Innovation Remit

Innovation Title	INV00324 - FBG Fibre Optical Monitoring of Sprayed Concrete Lined (SCL) Tunnels at Bond Street Station - Trial Extension from Feasibility to Demonstration Phase.

Context / Issue / Opportunity / Motivation

Fibre Optic (FO) sensors are used widely in aviation, medicine and industrial processing. They have been more recently promoted as “structural health monitoring” for infrastructure. Installation of Fibre Optic cables to measure strain and temperature within Sprayed Concrete tunnel linings has been attempted for a number of years. In June 2013 Monitor Optics Systems ([redacted]) together with [redacted] (BFK C410) succeeded in installing Fibre Bragg Grating (FBG) strain cables at two locations in the CH3 concourse tunnel at Bond Street Station. This is believed to be the first successful installation inside the lining of a soft ground SCL tunnel anywhere in the world.

Crossrail Chief Engineer's Group received investment from the Crossrail Innovation Programme to install fibre optic monitoring into the SCL works under C300/C410 BFK in the western escalator and concourse tunnel at Bond Street (ES1/CH2) the installation into the secondary lining are scheduled to be completed January 2015.

The signal cables will be embedded in the sprayed concrete linings and run up the tunnel crown to the connection with the Western Ticket Hall to a "black box" analyser and computer and linked into BFK's server for real-time monitoring via the web. Details are provided in the attached drawings.

Since agreeing to the project, it has been identified that the installation could also serve as a useful monitoring tool during future over-site development. As a result, Crossrail’s Chief Engineer’s Group wish to safeguard the installation in perpetuity from May 2015 when C412 accepts the site from BFKJV.

Innovative Solution

Currently BFK plan to house the Interrogator and Computer in a cabin within the Western Ticket Hall at the slab level above the ES1 Escalator tunnel crown. The computer and Interrogator are connected to BFK’s server and from there to the DAmins web-hosting service allowing Real-Time remote monitoring. The BFK cabin will have:

- 2 LAN Connections, 1 of which has a fixed IP address
- Cat 5 Ethernet connection
- 2 standard 240v power sockets
- 50metres of Signal Cable

CSJV C412 have been requested to provide a price to protect the installation for as long as practicable without causing delay to their contract and a further price to design and incorporate the system into the permanent station design.

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What is the primary benefit / Why should Crossrail do this?

The trial installation has generated large amounts of (stable) data which may provide new insights into the behaviour of Sprayed Concrete Linings during construction, and throughout the tunnel asset's design life. The data is currently being reviewed in detail by CRL SCL designers C121 Mott MacDonald and the Chief Engineers Group.

The extended trial has enabled several assumptions used in the design of the SCL tunnels to be tested, improving efficiencies in tunnel design and construction productivity. The new knowledge is being gained will benefit Crossrail and its wider legacy for future projects. To make the most of the data produced, the output will also be shared with four university partners who have different research interests:
UCL, London – The impact of monitoring data on challenging design assumptions.
Warwick University – Early age strength performance of Sprayed Concrete Linings.
Liverpool University – Performance of Fibre Optic resin coatings.
Limerick University – Design and manufacture of strain sensors.

To capitalise on the success of the trials and provide valuable data to the over site developer to protect Crossrail's built asset.

To gain new insights into the behaviour and performance of Sprayed Concrete Linings tunnels during construction and throughout the tunnel asset's design life.

To publicise unique monitoring data by building relationships between university research departments and disseminating the knowledge gained to industry and asset owners.

The data from the system will continue to inform design assumptions on the behaviour of complex underground SCL construction. The data will also be available to both Crossrail's sponsors and the over-site developer to monitor the asset during the construction of the over site development and mitigate the risk of catastrophic failure.

The system will also provide an accessible demonstration of how fibre optic systems can be used to create smart infrastructure.

What is the desired outcome?

A permanent demonstrator of the system to inform future underground construction projects.

An risk mitigation measure for the oversite developer of a complex and exposed element of the underground Bond St Station infrastructure.

At least 5 technical papers / research streams with CRL, BFK, MOS, Mott MacDonald and four university partners in the following areas:

- Successful installation of FBG Fibre Optic strain cables to monitor SCL tunnels
- A review of the design assumptions of SCL design
- Early age performance of SCL tunnels
- Advances in protective FBG FO resin coatings
- Advances in the design of FO Strain Sensors

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What needs to be done to reach the desired outcome?			
Implementation Description	Start	Finish	Cost
Protection of the current the installation for as long as practicable without causing delay to their contract	May 2015	April 2016	[redacted]
To design and incorporate the system into the permanent station design.	April 2016	June 2018	[redacted]
		Total	[redacted]

Who is responsible for implementing the innovation and what resources are required?		
Name	Role	Hours
[redacted]	Construction Manager, CRL Bond St	10hrs
[redacted]	Monitor Optics	50hrs
[redacted]	Field Engineer, CRL Bond St	20hrs
[redacted]	Project Manager, CRL Bond St	5hrs
[redacted]	Project Manager, CSJV Bond St	5hrs
	Construction Manager, CSJV Bond St	20hrs
[redacted]	SCL, Mott MacDonald, C121	10hrs
[redacted]	Chief Engineer's Group, CRL	20hrs
What is the total funding sought to deliver the solution?	[redacted]	

Assumptions

1. CSJV do not unduly overprice the required scope of works
2. A permanent solution can be identified and constructed
3. London Underground accept the management of the permanent assets in perpetuity

How is success & failure to be measured?		
Description of success or failure	When will it be assessed	How will it be measured?
1. (Success) New insights into the behaviour of SCL tunnels during construction and design life.	February 2015	Research streams conducted by universities to ensure wide dissemination of data and findings
2. (Failure) neglect or destruction of the data analyser and equipment through poor communication of the importance of the installation to site operatives.	During construction	A real-time web-hosted data feed will enable the working order of the installation to be assessed. Regular briefings to site operatives to explain purpose and value of the trial.
3. (Success) System informs the oversite developer of the underground environment during the oversite construction works	From 2017	Reduction in the risk register on provision of the real-time web-hosted data feed to the oversite developer

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Are there any hold points?		
Description of hold point	Authority to proceed	
Review of the costs submitted by CSJV at Bond Street	[redacted]	February 2015
Acceptance by London Underground that they are happy to accept the maintenance of the system in perpituity	[redacted]	February 2015
Design Approval of the proposed solution by CSJV	[redacted]	July 2015
Commissioning of permanent system installation	[redacted]	December 2016

List of those who support this innovation	
Name	Role
[redacted]	Chief Engineer, Crossrail
[redacted]	Project Engineer, C121 SCL Tunnels, Crossrail

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