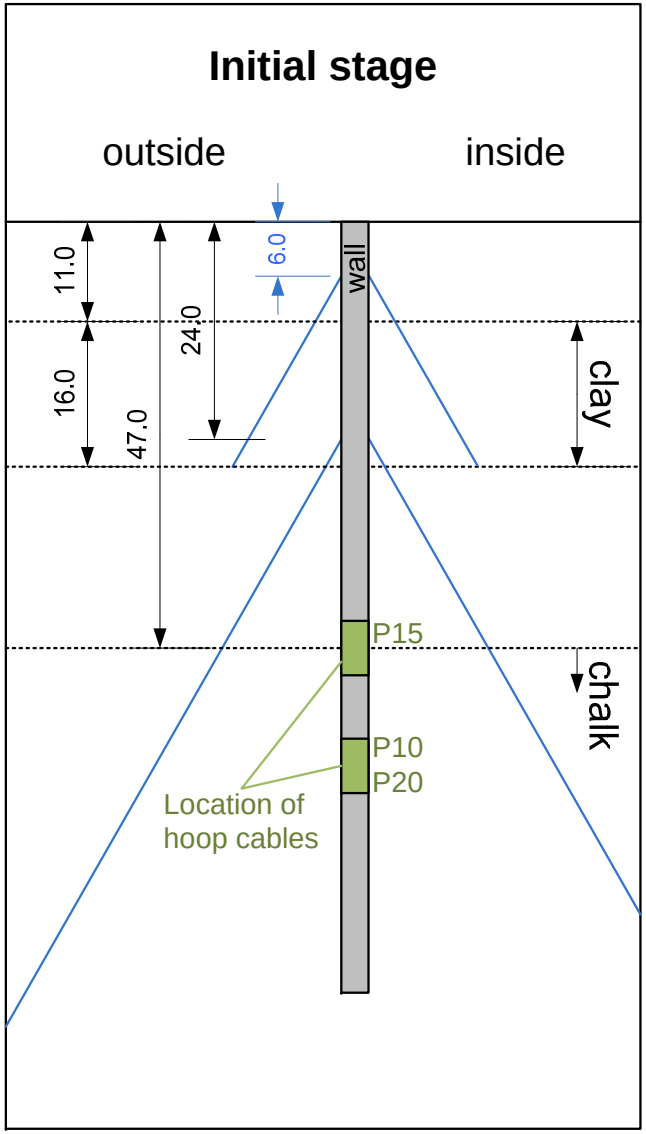
Results – Hoop - Dewatering

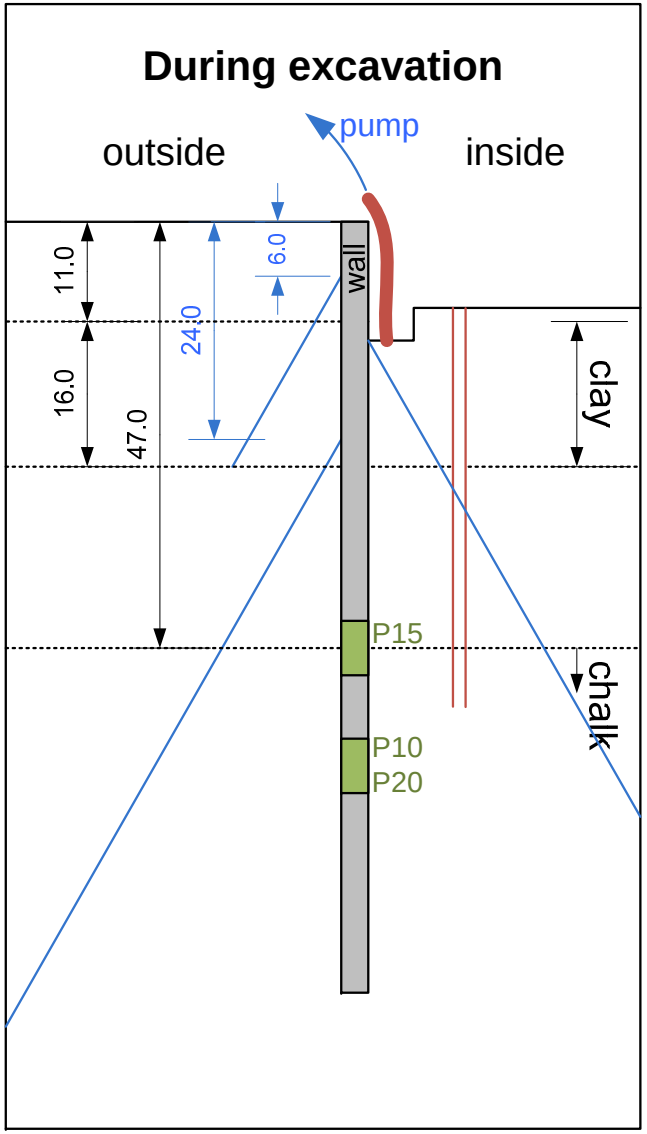


- P15/P20 in compression
- P10 far away from well / measurements taken directly after lowering the water table



Early activation due to hydraulic connection





Construction sequences

Model all stages of the construction and match the observed behaviour **at each and every significant construction stage.**

The construction sequence and geometry of the **'as-built' works**

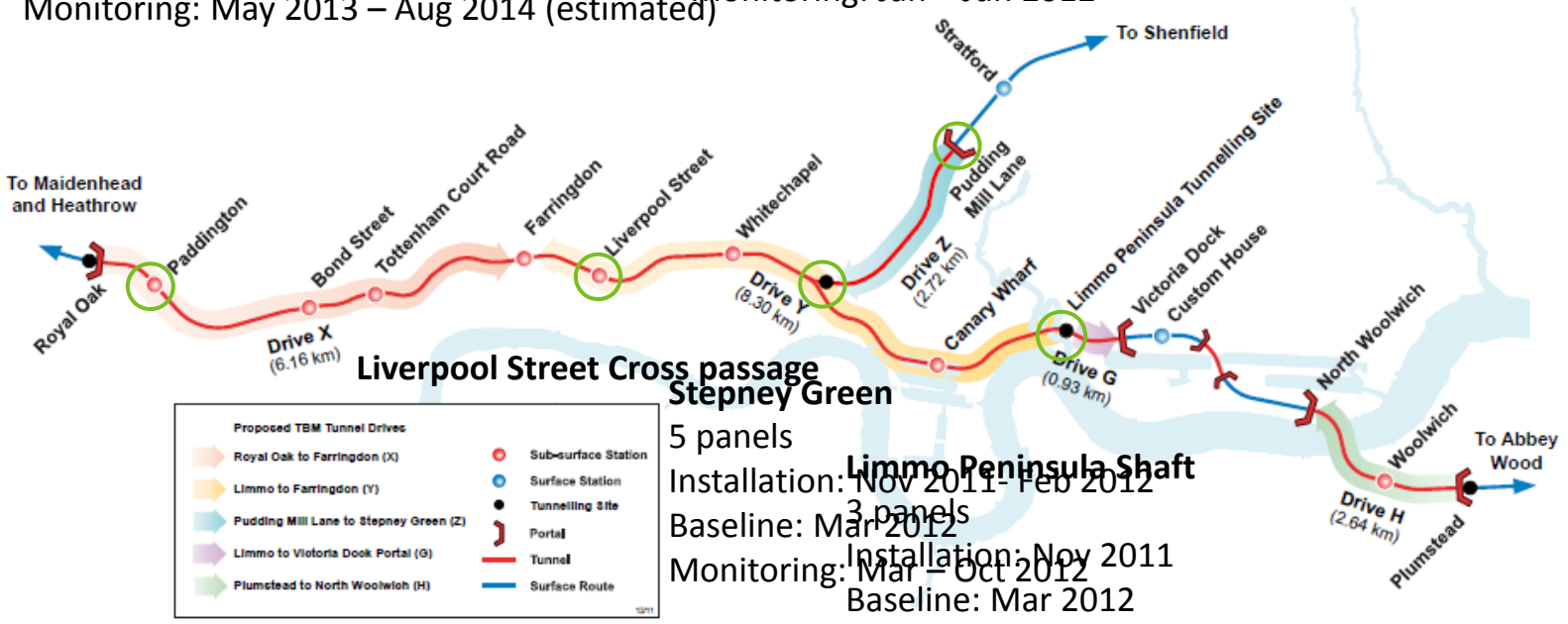
The soil conditions and material properties determined from the model are **realistic and compatible**

within the range of foreseeable parameters from the site investigation data

compatible with empirical correlations for that soil type.

Paddington Station Main Box
2 panels
Installation: Oct 2012 – Jan 2013
Baseline: Feb 2013
Monitoring: May 2013 – Aug 2014 (estimated)

Pudding Mill Lane Portal
3 panels
Installation: Jan 2011- Mar 2011
Baseline: Jul 2011
Monitoring: Jan – Jun 2012



Liverpool Street Cross passage
Stepney Green
5 panels
Installation: Nov 2011- Feb 2012
Baseline: Mar 2012
Monitoring: Mar – Oct 2012

Limmo Peninsula Shaft
3 panels
Installation: Nov 2011
Baseline: Mar 2012
Monitoring: Mar – Nov 2012

Efficient interpretation of monitoring data

Outline objectives of research:

- Review clarity of monitoring data presentation;
- Linkage between construction progress, design and monitoring results;
- Data interface for transfer of monitoring data;
- Use of laser scanning and photogrammetry (documentation and change monitoring);
- Improving monitoring viewer systems and use of dashboards; and
- Long term storage of monitoring data & collation of case studies.

Industrial steering panel set up to offer guidance to study

ARUP UNDERGROUND Crossrail itmsoil UCL

Other important issues

- National and corporate policies in providing an appropriate framework for use of the OM.
- Project organisation and culture to support to the OM.
- Open communication approach to investigating and resolving unexpected events.

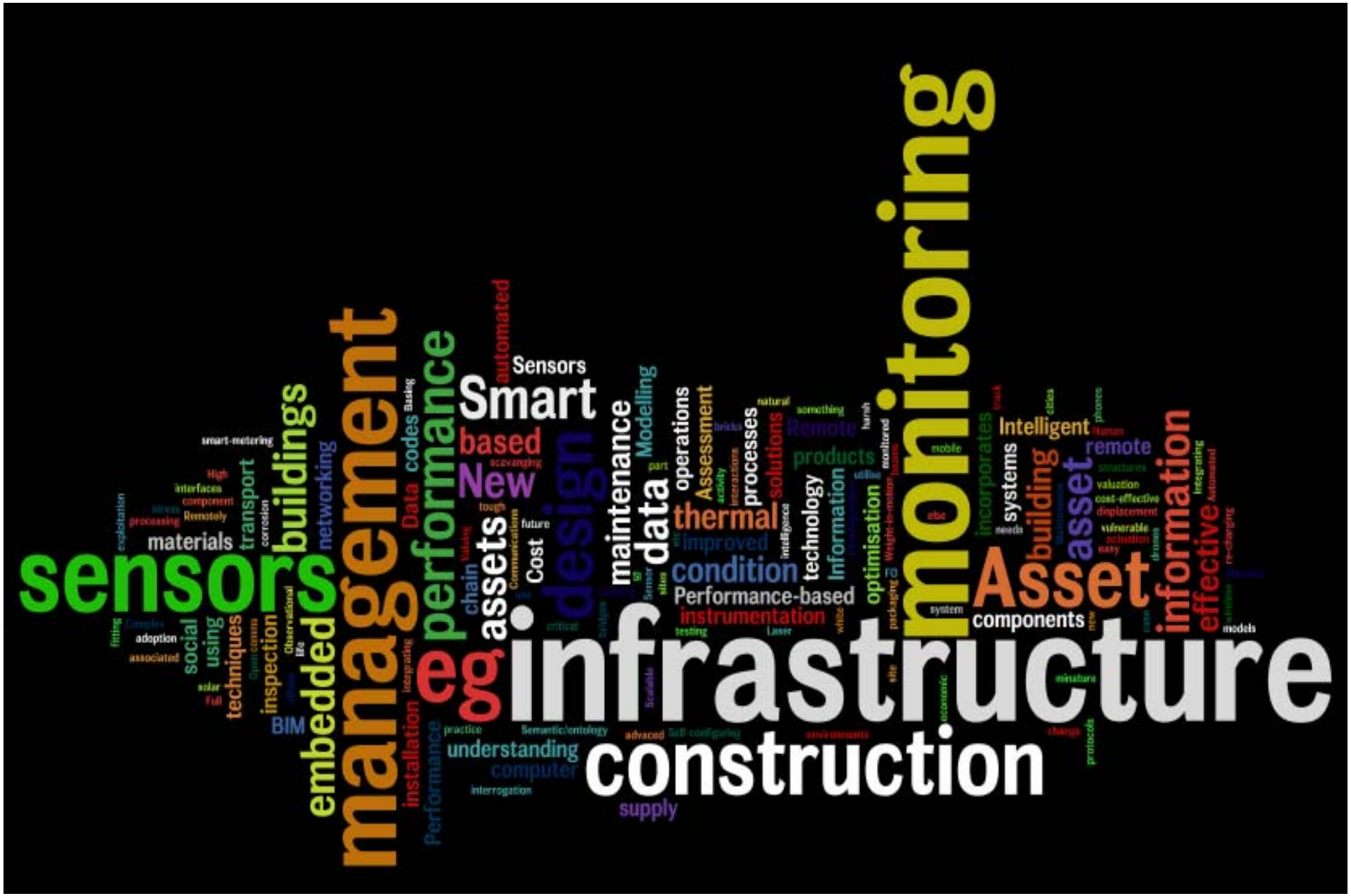
OM and Performance based design

The purposes of the back analysis process is

(a) to refine the designer's understanding of the actual behaviour of the structure, and

(b) to reduce the level of uncertainty

for this project as well as **future projects**.



ご清聴ありがとうございました。