JSPS/CSIC international symposium on Smart Infrastructure and Construction

Business opportunities for Smart Infrastructure

13 November 2012 - 10:30 – 11:00
Crossrail, CSIC and using instrumentation to make savings in design and assessment

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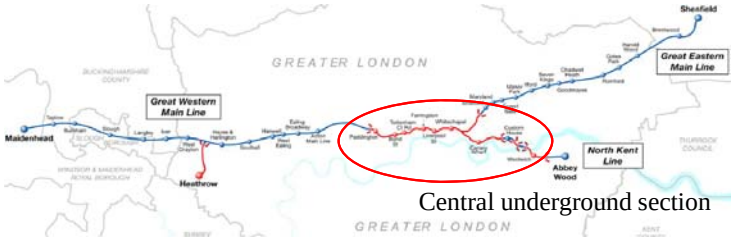
1. Research on Crossrail

28 existing surface stations upgraded
(11 major reconstructions)



Central underground section

90km of existing surface network

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1. Research on Crossrail

21km of new sub-surface twin-bore railway through London

9 sub-surface stations

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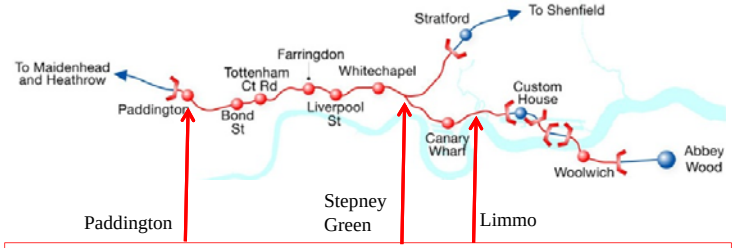
1. Research on Crossrail



Fibre optic and wireless sensor network monitoring of retaining walls and shafts

Stepney Green

Limmo shaft

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1. Research on Crossrail

Fibre optic monitoring of sprayed concrete tunnel linings

Sprayed concrete lined excavation at Liverpool Street.

Cross passage openings are proposed to be monitored using fibre optics.

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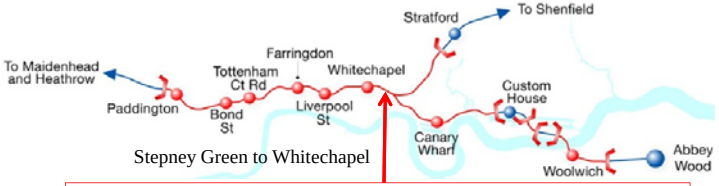
1. Research on Crossrail



Monitoring of geothermal segmental tunnel linings using fibre optics

GSH tubes in segmental linings. Image on right shows joint connection at segment joint.

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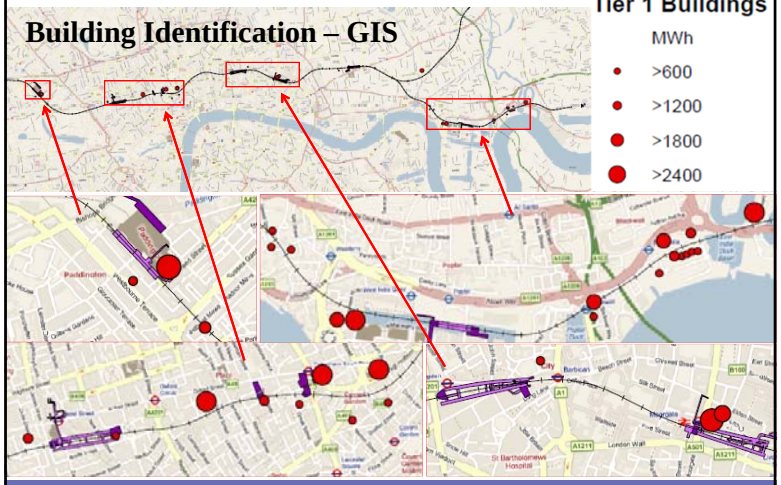
1. Research on Crossrail

Building Identification – GIS



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1. Research on Crossrail

Thermal walls and piles and district heating networks

Excavation of Dean Street box formed by diaphragm wall panels including ground source heat pipes

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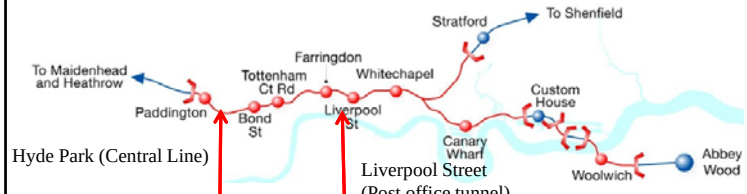
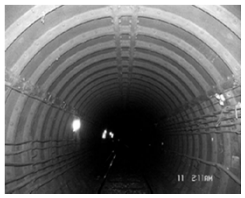
1. Research on Crossrail



Research on deformation behaviour of cast iron tunnels



Section 3 will consider the research being carried out at Liverpool Street.

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1. Research on Crossrail

Interpretation of instrumentation and monitoring data (route – wide)

- Arup have many projects where staff are required to interpret monitoring data.... key driver to carrying out research
- Crossrail offers a good opportunity to review how monitoring data is interpreted from many construction activities – Discussed further in Section 2

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2. CSIC project KS03 – 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

UNDERGROUND Crossrail itmsoil UCL

Skanska and Costain have also been contacted to be part of Industrial Steering Panel.

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2. CSIC project KS03 – Efficient interpretation of monitoring data

Project research setup

- Arup funded CASE award PhD, run from Cambridge
- Project to be run closely alongside Crossrail
- To link in and benefit from other research described at the start of this presentation

Mehdi Alhaddad (from Arup) – selected to be the PhD student.

Timetable

- Jun 12 – Sep 12 – Mehdi Seconded into Crossrail as Asset Protection Engineer (APE)
- Oct 12 – end 13 – Start of PhD. Collection of data from Crossrail
- 2014 & 2015 Remainder of study. 1 day / week in Arup remainder in Cambridge

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2. CSIC project KS03 – Efficient interpretation of monitoring data

Key question: Is the ground or asset performing as expected?

a.) Clear graphical presentation of appropriate monitoring results

Layout, axis, units and format of graph is important.

b.) Construction progress data

Must know what construction works have taken place in the vicinity of the monitoring point over the period you are reviewing the monitoring data.

c.) Comparison with ground movement assessment calculations

Important to compare monitoring data against earlier calculations. Therefore have a model of what you expect.

Assimilation of all three into a single sheet of paper for each asset = "dashboard".

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2. CSIC project KS03 – "Efficient interpretation of monitoring data"

Desk study

Heathrow tunnel collapse 1994 – Appropriate interpretation of instrumentation and monitoring data in a timely fashion was considered to be a contributing factor to the cause of the collapse

- Review of case studies where failures have occurred in the past
- Review of current procedures on a number of construction projects to identify best practice

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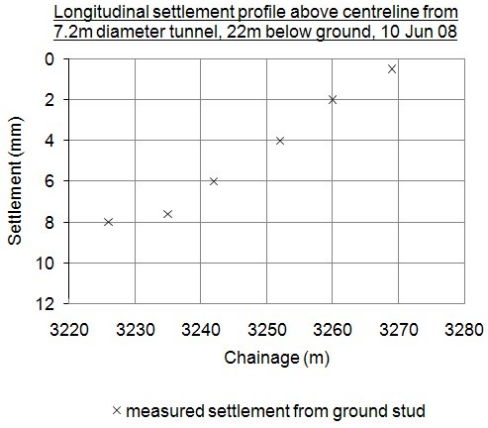
2. CSIC project KS03 – "Efficient interpretation of monitoring data"

An example:..... Not so good!



- Typical monitoring results monitoring of settlement longitudinally ahead of face from drive of tunnel.
- All we know from graph is how ground studs have settled on a given day.
- Doesn't tell us anything about construction progress or relationship with contractual limit.

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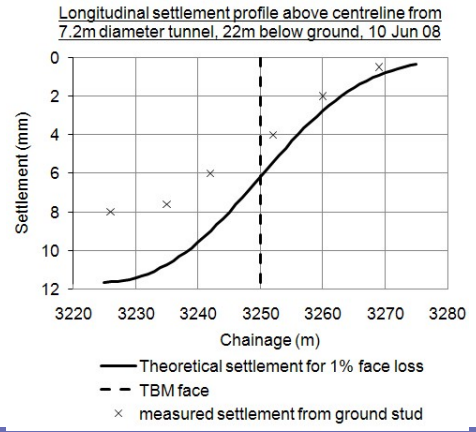
2. CSIC project KS03 – "Efficient interpretation of monitoring data"

An example:.... better!



Graph shows:

- Where TBM face is located.
- Theoretical settlement profile for contractual limit (for example 1% face loss).
- With this information, the contractor if not achieving contractual limit could adjust tunnelling method (eg. tail grouting , face pressures etc.).

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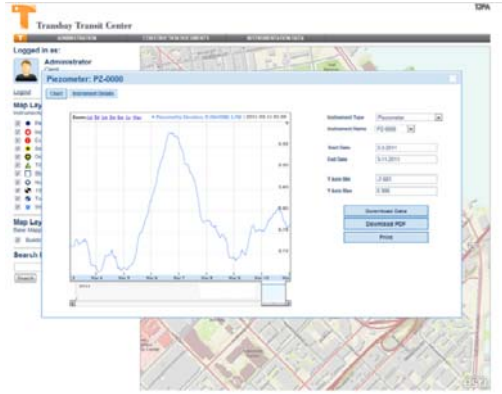
2. CSIC project KS03 – "Efficient interpretation of monitoring data"

Review of systems used to display monitoring data



Screenshots from Arup designed system called Global Analyzer.

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2. CSIC project KS03 – "Efficient interpretation of monitoring data"

Investigating new technologies for logging construction progress or deformation

Laser scanning of SCL excavation

Image from Lemy et al (2006)

Planar view of laser scan from UCLH site, London

Image from Fuentes (2012)

Use of laser scanning to document construction progress.

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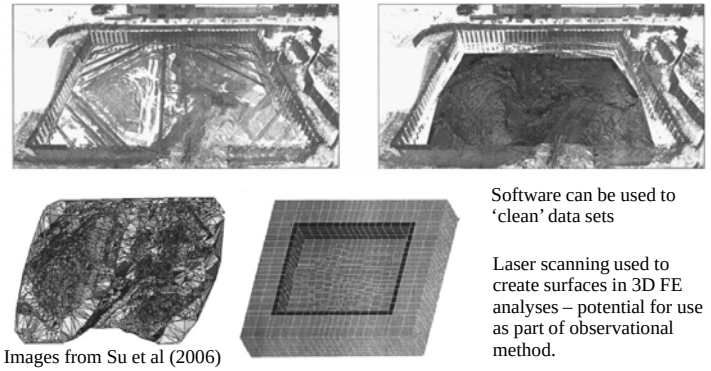
2. CSIC project KS03 – "Efficient interpretation of monitoring data"

Investigating new technologies for logging construction progress or deformation



Images from Su et al (2006)

Software can be used to 'clean' data sets

Laser scanning used to create surfaces in 3D FE analyses – potential for use as part of observational method.

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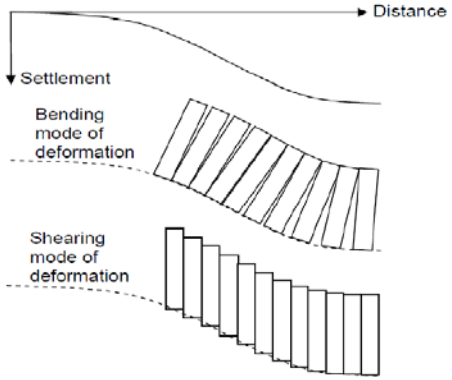
3. Using instrumentation to solve uncertainties in design and assessment

Longitudinal deformation of cast iron tunnels



"When existing tunnels are subject to ground movements from nearby construction works causing displacements transverse to the tunnel axis, Does the tunnel predominantly shear or bend to accommodate the movement?

Mitigation is often to loosen circumferential bolts. Is this necessary and what threshold should it be carried out?

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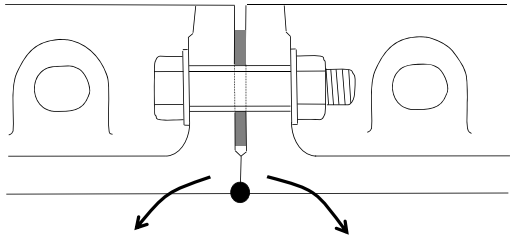
3. Using instrumentation to solve uncertainties in design and assessment

Longitudinal deformation transverse to axis (bending deformation)



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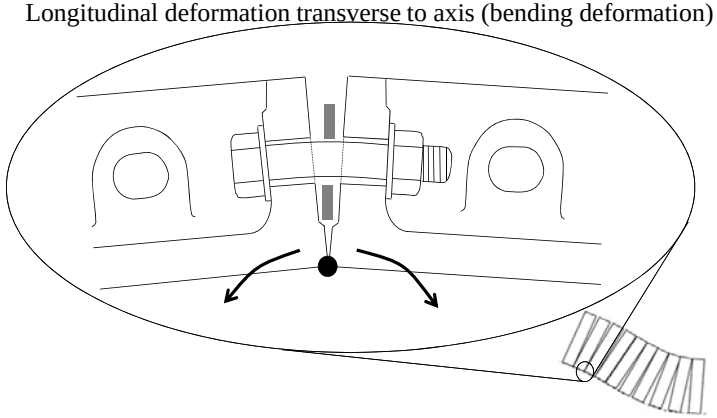
3. Using instrumentation to solve uncertainties in design and assessment

Longitudinal deformation transverse to axis (bending deformation)



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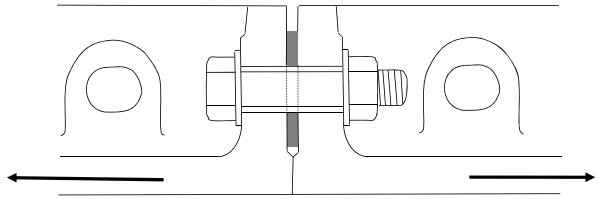
3. Using instrumentation to solve uncertainties in design and assessment

Longitudinal deformation parallel to axis



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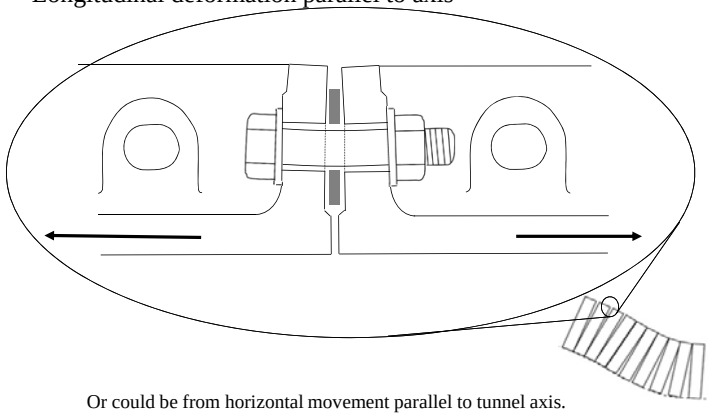
3. Using instrumentation to solve uncertainties in design and assessment

Longitudinal deformation parallel to axis



Or could be from horizontal movement parallel to tunnel axis.

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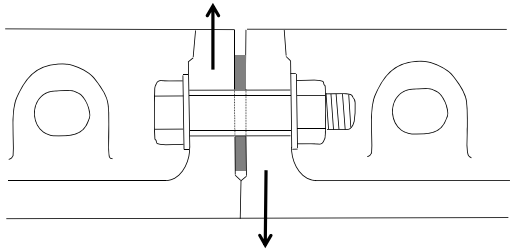
3. Using instrumentation to solve uncertainties in design and assessment

Longitudinal deformation transverse to axis (shearing deformation)



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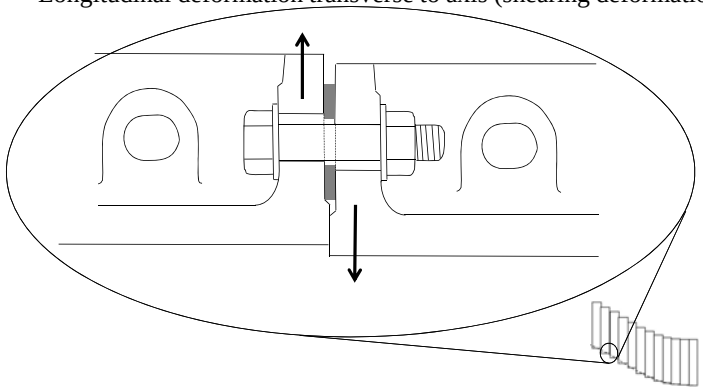
3. Using instrumentation to solve uncertainties in design and assessment

Longitudinal deformation transverse to axis (shearing deformation)



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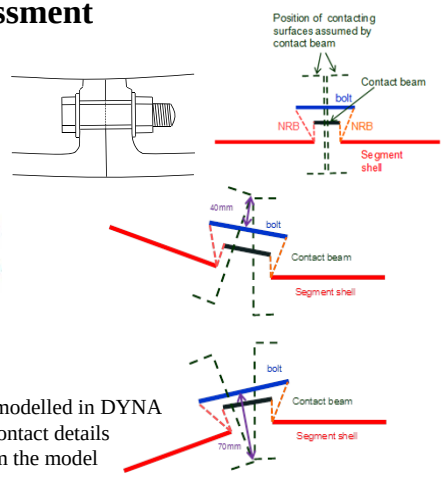
3. Using instrumentation to solve uncertainties in design and assessment



- 3.5m diameter cast iron tunnel modelled in DYNA
- Contact beams represent joint contact details
- Bolt forces can be obtained from the model

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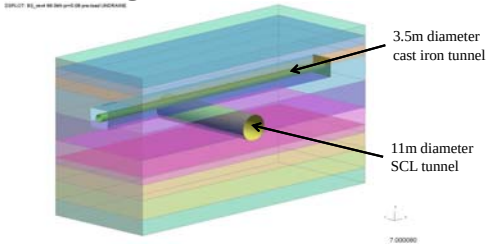
3. Using instrumentation to solve uncertainties in design and assessment



- FE model of 11m tunnel constructed 4m below cast iron tunnel – segments modelled
- More detailed FE to consider bolt / flange connection

Input parameters varied in analysis
- Bolt pre-load
- Friction at circumferential joints
- Gap between bolt and lining

Conclusions
- Shearing dominant
- Movements parallel to tunnel axis dominate bolt forces and stress in lining
- Some evidence from case studies to support this

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3. Using instrumentation to solve uncertainties in design and assessment

Understanding deformation of cast iron tunnels

- Monitoring on Crossrail to review findings of FE.
- Connections of rings of Post Office tunnel at Liverpool Street will be monitored with LVDTs to pick up shearing and bending.
- Fibre optics also installed to supplement the detailed monitoring.

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4. Conclusions

- Crossrail project provides a great opportunity to improve knowledge in the profession.
- Dissemination of this knowledge will assist other forthcoming projects in the UK and overseas.
- Appropriate and efficient interpretation of construction monitoring data is important to the profession.
- Important to identify where new technologies can offer cost savings (both in terms of staff time and material cost).
- Important that practicing engineers doing design and assessment consider where uncertainties lie – Research can be shaped around solving these.

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