「リスク共生から見た地盤工学上の課題」

地盤工学の新たなる課題と モニタリングの重要性

ケンブリッジ大学、横浜国立大
曽我健一

社会インフラストラクチャー リスク共生、イギリスでは。。。

- 外貨獲得のためのインフラ開発
- データに基づいた政策決定
- Building Information Modellingの活用
- リスクベースの維持管理
- 工学的知識を活用したモニタリング

CabinetOffice

Government Construction Strategy

May 2011

Establishment of "Infrastructure UK" in 2010

HM Treasury

From 2010 to 2014

National Infrastructure Plan 2014

トンネル！

National Infrastructure Plan

- "High quality infrastructure is essential for supporting productivity growth. Delivering the right infrastructure at a local, regional and national level, across the UK, is […] **key to the government's long-term economic plan**."
- **£466B (90兆円）** for the next generation of infrastructure by 2020
- **2,500 different projects**
- **A step-change** in the nation's approach to infrastructure investment.
- **An export potential** for an international market that is valued at least **$57 trillion (5700兆円）** in the period up to 2030.

Crossrail – New London Underground Line in London

- 118 km from east to west
- 37 stations
- 9 new stations (8 sub-surface)
- Increase London's rail-network capacity by 10%

Industrial Strategy (2013)

過大設計
安全率の神話化

品質向上

Lower costs 33%	Faster delivery 50%
Lower emissions 50%	Improvement in exports 50%

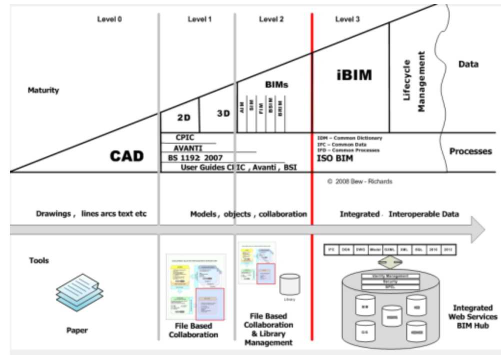
建設材を少なく。 他にない地盤工学

UK Infrastructure - Risk

- The cost to the nation of inadequate infrastructure is estimated to be in the order **£2M per day** or **$0.75B per year**.
- For extreme events, direct costs can be in **the £100Ms per incident**.
- National economic infrastructure is **largely privatized and sectorally divided**.
- As foreign investment in infrastructure systems and networks increases, trans-national **corporate governance priorities** may also come into **conflict with these national hierarchies,** with fiscal and political consequences.

Evidence base decision making

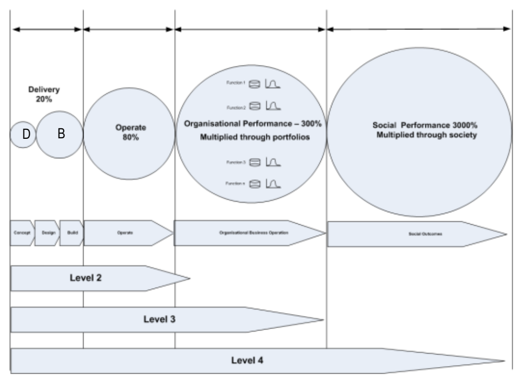
Building Information Modelling



CSIC Cambridge Centre for Smart Infrastructure and Construction EPSRC Technology Strategy Board Driving Innovation UNIVERSITY OF CAMBRIDGE

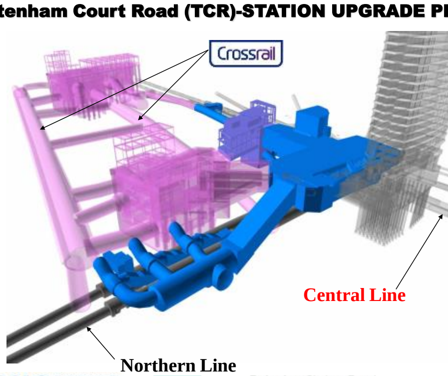
London Underground
Victoria Station Upgrade
Building Information Modelling
(courtesy Mott MacDonald)

CSIC Cambridge Centre for Smart Infrastructure and Construction EPSRC Technology Strategy Board Driving Innovation UNIVERSITY OF CAMBRIDGE



CSIC Cambridge Centre for Smart Infrastructure and Construction EPSRC Technology Strategy Board Driving Innovation UNIVERSITY OF CAMBRIDGE

Tottenham Court Road (TCR)-STATION UPGRADE PROJECT



CSIC Cambridge Centre for Smart Infrastructure and Construction EPSRC Technology Strategy Board Driving Innovation UNIVERSITY OF CAMBRIDGE

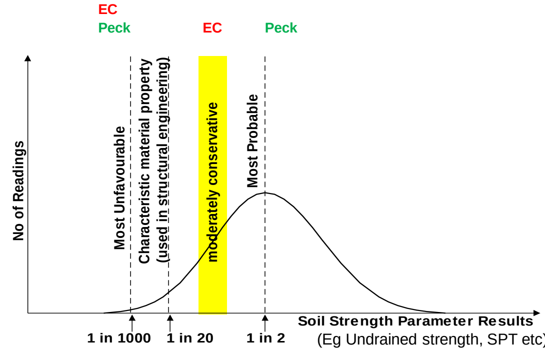
新しいインフラと古いインフラ

- 新しいインフラ
  - 建設および維持管理を安く
  - 本当のパフォーマンスとは。
  - Observational method
  - 長期モニタリング、そして劣化モデルの構築
- 古いインフラ
  - 実際の挙動を示したデータが必要
  - 他のシステムとの相互作用から検討
  - 劣化モデルの構築

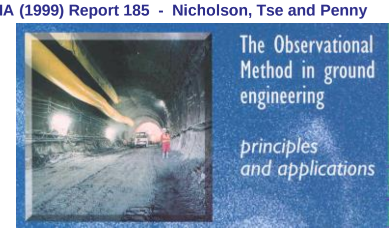
CSIC Cambridge Centre for Smart Infrastructure and Construction EPSRC Technology Strategy Board Driving Innovation UNIVERSITY OF CAMBRIDGE

Observational Method

UK Design Codes - Soil Strength Parameters



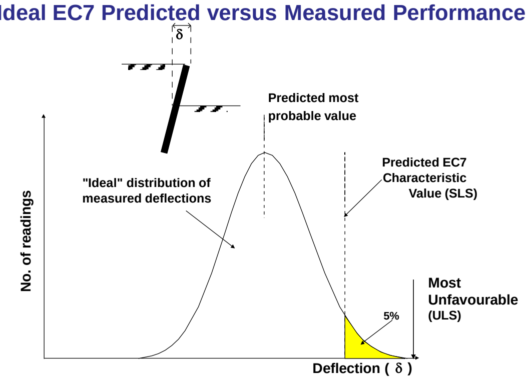
CIRIA (1999) Report 185 - Nicholson, Tse and Penny



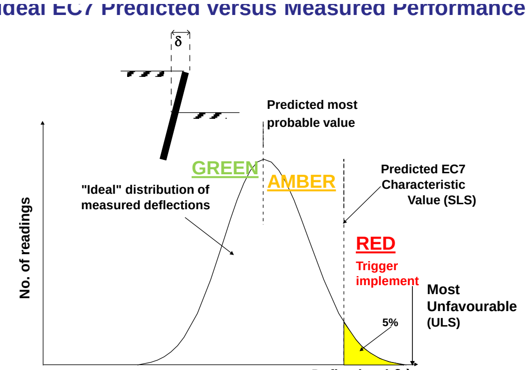
Goals

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

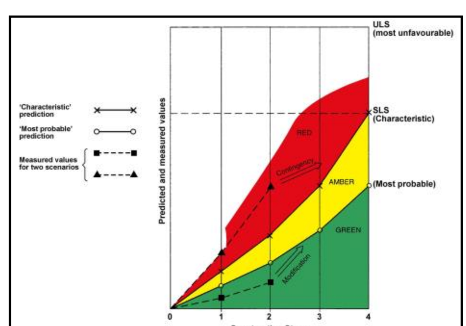
Ideal EC7 Predicted versus Measured Performance

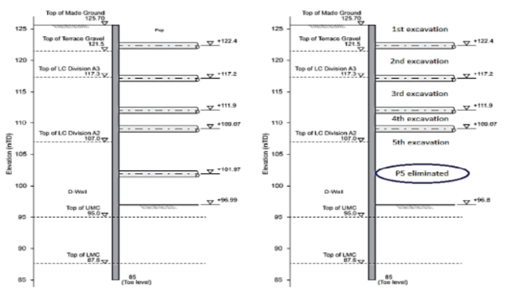


Ideal EC7 Predicted versus Measured Performance



CIRIA (1999) Fig 3.13 Multi Stage Excavation

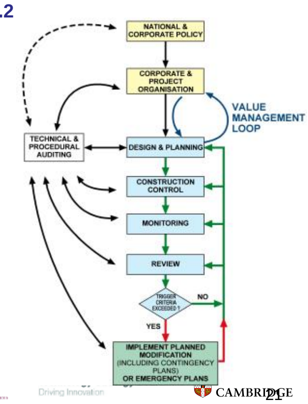




CSIC Cambridge Centre for Smart Infrastructure and Construction | EPSRC | Technology Strategy Board Driving Innovation | UNIVERSITY OF CAMBRIDGE

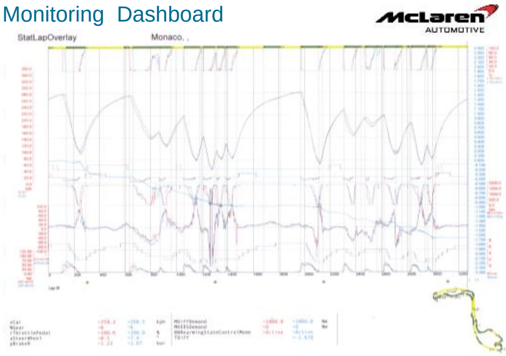
CIRIA (1999) R185 Figure 1.2

The OM Process



CSIC Cambridge Centre for Smart Infrastructure and Construction | EPSRC | Driving Innovation | CAMBRIDGE 21

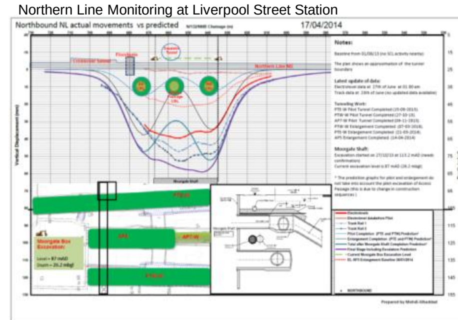
Monitoring Dashboard



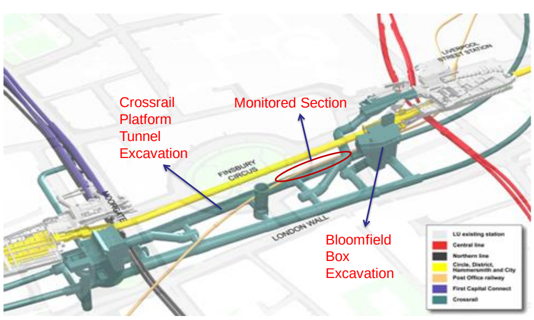
CSIC Cambridge Centre for Smart Infrastructure and Construction | EPSRC | Technology Strategy Board Driving Innovation | UNIVERSITY OF CAMBRIDGE

Data Interpretation Optimisation - Dashboards

Northern Line Monitoring at Liverpool Street Station



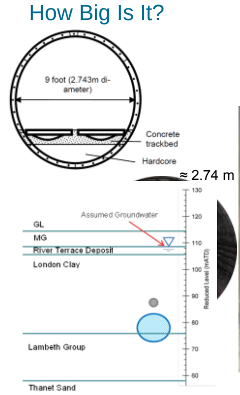
Monitored Section of the Royal Mail Tunnel Crossrail – Liverpool Street Station – C510

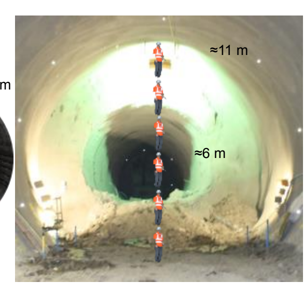


After Crossrail

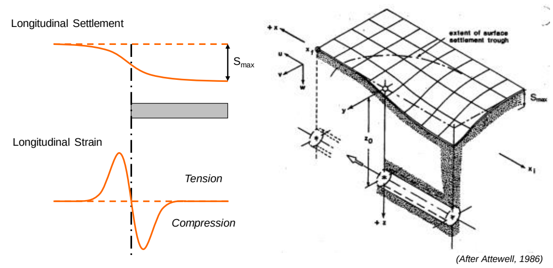
How Big Is It?

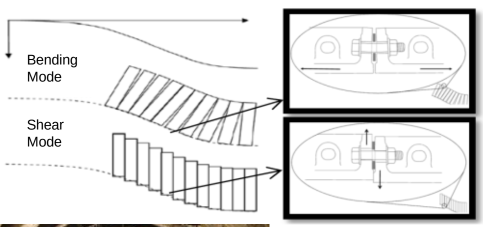
Constructed: 1917 - 1923
Made of cast iron
Suspended: 2003





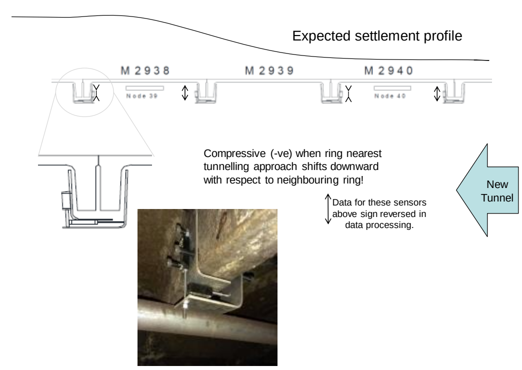
Tunnelling Induced Greenfield Settlements





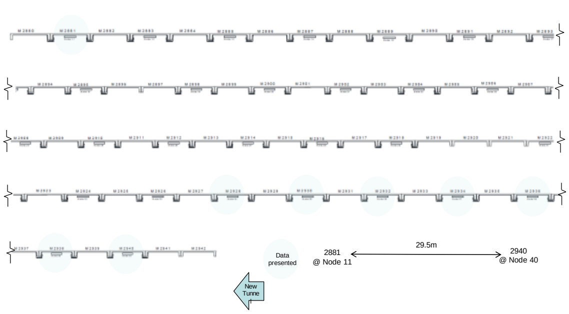
After Devriendt

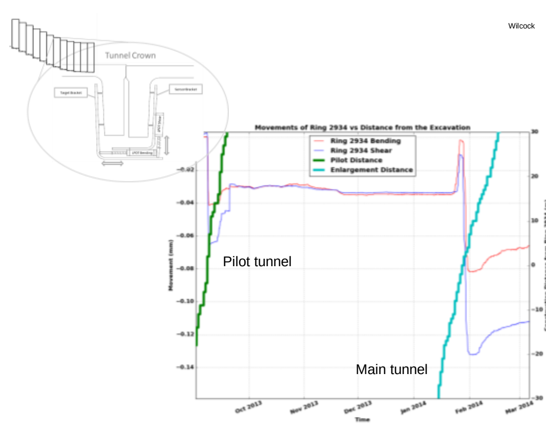
Shear LPDT Orientation

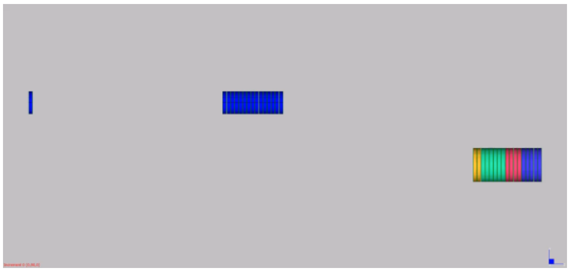


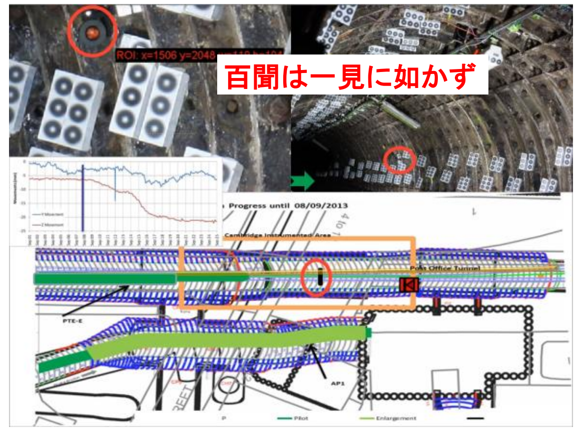
Layout of Sensors & Location of Sensors 11, 34-40

120 Wireless Sensors to monitor movements of 60 joints



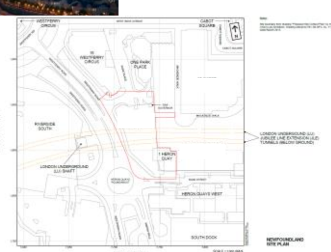




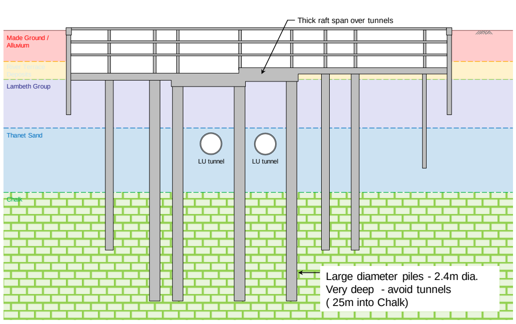


Loizos Pelecanos

A building construction at the Isle of Dog, London

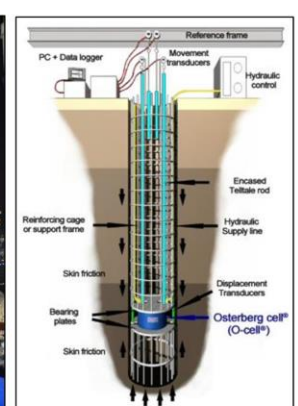


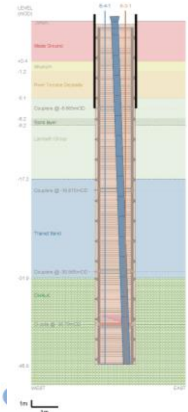
CSIC Cambridge Centre for Smart Infrastructure and Construction

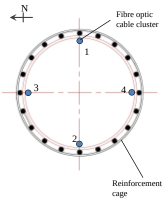


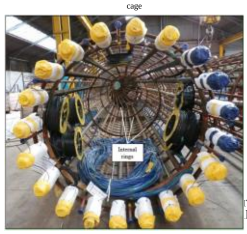
CSIC Cambridge Centre for Smart Infrastructure and Construction

UNIVERSITY OF CAMBRIDGE



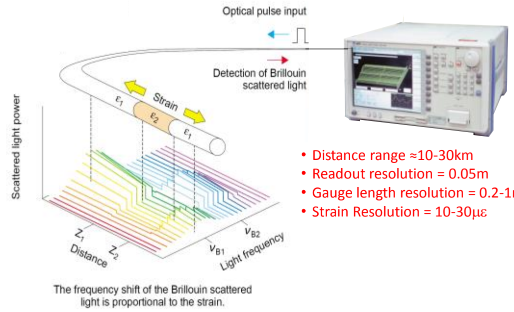




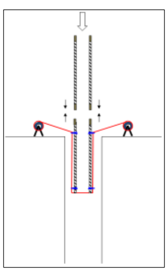


TY OF
IDGE

Distributed Brillouin Sensing
Providing "Continuous Strain Profile"

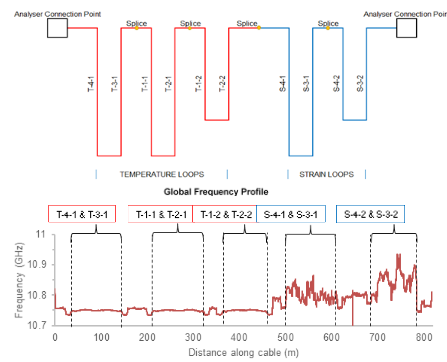


- Distance range ≈10-30km
- Readout resolution = 0.05m
- Gauge length resolution = 0.2-1m
- Strain Resolution = 10-30$\mu\varepsilon$



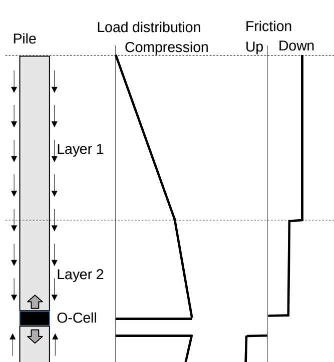
CSIC Cambridge Centre for Smart Infrastructure and Construction

UNIVERSITY OF CAMBRIDGE



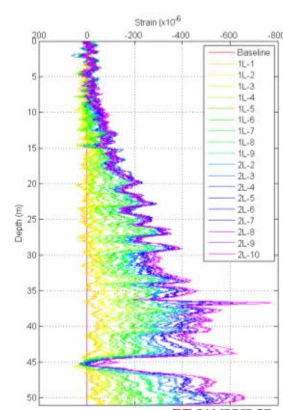
CSIC Cambridge Centre for Smart Infrastructure and Construction

UNIVERSITY OF CAMBRIDGE



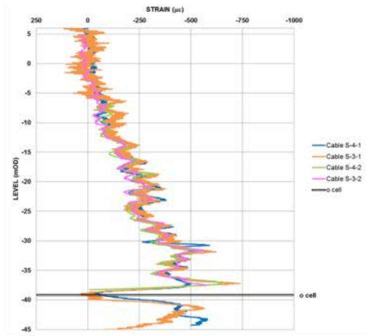
CSIC Cambridge Centre for Smart Infrastructure and Construction

UNIVERSITY OF CAMBRIDGE



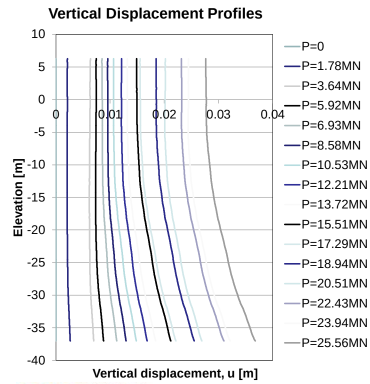
CSIC Cambridge Centre for Smart Infrastructure and Construction

CAMBRIDGE



CSIC Cambridge Centre for Smart Infrastructure and Construction

UNIVERSITY OF CAMBRIDGE



Integrated FO distributed strain and can provide distributed values of vertical displacement

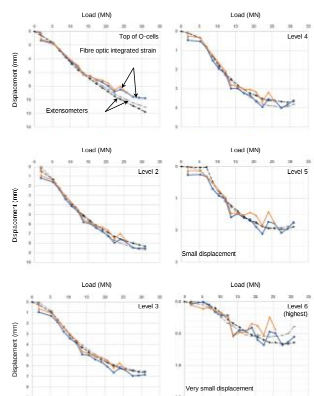
This shows the evolution of vertical displacement with applied load at every point along the pile depth

CSIC Cambridge Centre for Smart Infrastructure and Construction

UNIVERSITY OF CAMBRIDGE

Fibre optic displacement from integration of strain

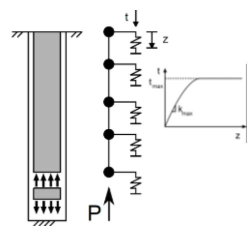
Good agreement between fibre optic and extensometers for all levels, even for small displacements at higher levels



Displacements are relative to the top of the pile

CSIC Cambridge Centre for Smart Infrastructure and Construction

Further post-processing:

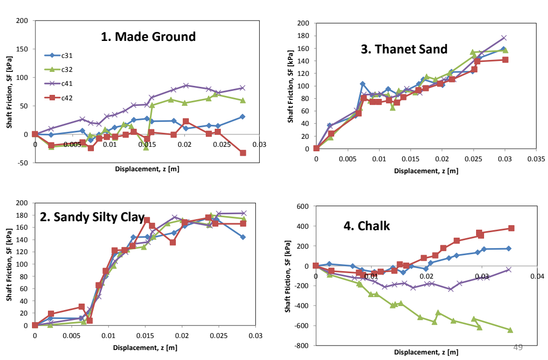


- Split soil into 4 layers:
  > Layer 1: Made Ground
  > Layer 2: Sandy Silty Clay
  > Layer 3: Thanet Sand
  > Layer 4: Chalk
- Calculate:
  (a) Shaft Friction
  (b) Vertical Displacements

CSIC Cambridge Centre for Smart Infrastructure and Construction

48

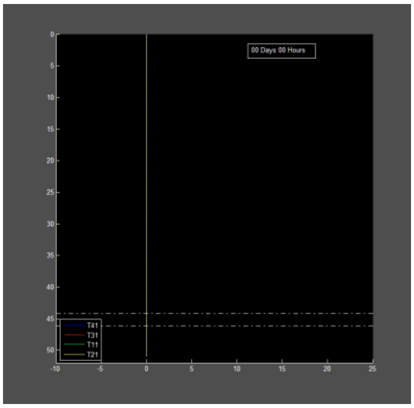
UNIVERSITY OF CAMBRIDGE



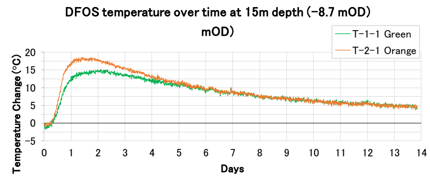
PROBLEMS WITH PILE CONSTRUCTION

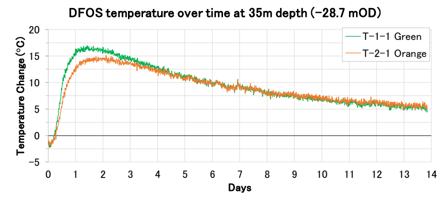
- Construction can be challenging – alignment, concrete quality and placement, soil collapse
- Visible inspection not possible
- Repair and rework is very difficult
- Not all anomalies are defects/detrimental

Image Source: Pile Dynamics and National Highway Institute

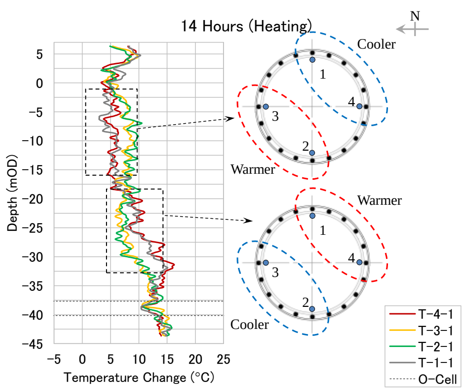


TEMPERATURE AT A GIVEN DEPTH OVER TIME





DIFFERENTIAL TEMPERATURE AT 14 HOURS



Value = Product (what it claims it will do) + Confidence in delivery (do I believe it will work?)

CSIC Cambridge Centre for Smart Infrastructure and Construction

An Innovation and Knowledge Centre Funded by EPSRC and Innovate UK

Mission:

"Transform the future of infrastructure through smarter information"

Vision:

- Enable step changes in construction practice
- Establish a world-leading sensing and monitoring industry
- Extend asset life & reduce management costs

17 Million pounds investment for five years from UK government and Industry

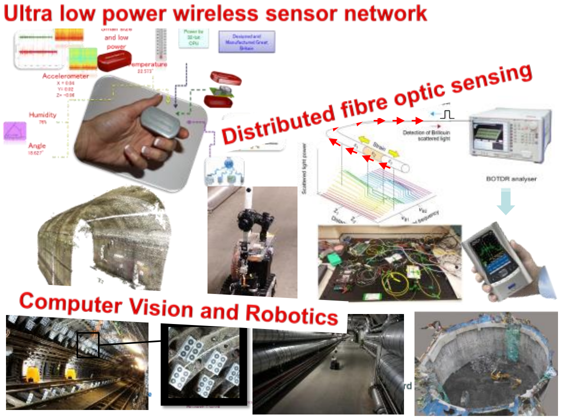
Infrastructure Clients (Owners and Operators)

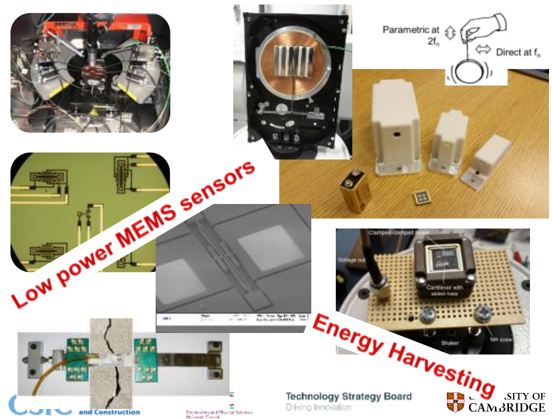
Consultants, contractors and asset managers

Technology and information supply chain

Knowledge partners

Ultra low power wireless sensor network





Field demonstrations & case studies

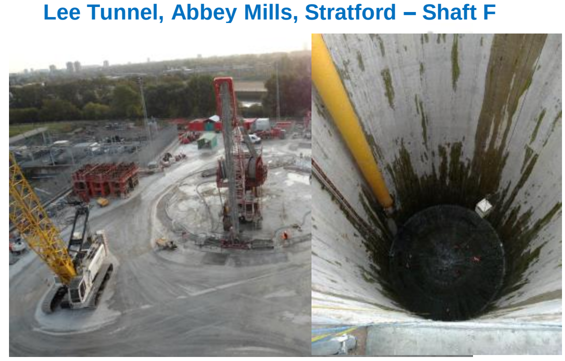
Examples of Monitoring Applications

Piles

Examples of Monitoring Applications

Masonry Arches

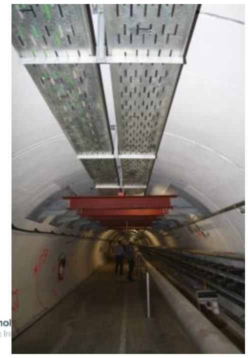
Lee Tunnel, Abbey Mills, Stratford – Shaft F



Winner of the 2013 Fleming Award: MVB JV, CH2M Hill, AECOM, Bachy Soletanche, Underground Professional Services, University of Cambridge, Mott MacDonald, WJ Groundwater and ESi

Examples of Monitoring Applications

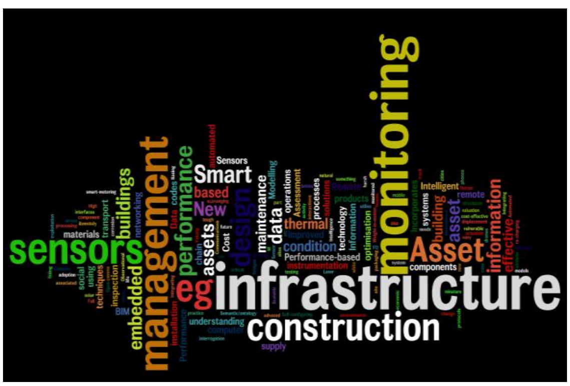
Tunnels



社会インフラストラクチャー

- インフラストラクチャーの社会の役割。
- データに基づいた意志決定、Building Information Modellingの活用。
- Observational Methodなどリスクを考慮した設計、施工、維持管理。
- 工学的知識を活用したモニタリング 。その中での地盤工学者の役割。

CSIC Cambridge Centre for Smart Infrastructure and Construction | EPSRC | Technology Strategy Board Driving Innovation | UNIVERSITY OF CAMBRIDGE



CSIC Cambridge Centre for Smart Infrastructure and Construction | EPSRC | Technology Strategy Board Driving Innovation | UNIVERSITY OF CAMBRIDGE