CLIENT: LONDON UNDERGROUND LIMITED

CONTRACT REF: TLL 7917

NORTHERN LINE EXTENSION

MAIN WORKS CONTRACT

THERMAL INTEGRITY TEST REPORT PANEL 30

FERROVIAL AGROMAN
LAING O'ROURKE JV

Prepared by	Checked by	Approved by	Date	Rev
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Panel 30, Northern Line Extension

Thermal Integrity Test Report

25th February 2016

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1	25/02/16	Peter Payne	Echo Ouyang	Andrew Bell

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Content

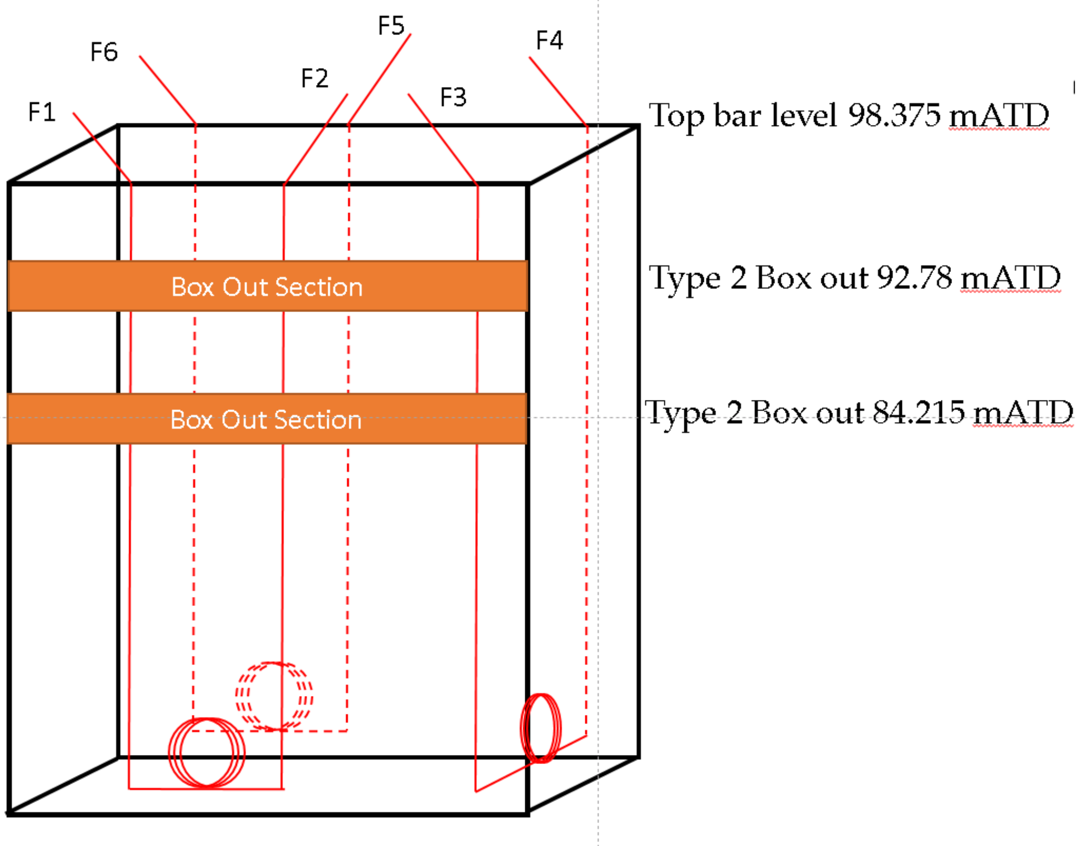
1. Introduction

This document details the thermal integrity testing on panel 30 at the Northern Line Extension project using CemOptics, the distributed optical fibre sensing system. Panel thermal integrity test started immediately after the concreting on 22nd February 2016, and continued until beyond the active cementation hydration process was achieved after 48 hours. The point at which it effectively generates the maximum amount of heat, when the integrity of the panel can be best assessed. The panel geometry and volume of concrete used are presented in Appendix 1.

2. Panel Thermal Integrity Testing

Three loops of fibre optic cable were installed to the full depth along the panel. The following section provides the integrity assessment of the panel based on the measurement collected over a period of 48 hours after concreting process. Fig. 1 indicates the relative positions of the fibre optic sensor on the reinforcement cage and breakout boxes cast along the panel at near face.

Fig. 1. Schematic drawing about the



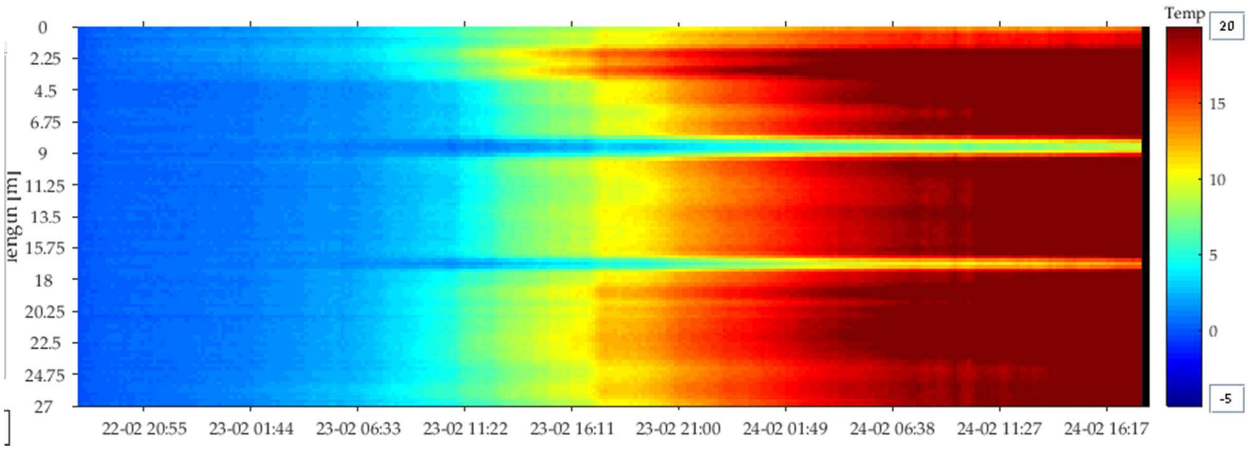
instrumentation layout for panel (Not to scale).

The reference reading is chosen on 22nd February 2016 after finishing the concreting pouring process. The panel integrity is assessed based on the development of temperature from the average reading as the baseline for the analysis. The average development of temperature for a period of 48 hours is shown in the heat map in Fig. 2.

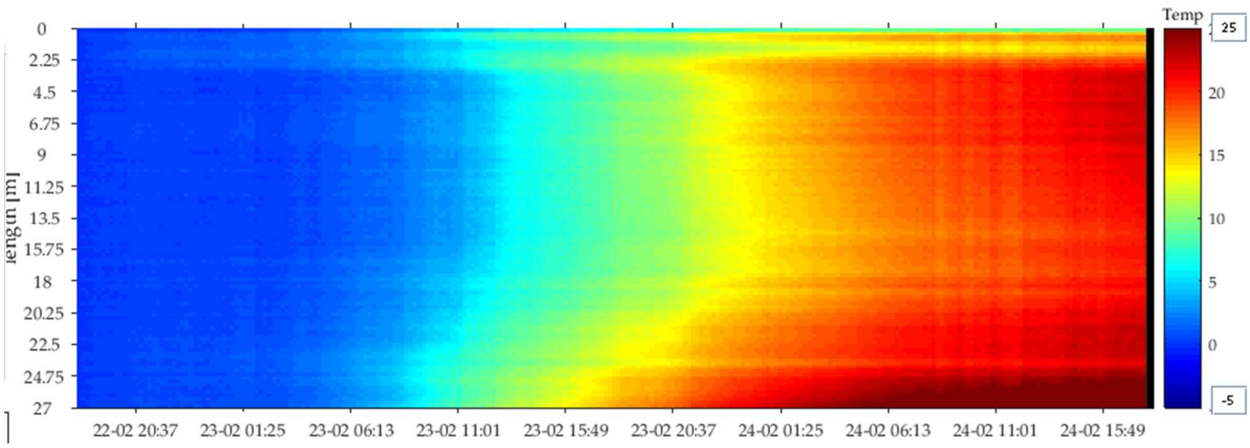
The detailed change in temperature profiles from the six positions along the panel are shown in Fig 3. Six independent temperature profiles have shown temperature development along the panel, where F1, F2 and F3 were positioned on the near face of the panel facing into the excavation, and F4, F5 and F6 were positioned on the far face side. The temperature profiles from F1, F2 and F3 clearly identify the position of two breakout sections along the panel at 92.78 mATD and 84.215 mATD separately with a reduction in the recorded temperature profile noted.

Due to breaks in the cables no data was recorded below 78.25mATD on position F3 and below 86.5mATD on position F6. Two channels were used to record the data as detailed in Fig 2.

Temperature profiles from six positions show consistent development in temperature apart from two breakout sections and the average change in temperature along the panel being 21.7 degC.



Near Face



Far Face

Fig. 2. Heat map of temperature change along the panel shaft over the monitoring period
(Length noted is below the top of guide wall)

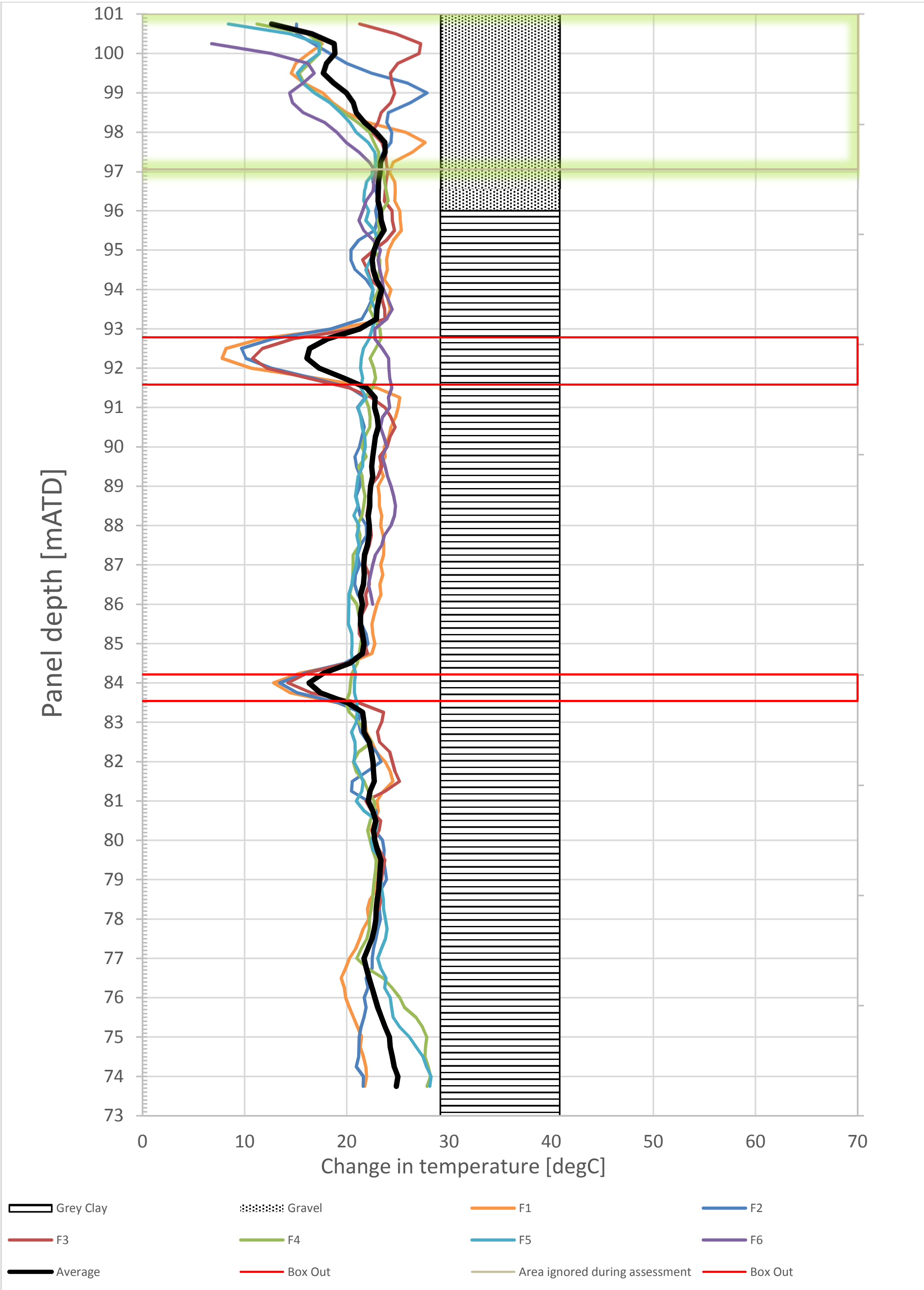


Fig. 3. Temperature profiles from six measurement positions along the panel after 48 hrs of concreting process (mATD denoted metres Above Tunnel Datum).

3. Conclusion

Temperature measurement from fibres F4 and F5 show an approximate increase in temperature of 6 degC when compared to F1 and F2 close to the toe. As the panel was installed in the London Clay formation and the temperature magnitude from F1 and F2 is fairly consistent throughout the entire panel length the noted increase is likely to be attributed to an increase in Overbreak between 77mATD and 74mATD.

Based on the measurement from six positions along the panel, all panel thermal profiles show the panel to be of reliable integrity with the features showing being the box out sections installed at the intended depths.

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4. Appendix 1 Panel Details

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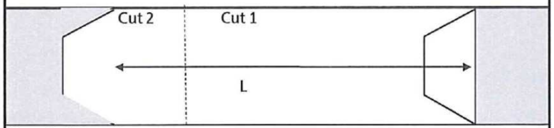
DIAPHRAGM WALL PANEL EXCAVATION RECORD

Contract No.	300550	
Drawing No./ Rev	MMD-N205-230000-STR-DRW-19211 P02	
Location / Date	NLE	10-Feb-16
Panel Number / Rig Number	25	Grab 2
Panel Type (Straight / Corner)	Straight	Intermediate

No of Tremies	No of Stop Ends
2	1
No of Sonic Tubes	No of Inclinometer Tubes
0	0

Panel Diagram & Location of Tremmie Pipes, Stop Ends, location of dips etc.



	DESIGNED	CONSTRUCTED	UNITS
Panel Cut-off Level (COL)	97.075	97.075	mAOD
Top of steel	98.375	98.375	mAOD
Casting Level	99.075	99.000	mAOD
Toe Level (TL)	74.000	73.900	mAOD
Level of Top of Guide Wall (TOGW)	101.000	101.000	mAOD
Depth of Panel (COL to TL)	23.075	23.175	m
PANEL DEPTH (TOGW to TL)	27.000	27.1	m

Stop End Details:-

1 STOP ENDS

DEPTH FROM TOP OF G/WALL TO TOE OF STOPEND 22.5 m

Grab width(mm)	1.2	1.2	m
After Panel open over night	26.000	26.0	m
Total Depth with Grab	27.000	27.1	m
After Bentonite Exchange	27.000	N/A	m
Before Concreting	27.000	27.1	m
Total Depth with Grab			

For Verticality Measurement Detail Refer to Grab Verticality Report

Koden used: YES

Water Bar Installed: YES

Notes:- Bentonite Exchange DATE / TIME

Start:	N/A	/	N/A
Finish	N/A	/	N/A

EXCAVATION LOG - Cut 1

Record changes in: basic soil type (clay, silt, rock etc), soil colour, water strikes, and standing water (if applicable)

Record Times at: start of panel construction, digging below toe of guide wall, Depth dug with Grab, completion of boring (Day 1 & Day 2 if applicable), addition of bentonite

Excavated area (m2) — Panel Length 4.05 m

SCALE BAR	LEVEL BTOGW (mAOD)	DEPTH BTOGW (m)	DATE	TIME	SOIL DESCRIPTION / DIGGING PROGRESS
0					
		1.0	10-Feb-16	15:15	Gravel
		5.0	10-Feb-16	15:30	Grey Clay
10					
		15.0	10-Feb-16	19:00	Grey Clay
20					
		26.0	11-Feb-16	12:00	Grey Clay
		27.1	12-Feb-16	08:00	Grey Clay
30					
40					
50					
60					

Signed as a correct record:

	Name	Signature	Company	Date
Above Details Completed By	Joash Clarkson	JEC	Cementation Skanska	15 February 2016
Above Details Checked By	Joash Clarkson	JEC	Cementation Skanska	15 February 2016
Above Details Accepted By	Niall Watson	[signature]	FLo	15-2-16

5. Appendix 2 Optic Fibre Temperature Measurement

Fibre optic instrumentation has been chosen for the instrumentation of the current project, which is based on the Raman back-scattering sensing principle. This system uses a single continuous fibre optic cable that can provide continuous temperature measurements along its length with an accuracy of ±0.6 degC at every 25 cm.

The universal unitube cable (see Fig. 4 below) is used for temperature measurement. The temperature measurement cable consists of four optical fibres in a gel filled tube so that it can contract and expand under temperature effects, independent of mechanical deformation.

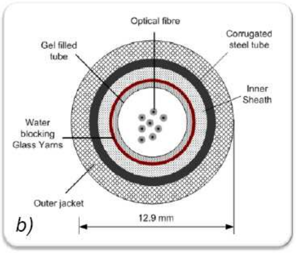


Fig. 4 Universal Unitube Cable for Temperature Measurement.

Once the fibres are installed their ends need to be spliced to an optical connector that is then plugged in to an analyser (see Fig. 5). An initial 'baseline' reading is then taken for comparison to future readings during the construction cycle.

Fig. 5. Splicing of Fibre Optic Cables and Connection to an analyser

The use of fibre optics for the measurement of temperature for assessing the integrity of the structure has a number of advantages over conventional systems. Fibre cable only requires to be attached along the outside of the cage, it eliminates any risks of trapping fingers inside the heavy reinforcement cage and improves health and safety on site.

The system can be connected immediately and start logging the change of temperature during concrete hydration for assessing the integrity of the panel. It provides timely assessment of the integrity than other conventional systems.