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0706_7.1_120626_AV

26 June 2012

Dear Sara

The Lighthouse Block,
283-297 Pentonville Road and 370-380 Grays Inn Road, London WC1X
Planning consent ref. 2008/5358/P

Please find attached documentation in connection with the discharge of pre-commencement condition 12 of the above planning consent dated 08 April 2009.

Planning consent Condition 12 states:

'*Before the development commences, details of the proposed design and works to the foundation arrangements must be submitted to and approved by the Council and London Underground Limited. Development shall be carried out in accordance with the approved details.'*

The following information is enclosed (in 3 sections):

- Tunnel Lining Analysis Report by Ramboll (structural engineers).

I trust the enclosed is acceptable but should you have any queries, please do not hesitate to contact me.

Yours sincerely

Anurag Verma
Architectural Assistant

Encl.

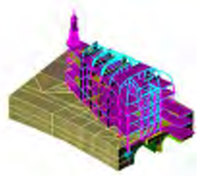
Intended for
UK REAL ESTATE

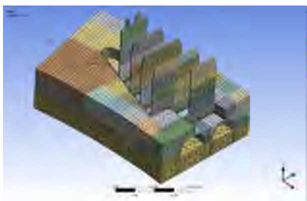
Project no.
18885 ST R10

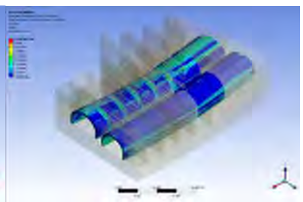
Date
22 June 2012

THE LIGHTHOUSE BUILDING, KINGS CROSS

TUNNEL LINING ANALYSIS REPORT







RAMBOLL

Revision History

Revision	Date	Purpose / Status	Document Ref.	Comments
	22-06-12	For Approval	18885-ST-R10	

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FIGURES

1. INTRODUCTION

The Lighthouse Building is located at the junction of Pentonville Road and Gray's Inn Road, Kings Cross, London and lies over two masonry lined tunnels.

The south tunnel was opened in 1863 by the Metropolitan Railway and is known as the Circle Line Tunnel. It carries Metropolitan and Circle underground trains and is owned by Transport for London, London Underground (TfL).

The north tunnel was built soon after the first for the Northern Railway and is now known as the City Widened Lines Tunnel. It carries Thameslink Network Rail trains. It is owned by Network Rail Limited (NwR).

The Lighthouse Building is thought to be constructed between 1875 and 1894. The two westerly units are listed grade II within the building.

The Lighthouse Building is to be developed into office and retail accommodation. Works will include the removal of internal walls and floors together with the insertion of a new steel frame, composite concrete floors and new timber roof with an additional storey.

In 2011 an Approval in Principle (AiP) was submitted to TfL and a Form A was submitted to NwR for their approval. These documents described the methods of assessment to predict the effects of the proposed developments on the tunnels.

This report describes the structural analysis of the masonry tunnel linings, which underlie the foundations of the Lighthouse Building, that has been undertaken in accordance with the Form A and AiP. It describes the methodology that has been developed to numerically simulate the load path from the building through the foundations and tunnel linings and how these simulations have been used to calculate the expected response of the tunnel linings to the development.

The purpose of this report is to demonstrate to TfL and NwR that the proposed works will not have a detrimental effect on their assets so the works can be undertaken with the necessary approvals of these organisations. The report will also be submitted to the Local Planning Authority to discharge a relevant planning condition.

2. BACKGROUND

The existing building is supported on cross walls, sitting on wrought iron girders spanning north-south over the tunnels. It is intended to maintain these wrought iron girders *in situ* and to load the tunnels with load paths similar to the current load paths. Figure 2.1 Geometric model of existing arrangement of tunnels and cross walls shows the geometric model of the existing arrangement of tunnels and load bearing cross walls. Further ground surrounding the building has been removed so the tunnels are visible.

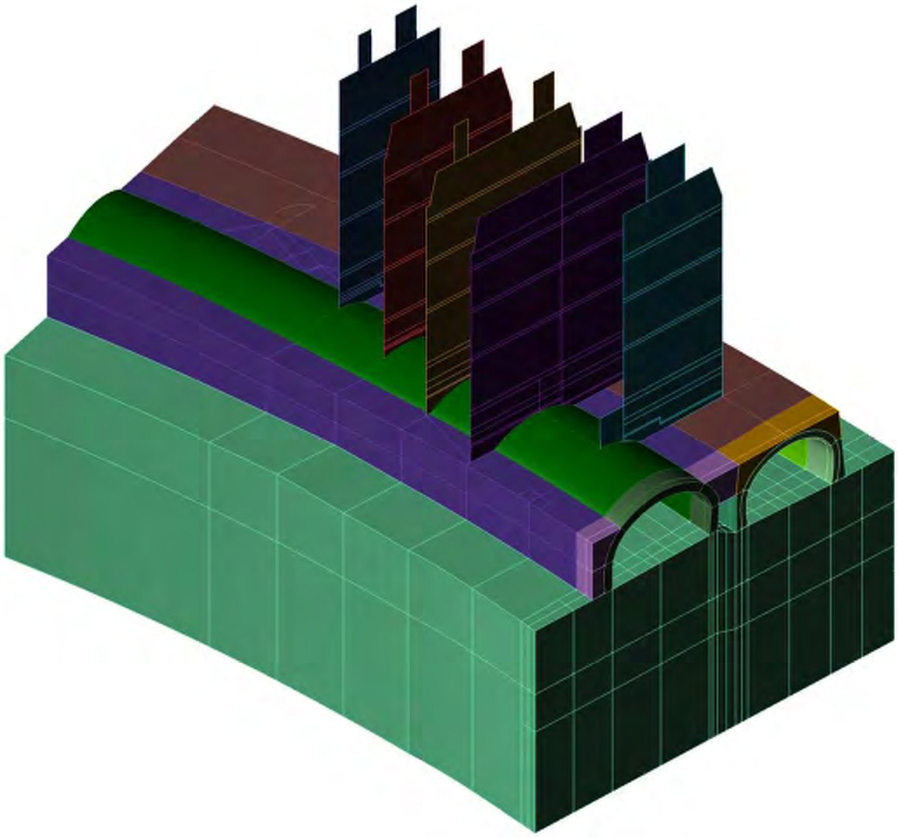


Figure 2.1 Geometric model of existing arrangement of tunnels and cross walls

In 2006 a preliminary 2D Finite Element model was undertaken to give an initial understanding of the building - tunnel interactions. Further, more accurate, information regarding the proposed design and loads from the building, the position of the tunnels (from surveys) and the tunnel construction (based on trial holes and research) are now available so a more accurate 3D analysis has now be undertaken.

3. OBJECTIVES

The principal objectives of the tunnel lining and foundation structural analyses are as follows:

i) To predict likely displacements (settlement) that may result in the two tunnel linings from the proposed alterations in the building comprising the removal of existing cross walls above ground floor level, insertion of a steel frame, new foundations locally at two locations and additional facade walls.

ii) To compare predicted maximum displacements with any available acceptable values below which no further assessment is required.

iii) To calculate tunnel lining masonry stresses and compare the results with lower bound representative characteristic strengths of masonry.

4. SOURCES OF INFORMATION

Table 4.1 Sources of Information

Drawing/Report Number	Title	Year	Originator
11.6713 11.6866 12.7041	Three Trial hole Investigation Reports	2011 2012	Constructive Evaluation
23008-001F-01A	Trial hole survey	2011	Plowman Craven
Lighthouse.ptx	Exterior Building Laser Scan	2011	Plowman Craven
SU-ABA-210120-001-R00	3d Tunnels survey	2010	ABA Surveying
4821/01 Rev C	Basement Floor Plan	2011	Michael Gaille
4821/02 Rev D	Ground Floor Plan	2011	Michael Gaille
18796/S1/01	Lighthouse Building, Soil Parameters for Building/Tunnel Interaction	2011	Gifford, now Ramboll

5. METHODOLOGY

5.1. Numerical Modelling

5.1.1. Description

The geometry of the existing building and tunnels has been obtained partially by laser scan survey. Figure 5.1 shows an overlay of the tunnels and the building exterior, both obtained through laser scanning with an outline of the cross walls, obtained by traditional topographical surveys, superimposed in red.

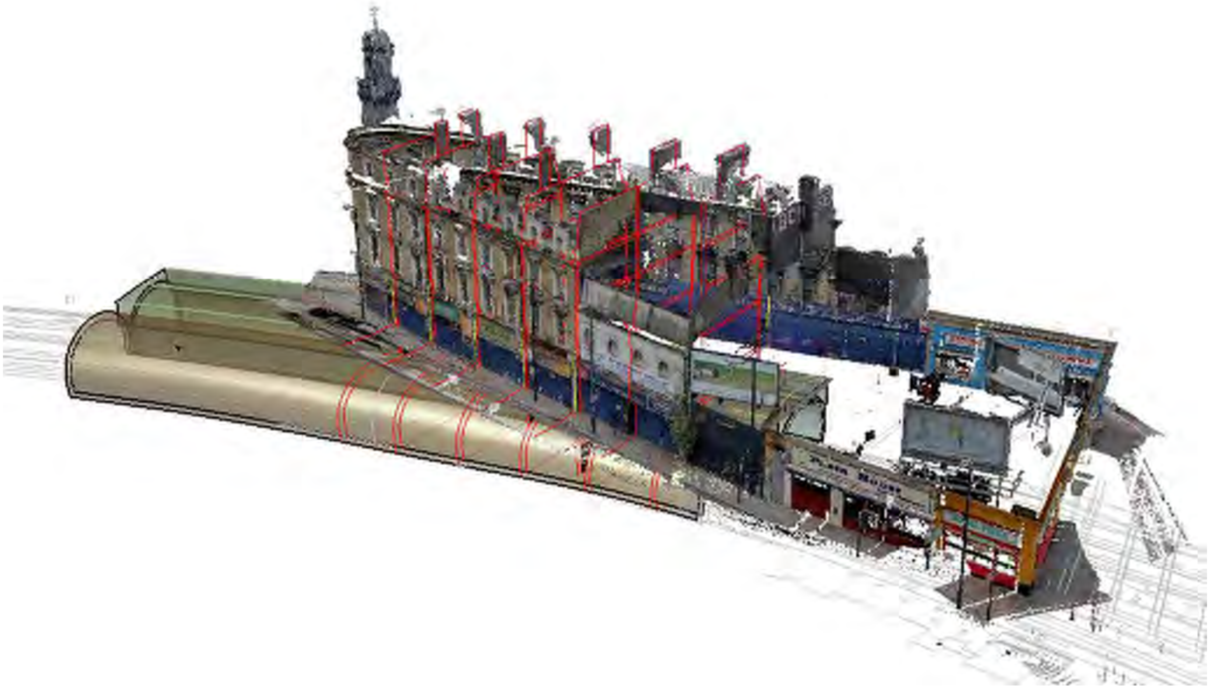


Figure 5.1 Plot of laser scan and geometric tunnel model showing arrangement of tunnels and cross walls

The masonry tunnels including the brick tunnel linings, foundations, fill and overlying structures were analysed using the Finite Element (FE) method and the computer program ANSYS. The analysis was carried out using a 3D linear elastic model, with solid elements to represent the tunnel linings and backing, and 3D linear shells to represent the structure above i.e walls.

Three FE models were created and analysed:

Model 1, shown in Appendix A, Figure A1, includes the 3D model of the ground and the tunnels together with the cross walls of the existing building.

Model 2, shown in Figure A2, has the existing cross walls removed above ground floor level and has loading distributions applied to represent the retained structure.

Model 3 is similar to Model 2, but with the basement cross walls thickened to include concrete encasement of the wrought iron beams, and has different loading distributions applied to represent the new building and lift.

Loading on the three models is explained in section 5.1.4.

5.1.2. Material Properties

lists the material properties that were used for the analysis.

Table 5.1 Material Properties

Material	Density [kg/m³]	Young's Modulus [N/mm²]	Poisson's Ratio
North tunnel masonry	1800(1)	8500(2)	0.2
South tunnel masonry	1800(1)	8500 (2)	0.2
Backing	1800(1)	8500 (2)	0.2
Concrete (Old concrete, assumed to be weak)	2300(1)	8500 (2)	0.2
Retaining-wall	1800(1)	8500 (2)	0.2
Wall	1800(1)	8500 (2)	0.2
Fill	1900(3)	100(3)	0.45
London clay	2000(3)	360(3)	0.45
New concrete	2300(1)	30000(1)	0.2

The properties of materials used in the structural analysis have been based on lower bound representative values and based on those given in BD21/01 (1), "Behaviour of long structures in response to tunnelling" by Bloodworth *et al.* (2). Properties for the fill and London Clay have been taken from Gifford, now Ramboll, Geotechnics Technical Note (3), included in Appendix B.

Following intrusive inspection, it has been conservatively assumed that the existing wrought iron plate girders are severely corroded, and so cannot redistribute load through bending or shear. However, it is assumed that they can continue to carry load vertically to support the building, and they will be encased in concrete as part of the building works. They have been effectively modelled as part of the masonry, with the same material characteristics.

5.1.3. Boundary Conditions

The surrounding soil has been modelled to an appreciable distance from the tunnels so as to be remote enough not to influence any load redistribution arising from building alterations. The bottom surface of the model is constrained from translation in the x, y and z directions, and the sides of the model are constrained in the x and y directions.

5.1.4. Building Loading

The initial and permanent stress states have been calculated by modelling the construction of the existing building, then conservatively full demolition of all parts of the existing building which are to be removed (cross walls above top of basement level, and retained facade loads still present) and subsequent construction of the new building. Loads have been based on conservative estimates of the existing building loading and design loading from the new building. These included unfactored dead and imposed loads. Five loadcases were considered, and applied to the 3 FE models described in section 5.1.1.

MODEL 1 Existing building

- DL + LL
- DL + LL + crane load

MODEL 2 No building

- DL

MODEL 3 New building

- DL + LL
- DL + LL + lift load

The following five load cases were considered;

a. Existing building – The existing building with masonry cross walls and traditional roof with timber floors and residential loading. Dead and live loads from the floors and roof were distributed to the nearby cross walls. Façade loading is applied as point loads to the relevant locations.

b. Complete removal of existing building - Worst case scenario of existing building removed, new building not yet added. The cross walls are retained to the top of the basement level and the retained façade loads are included. It is intended that the construction sequence will be carefully planned to avoid removing too much of the existing building without replacing the load, in order to minimise any heave of the tunnels.

c. New building - The completed new building with office and retail loads, new floors and roof. Loads from the new steel columns, and from retained façade, are included as point loads.

d. Crane loading – The crane loading used in the analysis was based on a POTAIN IGO 50, with a 40 metre jib. Loads from the 4 screw jacks were supplied by the crane manufacturer for a number of jib positions. The load case chosen was that with the maximum single point load in a location nearest to the tunnels. This corresponded to an in-service load with the jib positioned diagonally across the crane.

The location of the crane considered in this loadcase is shown in Figure 5.2 superimposed onto a plan of the proposed foundations. Point loads for this loadcase are shown in Table 5.2.

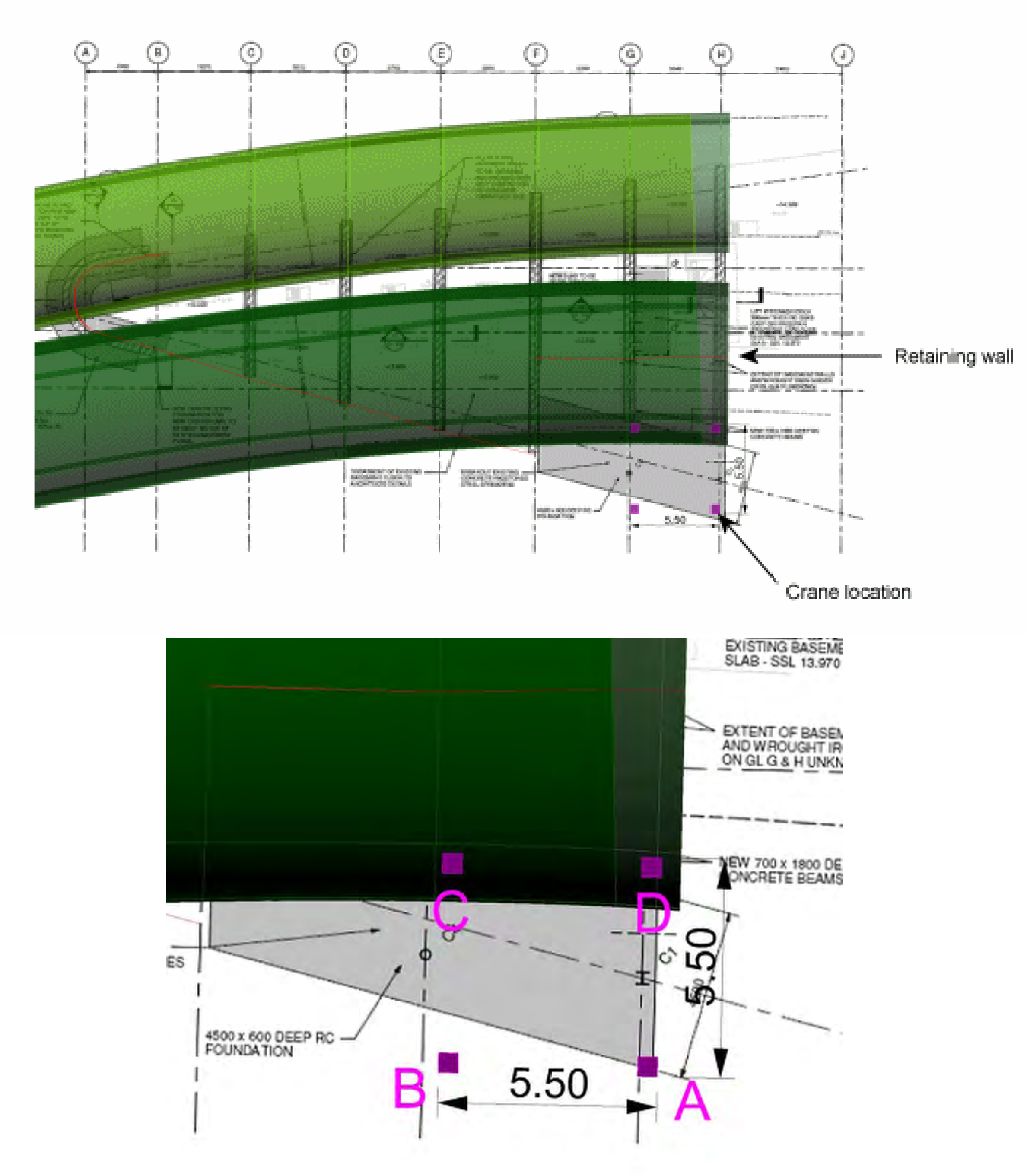


Figure 5.2 Crane loading considered

Table 5.2 Crane Loads

Point Load Location (refer to Figure 5.2 above)	A	B	C	D
Point Load (kN)	0	104	263	104

e. Lift impact- Lift impact loading from a typical 825 kg lift (Mitsu 825) was considered. A single loadcase was applied, consisting of the vertical rail reaction loads and fully loaded car impact. Loading was applied as point loads on the lift deck. Only one lift was considered, since the other lift is situated almost directly between the two tunnels, and is likely to be less critical.

The location of the lift loading considered is shown in Figure 5.3 superimposed onto a plan of the proposed building foundations. Point loads considered for this loadcase are shown in Table 5.3.

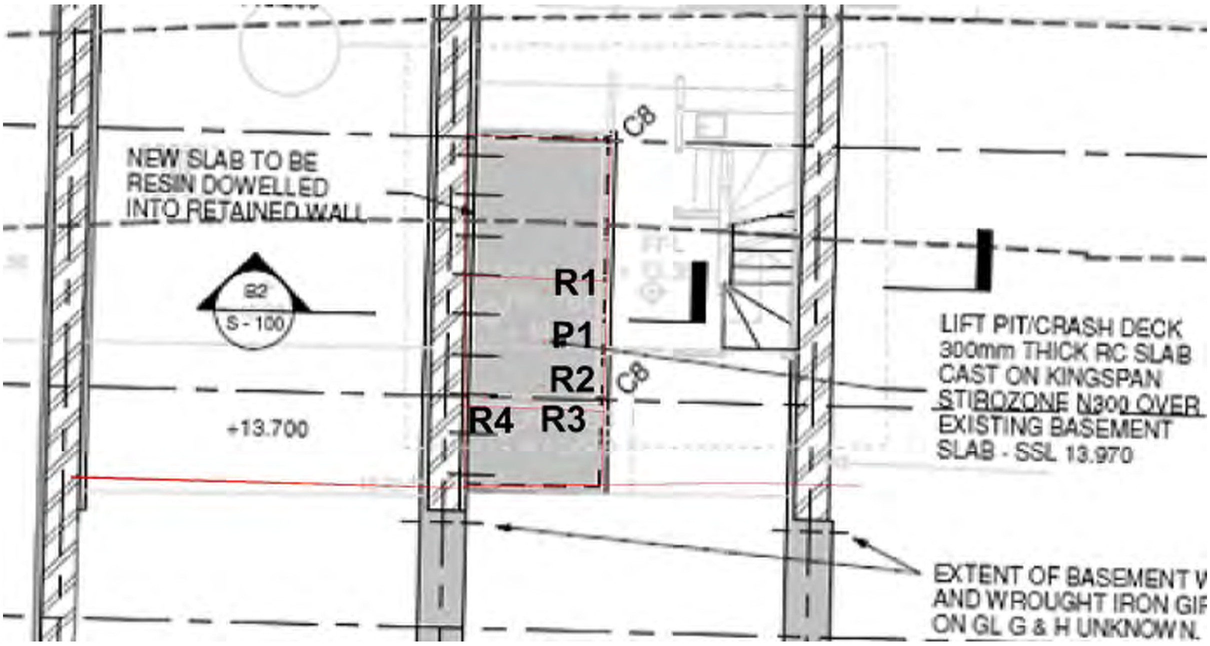


Figure 5.3 Lift impact loading considered

Table 5.3 Lift impact loads

Point Load Location (refer to Figure 5.3 above)	P1 (lift impact)	R1	R2	R3	R4
Point Load (kN)	92	48	35	35	28

5.1.5. Other Loading

Live loading from highway load and rail loads will be not be considered since these remain unchanged.

5.2. Acceptance Criteria

5.2.1. Stresses

Predicted stresses in the masonry linings will be compared against the masonry characteristic strength. In the absence of any material investigations a lower bound ultimate limit characteristic strength as given in BD 21/01 of 2.5 N/mm^2 is suggested. This is based on brick unit strength of 10 N/mm^2 and 1:3 Lime Mortar joints and which is appropriate for masonry construction of the nineteenth century, and considers the brick type referred to in "The Metropolitan and Metropolitan District Railways", by Baker (4). It is considered that 2 N/mm^2 would be an appropriate limit for comparison with nominal loading.

5.2.2. Displacements

A 3 mm deflection limit for tunnel movement was agreed at a meeting with NwR on 7/11/2011.

Deflection of the tunnels will be monitored during the works, as agreed with NwR and Tfl.

6. RESULTS AND DISCUSSION

6.1. Introduction

The structural response of the two tunnel linings has been calculated for each load case considered. Results are presented in terms of vertical displacements and Von-Mises stress on the intrados surface of the tunnels. Von-Mises equivalent stress is a non-directional stress intensity, commonly used to predict failure. It is widely used as it can be directly compared with uniaxial stress data. The vertical displacement results have also been post-processed to obtain the difference in vertical displacements between the existing building and no building, and between the existing building and new building. i.e. the results show the predicted future displacement relative to the current theoretical deflected shape.

The graphs of results have been recorded on the intrados of each tunnel, at the position of gridlines A to H, and labelled according to whether they lie on the south or north tunnel. Figure 6.1 shows the positions of the gridlines considered.

Figure 6.2 indicates the locations the graphical results refered to, and Figure 6.3 shows an example results graph.

In each results graph the position 0 metres relates to the most southerly point of the south tunnel lining. Results are presented plotted with distance around the intrados of the south tunnel lining. Results are presented in a similar manner for the north tunnel, but with the most southerly ordinate moved to 20 metres, so that results can be viewed on the same graph, for easier comparison. The gap between the two results sets is included so that the results of north and south tunnels can be clearly recognised. Shaded areas indicate the near vertical parts of the tunnel lining.

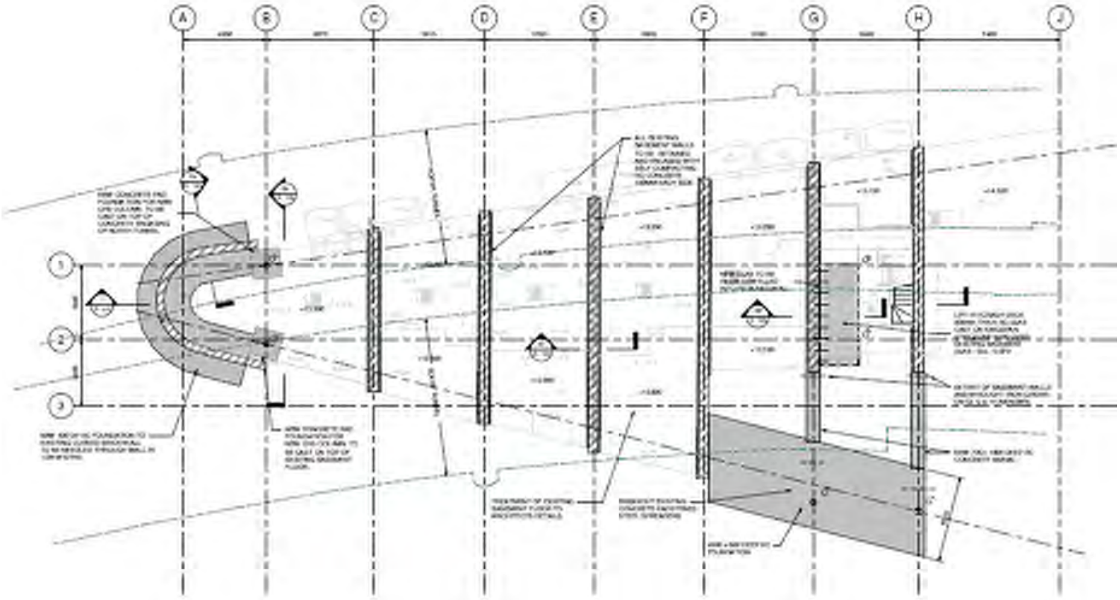


Figure 6.1 Extract from foundation drawing showing gridlines

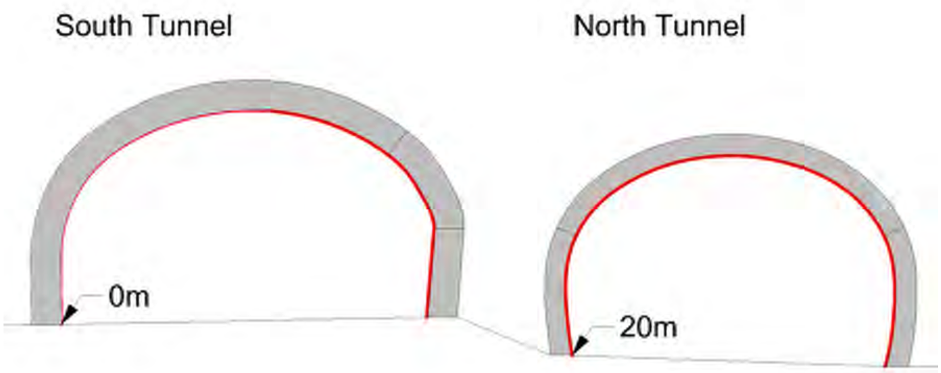


Figure 6.2 Tunnel cross section with results locations shown

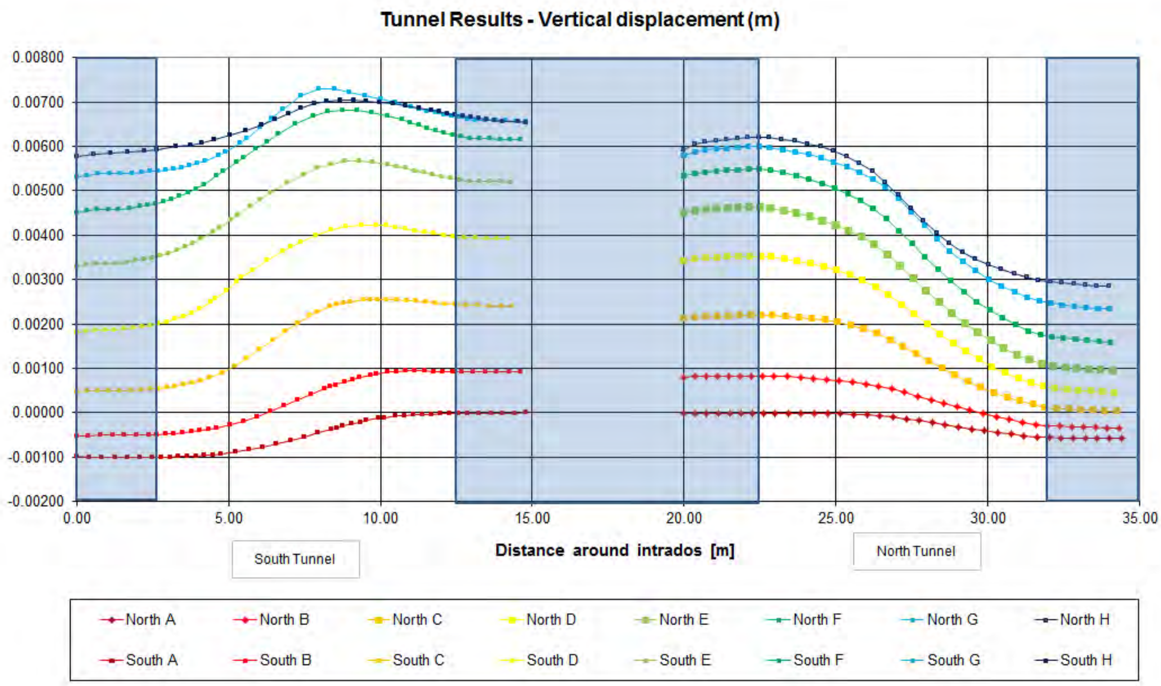


Figure 6.3 Example results graph, displacement of the tunnel inside surface

(shows results for both tunnels at a single gridline)

6.2. Displacements

Comparison of the total vertical deflection of the FE models for the existing building, no building and the proposed building show that the majority of vertical displacement is due to the compression of the soil below the tunnels, under self weight as well as the weight of the building and tunnels. Figure 6.4 shows a plot of vertical displacement in the model of the existing building. It is therefore more useful to compare relative displacements of the tunnels with the existing and proposed loading.

Predicted vertical displacements relative to the existing condition are shown in Figures C1 to C4 in Appendix C. Each figure shows displacements around the tunnel linings. The units are metres. Positive displacements are upwards, and negative displacements are downwards.

Results have been post-processed to give relative vertical displacements between the existing building and no building, between the existing building and new building, for crane loading only and lift impact loading only.

Relative vertical deflection results and the Figures in Appendix C that they relate to are summarised in Table 6.1. The combined effect of the new building and lift impact loading can be found by summing the two values.

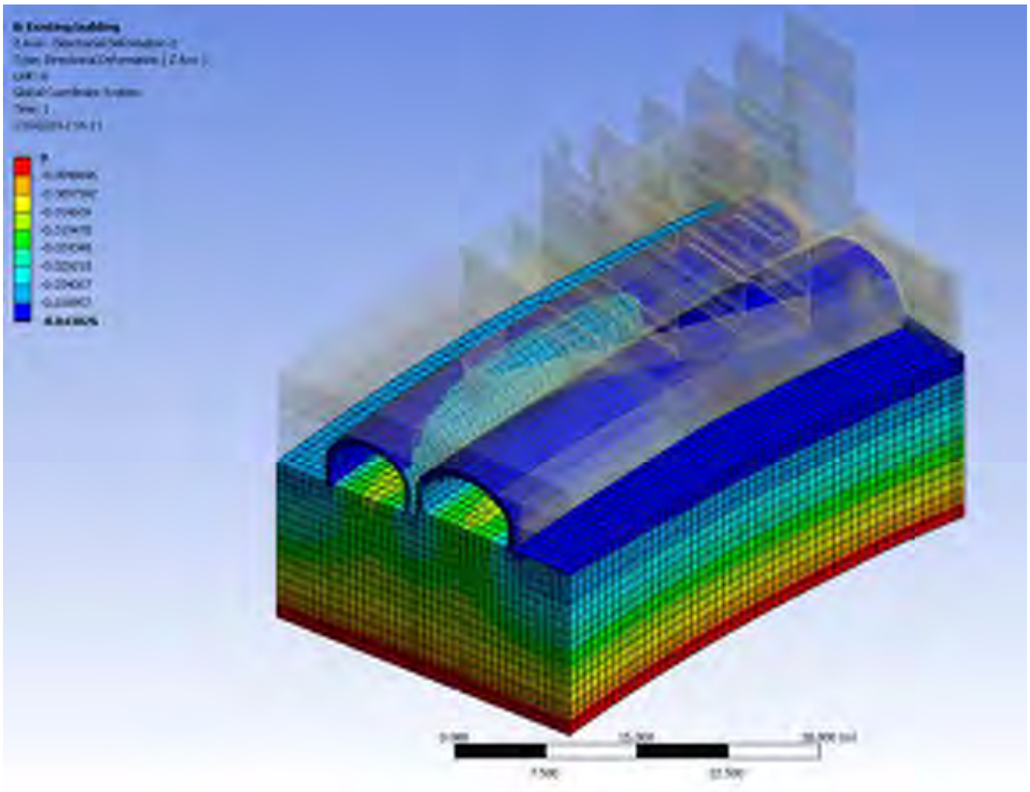


Figure 6.4 Vertical displacement of the existing building model

(tunnels and underlying ground only, other parts of model shown ghosted)

Table 6.1 Vertical Displacement Results

	Figure	Maximum Vertical Displacement [mm]		Trigger Value
		South Tunnel	North Tunnel	[mm]
Existing Building to New Building	Figure C1	-0.9	-0.8	3
Existing Building to No Building	Figure C2	8.0	6.2	3
Crane Loading Only	Figure C3	-0.5	-0.15	3
Lift Impact Loading Only	Figure C4	-0.3	-0.2	3
Existing Building to New Building and Lift Impact Loading	-	-1.2	-1.0	3

Vertical deflections are much lower than the trigger value of 3 mm in all cases except that of the old building being completely removed before building the new building. The construction sequence has been carefully planned to ensure this situation will not arise. The construction sequence is shown in Appendix G, and outlined in section 6.3 below.

Also, material properties for soil have been used that relate to long term loading, meaning that the displacement due to short term relief of loading would be expected to be significantly smaller.

6.3. Construction Sequence

To mitigate excessive displacements during construction (and to minimise temporary works) the following sequence is proposed:

1. The facade of the Lighthouse building will be retained while the internal structure is demolished and replaced by a new steel frame, working on one bay at a time.

   The demolition and construction works will be carried out on a bay by bay basis, starting from the stair core areas. Once the floors of one bay have been demolished, the new columns will be slotted in place and the floor beams connected to the columns, while the temporary retained cross walls continue to provide lateral stability. Once the floors have been cast and connected to the retained facades, the cross walls will be demolished. Then the process moves to the next bay until the internal structure of the Lighthouse building is replaced by the new steel frame.

   This method allows only the load of one bay to be removed from the tunnels at any time, thus considerably reducing the deflection of the tunnels' brick lining.

2. The two storey building on Grays Inn Road will be completely demolished and replaced by a new five storey steel structure with brick facing, to match the rest of the Lighthouse building.

3. The three storey building on Pentonville Road will be demolished down to first floor level and rebuilt as a similar three storey load bearing masonry structure. The current floor levels will be altered to match those of the adjacent Lighthouse building, and the total height of the building will increase by about 1.5 metres as a result. This part of the building has not been included in the analysis as the new and existing configuration are very similar and the changes in loading experienced by the tunnel are negligible, as this building does not sit over the masonry tunnels.

6.4. Stress

Predicted stress results are shown in Figures D1 to D5 in Appendix D. The figures show Von Mises stress around the tunnel intrados for each of the 5 loadcases. The units are N/m^2.

Spurious high local values of Von Mises stress were calculated in the tunnel linings at the bottoms of tunnel linings in some places, where the tunnel would be connected to the tunnel foundations. This is the case for all of the loadcases considered, including that for the existing building. These spurious results were related to the mesh spacing and issues with the contact elements, and have not been included in the results graphs.

The results show that the Von Mises stress does not change significantly with the introduction of the new building,

A typical diagram of Von Mises stress in the tunnels is shown in Figure 6.5, to illustrate typical variation along the tunnel.

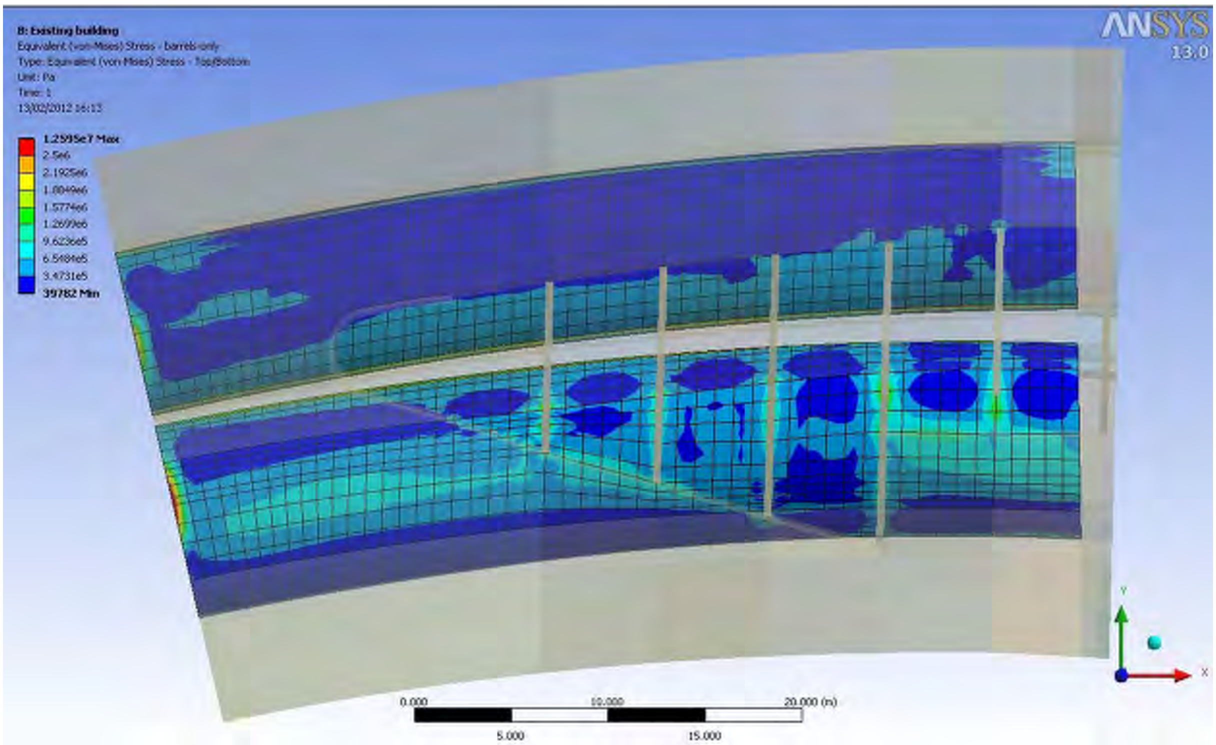


Figure 6.5 Von Mises stress for the existing building

(stress shown in tunnel linings only, note contour scale is not linear)

Table 6.2 Von Mises Stress Results

Result	Figure	Maximum Von Mises Stress [N/mm²]		Characteristic Strength Limit [N/mm²]
		South Tunnel	North Tunnel	
Existing Building	Figure D1	1.7	1.9	2.0
No Building	Figure D2	1.9	1.6	2.0
New Building	Figure D3	1.9	2.0	2.0
Crane Loading and Existing Building	Figure D4	1.8	1.9	2.0
Lift Impact and New Building	Figure D5	1.9	2.0	2.0

6.5. Hand Calculation

Approximate hand calculations were undertaken to help verify the FE analysis findings. Comparing the loading from the old building to the new building, there is a relatively small increase in loading, from approximately 22.4 MN to 23.7 MN, an increase of approximately 6%. (The load considered in each case is dead load and live load with no load factors)

7. CONCLUSIONS

Based on predictions made using a series of 3D linear Finite Element models, the following conclusions are drawn;

1. The vertical deflection of the tunnel linings resulting from the old building being replaced by the new building are well within the 3 mm tolerance. Further deflection due to crane loading or lift impact loading are insignificant.
2. Vertical deflections due to the old building being substantially removed prior to construction of the new building exceed the 3 mm tolerance. The careful planning of the construction sequence (see Appendix G) is essential to ensure this situation will not arise.
3. Von Mises stress in the tunnel linings does not change significantly due to the removal of the existing building and construction of the proposed building.
4. Loading due to the crane considered (POTAIN IGO 50) in the position considered does not exceed suggested deflection or stress limits.
5. Lift impact loading of the magnitude considered (825 kg lift, Mitsu 825) does not exceed suggested deflection of stress limits.
6. Hand calculations show the new building to represent an approximate increase in nominal loading of 6% over the existing building.

8. REFERENCES

1. Highways Agency. Design Manual for Roads and Bridges, BD 21/01, The Assessment of highway bridges and structures, August 2001
2. Behaviour of long structures in response to tunnelling, Y-C Lu, AG Bloodworth, FD Gleig, (metropolitan line)
3. Ramboll Technical Note Lighthouse Building Soil Parameters For Building Tunnel Interaction, Colin Millard, 6/9/2011 Included in Appendix G
4. The Metropolitan and Metropolitan District Railways, Baker, The Institution of Civil Engineers, Minutes of Proceedings, 17th February 1885, Paper No 2054

Appendix A - Finite Element Models

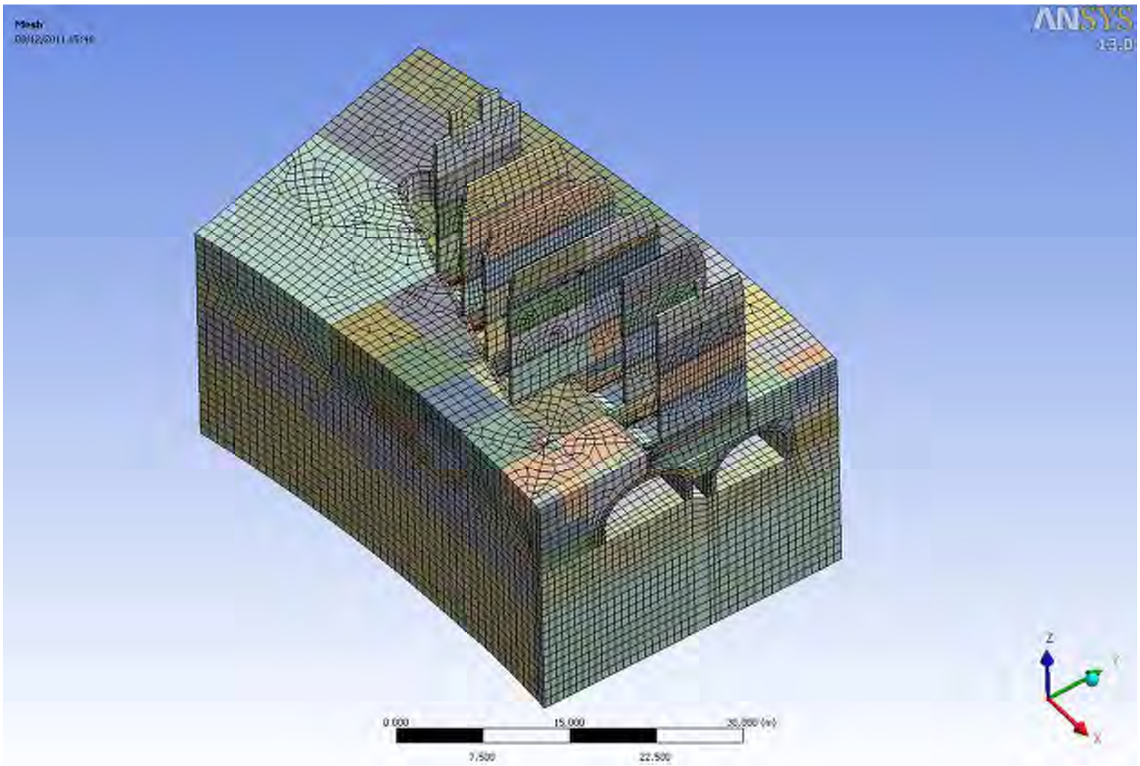


Figure A1 Existing Building Model, showing modelled existing cross-walls

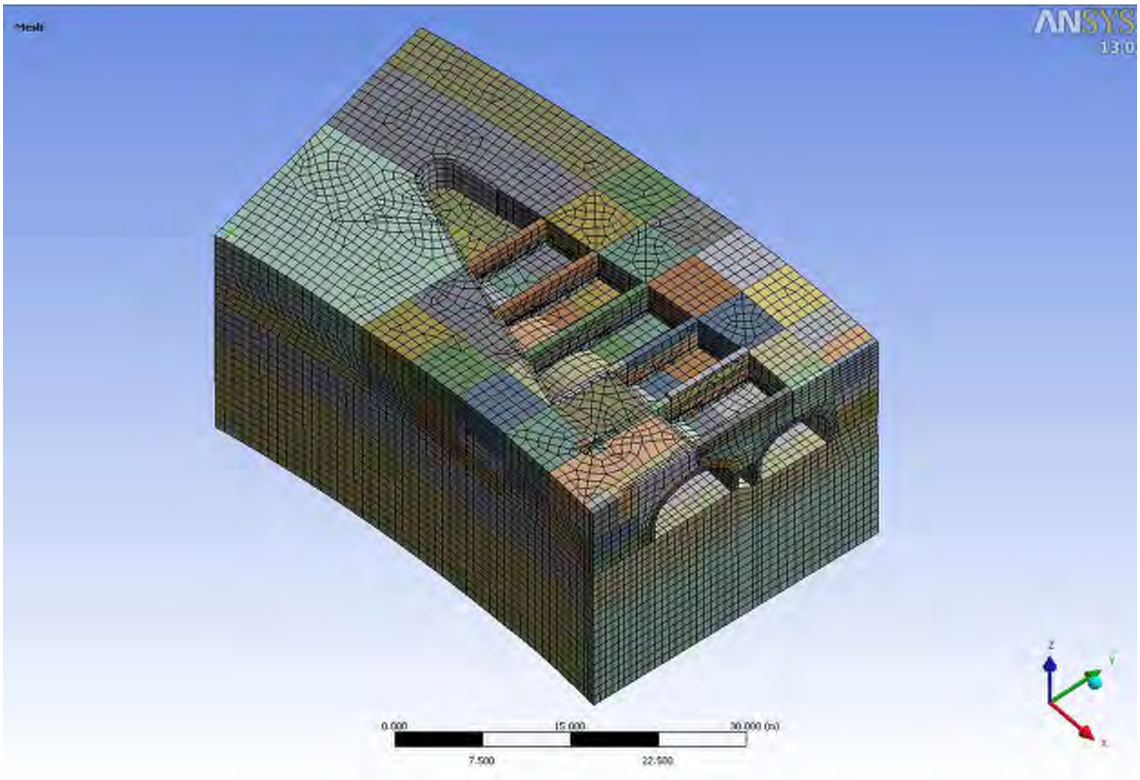


Figure A2 No Building Model, cross-walls removed to basement level

Appendix B – Lighthouse Building Soil Parameters for Building Tunnel

Gifford
part of Ramboll

Doc No. / Ref. : 18796/SI/01

TECHNICAL NOTE

Project:	Light House Building	Job No:	18885
SUBJECT:	**Soil Parameters for Building/Tunnel interaction**		
Prepared by:	Colin Millard	Date: 6/9/2011	
Distribution:	Jim Flack		

1. Brief

Referring to email Jackie Heath/Jim Flack dated 4/8/11, the task is to provide soil design parameters for input into a model to predict the effects of the load changes on the two tunnels beneath the Light House Building (LHB) during and after its proposed refurbishment.

2. Scheme Outline

The LHB lies over two masonry lined live tunnels that run approximately in line with the longitudinal axis of the building. The tunnel crowns are known from previous surveys to be within 1m of the existing foundations. The northern tunnel is operated by Network Rail and the southern tunnel operated by London Underground forming part of the Circle Line.

The proposed refurbishment is to gut the inside of the building leaving the existing facades and foundations, and convert the building into office/retail space supported on a steel frame. An additional floor will be added. In order to minimise stress changes to the existing tunnels and adjacent areas, the load paths shall remain unchanged by distributing the new loads using the existing basement cross-walls which are supported on an existing iron I beans.

It is expected that the existing foundations will be subjected to a 20% increase in load from the refurbished structure.

From historical data presented in the Baker paper (see below) the tunnels were constructed using cut and cover techniques.

3. Geology

BGS Sheet 256 indicates that the area is underlain by the London Clay Formation, which typically comprises in its unweathered state grey/blue stiff fissured clay.

4. Existing Soil Information

There are three sources of factual soils information:

1. Baker, B. (1885),The Metropolitan and Metropolitan and District Railways. Proceedings Institution of Civil Engineers.

2. BGS boreholes.

3. Constructive Evaluation Limited (2011), Ground Investigation Report at 283-297 Pentonville Road 386 Grays in Road, Kings Cross, London, WC1X 8BB, Report no. 11.6713.

5. Soil Conditions

Baker Report

At the location of Kings Cross Station, the longitudinal section identifies the following

Made Ground 0 – to 3.0m bgl

Clay and Gravel 3.0 to 3.6m bgl

Yellow Clay 3.6 to 5.6m bgl

London Clay 5.6m+ bgl

It is considered that the Clay and Gravel, and Yellow Clay, forms part of the River Terrace Deposits.

BGS

Boreholes SW684 and SW4219 were both sunk approximately 40m from the site. They revealed conditions typically expected in this part of London, i.e:

> Made Ground of firm sandy gravely clay 0m to 2.5 to 4.0m below ground level (bgl)
>
> River Terrace Deposits comprising approximately 1m of brown sandy clay and flint gravel between 3 and 4m bgl
>
> London Clay comprising firm becoming stiff and very stiff brown becoming light grey silty clay.

The Harwich Beds were proven to underlie the London Clay at approximately 18 to 20m bgl (approximately -3.0m OD), and comprised very stiff mottled red and brown silty sandy clay or clayey sand.

Constructive Evaluation Limited (CEL) Report

The report by CEL comprised hand dug pits from basement level (top of concrete slab at approximately 13.5m OD). The pits generally proved the level of the tunnel crowns and integrity of the existing foundations, including the I Beam. Only in pits TPN5 and TPN7 was the existing backfill around the tunnels proven, up to a maximum depth of 3.5m below slab level (bsl).

The soil in TPN5 was shown to be made ground comprising sandy gravel, over firm sandy clay, the gravels comprising brick, glass and flint. At 2.2m bsl (11.25m OD), firm brown clay was encountered, and may be undisturbed in-situ unweathered London Clay. The clay was proven to 3.5m bsl (9.95m OD).

TPN7 revealed 0.15m of concrete slab overlying brown sandy gravel together with cobbles of brick, the gravels consisting of brick glass and concrete, overlying firm brown clay at 0.7m bsl (12.75m OD) proven to 2.3m bsl (11.2m OD).

6. Groundwater

No groundwater was reported in the BGS boreholes.

The CEL investigation proved isolated seepages within the granular made ground generally within 0.5m from tunnel lining.

The Baker paper mentions the presence of groundwater within the River Terrace Deposits, generally approximately 1m above the base of the deposit.

7. Ground Model and Design Parameters

The ground model is made up of seven elements and are represented on Sketch 1.

Zone 1 – Made Ground – Tunnel backfill (loose to medium dense)

Zone 2 – General Made Ground (loose to medium dense)

Zone 3 – Granular River Terrace Deposits (medium dense)

Zone 4 – Cohesive River Terrace Deposits (firm)

Zone 5 – Weathered London Clay (firm to stiff clay)

Zone 6 – Unweathered London Clay (stiff to very stiff clay)

Zone 7 - Harwich Formation (very stiff clay)

The design parameters are summarised in the Table 1below.

Note due to no site specific in-situ or laboratory testing, the following parameters have been derived from published sources. The large range of values reflects the uncertainty of the ground conditions, and the effects of stress relief in the zone of influence of the excavations during tunnel construction.

The stiffness parameters assume strains under settlement of less than 0.01%. For stiffness moduli under heave the stiffness moduli under settlement have been factored by 2.

Table: Stiffness Parameters

Stratum	Base(m OD)	Soil Zone	E_{uv} (MPa)		E_{dv} (MPa)		E_{vh} (heave)		Anisotropy Factor	Bulk unit weight (kN/m^3)
			min	max	min	max	min	max		
Zone 1 Made Ground (Tunnel Backfill)	11.25	1	5	25	3	15	10	50	1.0	19
Zone 2 General Made Ground	13.0	2	5	25	3	15	10	50	1.0	19
Zone 3 River Terrace Deposits (granular)	12.4	3	10	20	10	20	20	40	1.0	19
Zone 4 River Terrace Deposits (cohesive)	10.5	4	5	40	3	24	10	80	1.0	19
Zone 5 Weathered London Clay	8.0	5	10	60	6	27	20	90	1.25	20
Zone 6 Unweathered London clay	-3.0	6	60	120	36	72	120	240	1.25	20
Zone 7 Harwich Formation	Below -3.0	7	60	120	36	72	120	240	1.25	20

E_{uv} = undrained (short-term) vertical stiffness
E_{dv} = drained (long-term) vertical stiffness
E_{vh} = undrained (short-term) vertical stiffness

For anisotropy effects multiply the relevant stiffness moduli, E, by the anisotropy factor to allow for any change in horizontal stiffness.

<u>Groundwater</u>

Assume hydrostatic conditions from underside of tunnel lining (5.0m OD)

Appendix C Predicted Displacement in Tunnel Linings

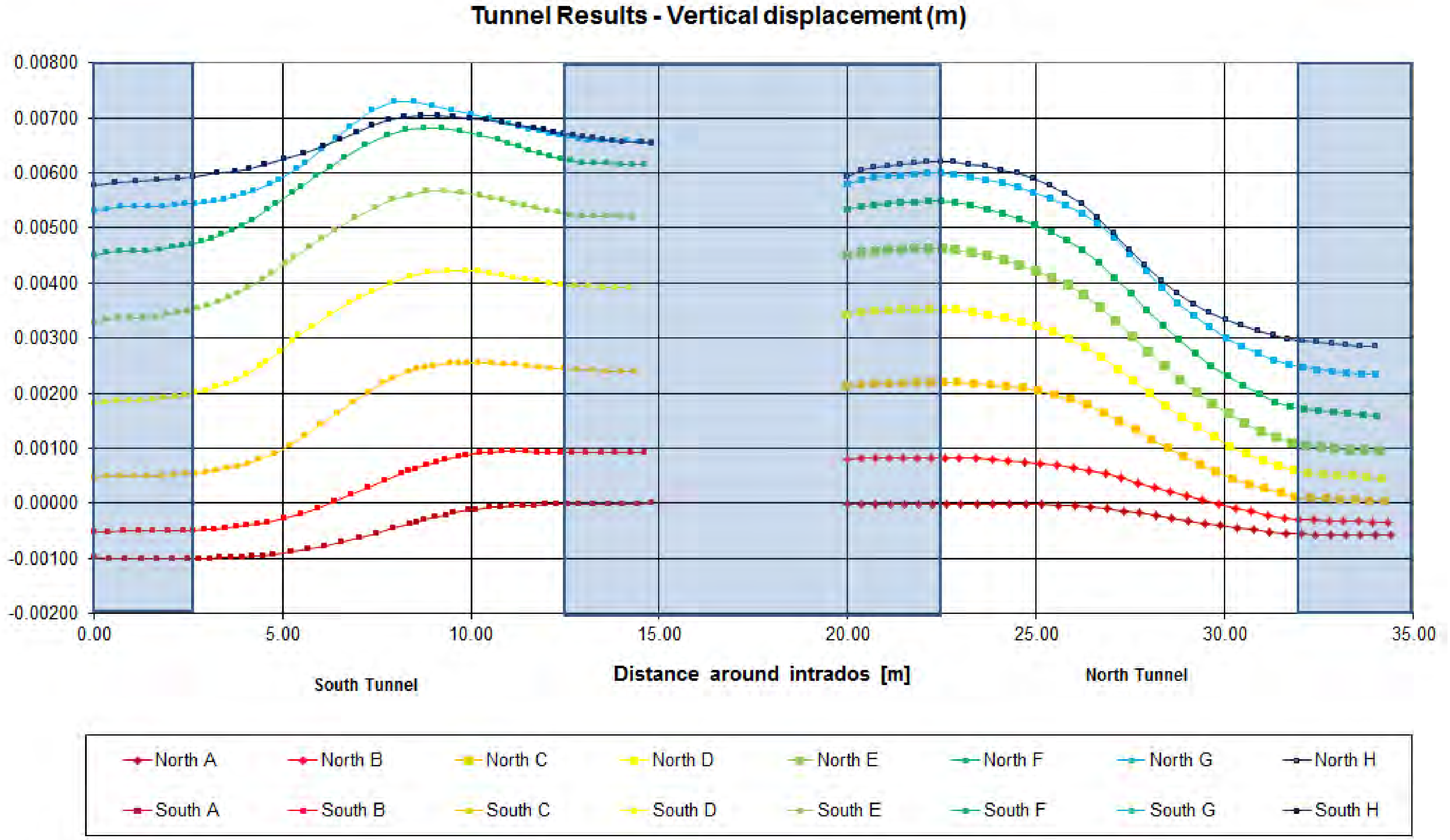


Figure C1. Predicted displacements of tunnel intrados – Existing Building to No Building

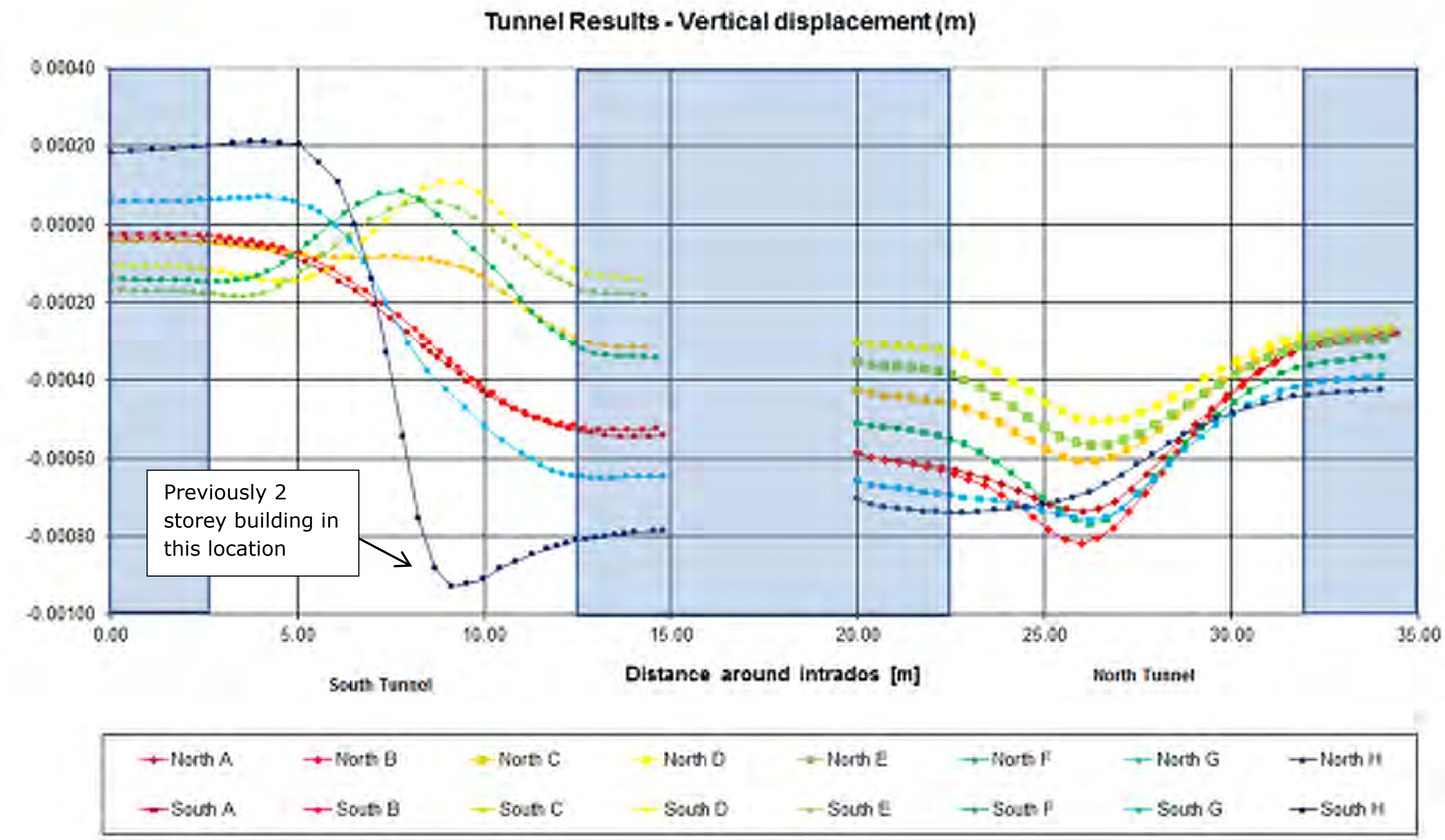


Figure C2. Predicted displacements of tunnel intrados – Existing Building to New Building

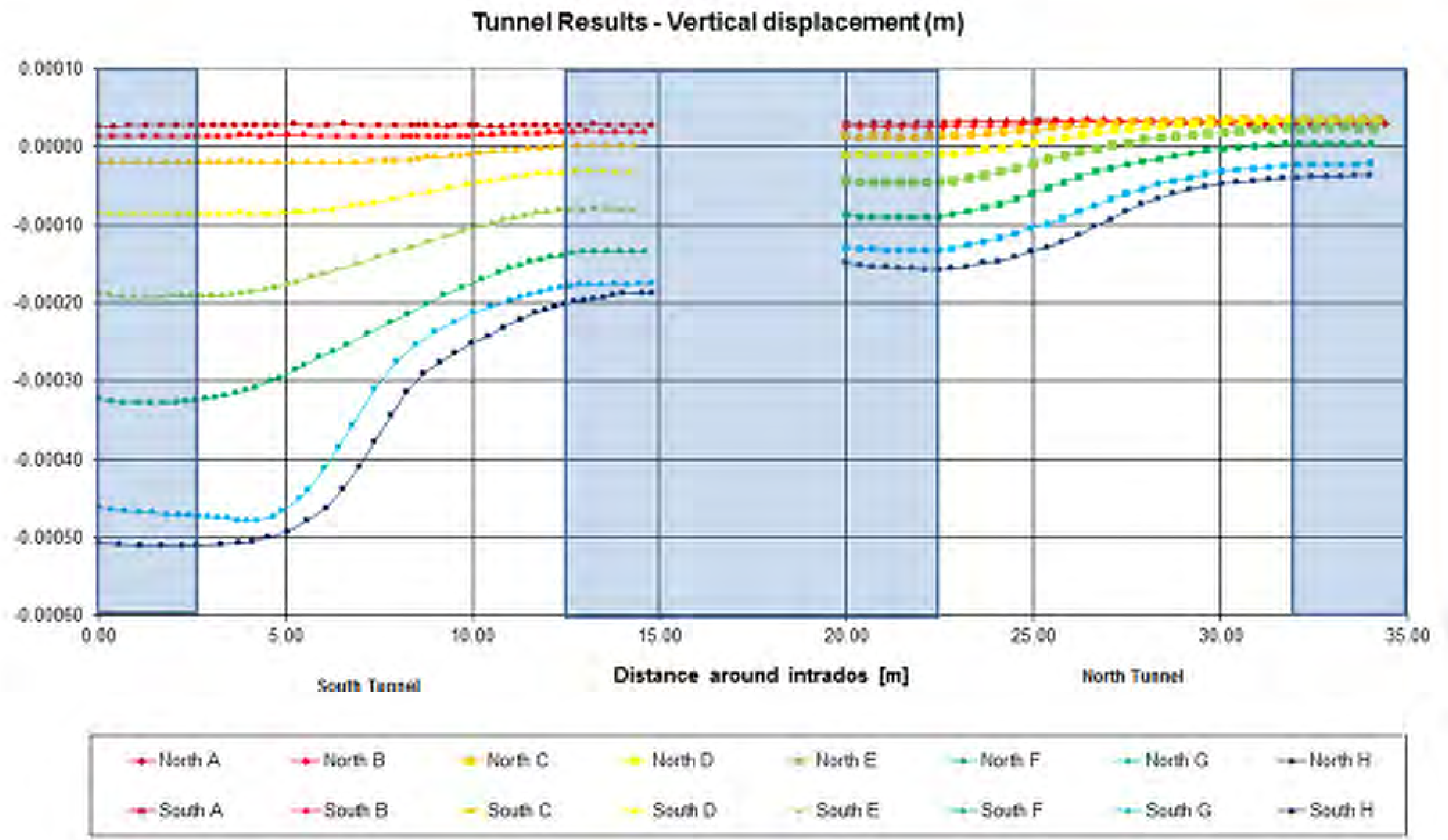


Figure C3. Predicted displacements of tunnel intrados – Crane Loading Only

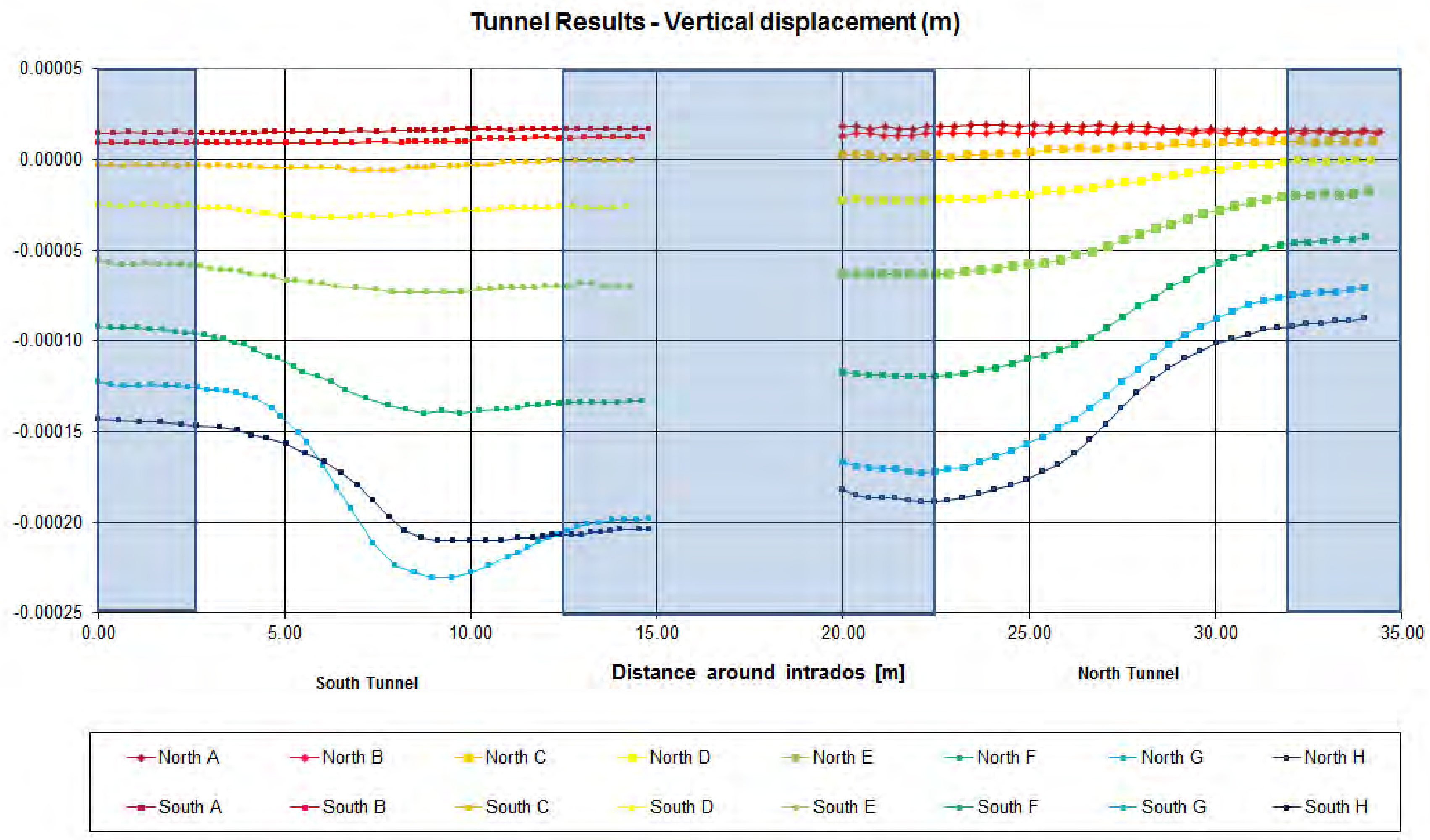


Figure C4. Predicted displacements of tunnel intrados –Lift Impact Loading Only

Appendix D Predicted Stress in Tunnel Linings

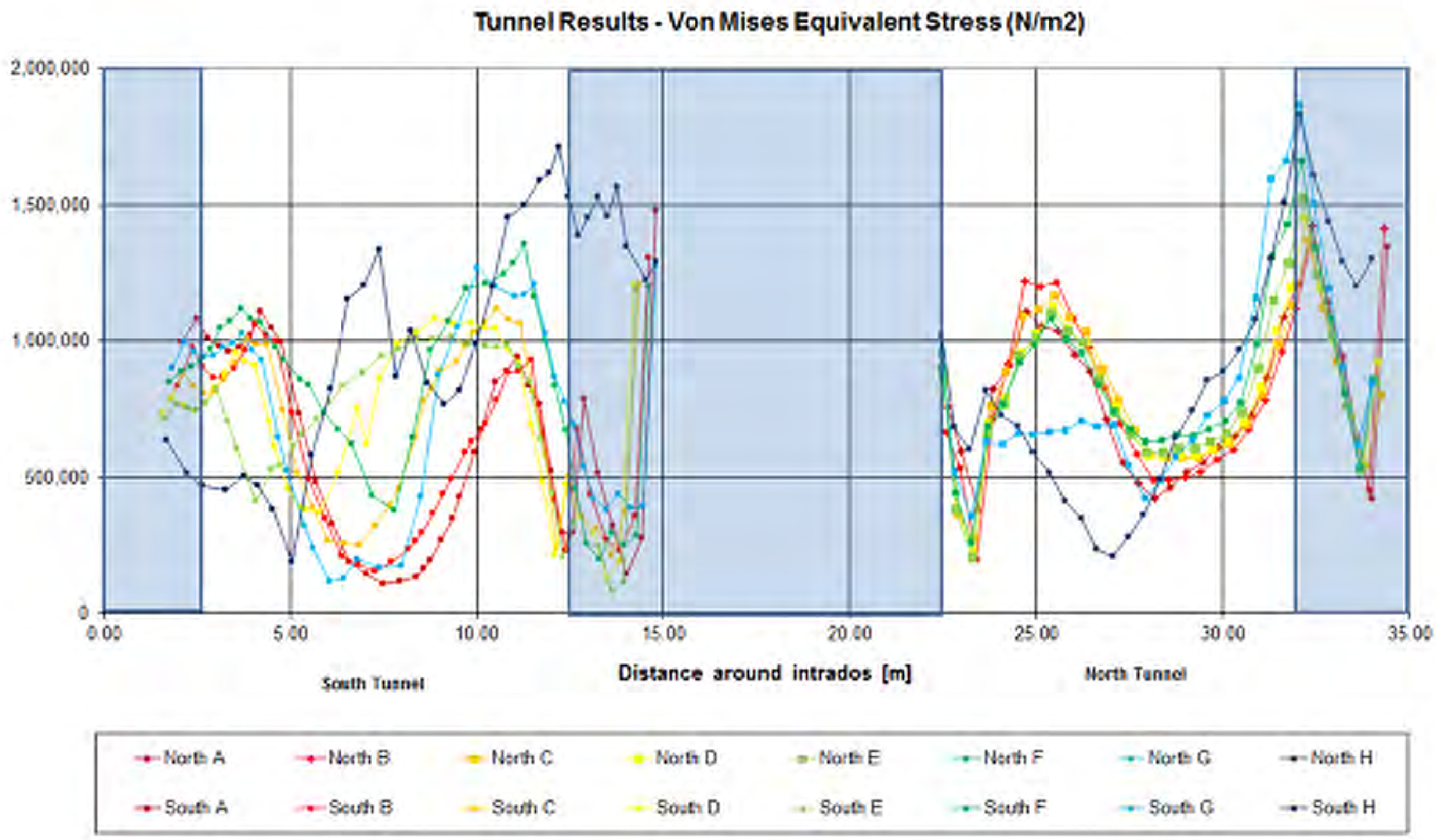


Figure D1. Predicted stress in tunnel intrados – Existing Building

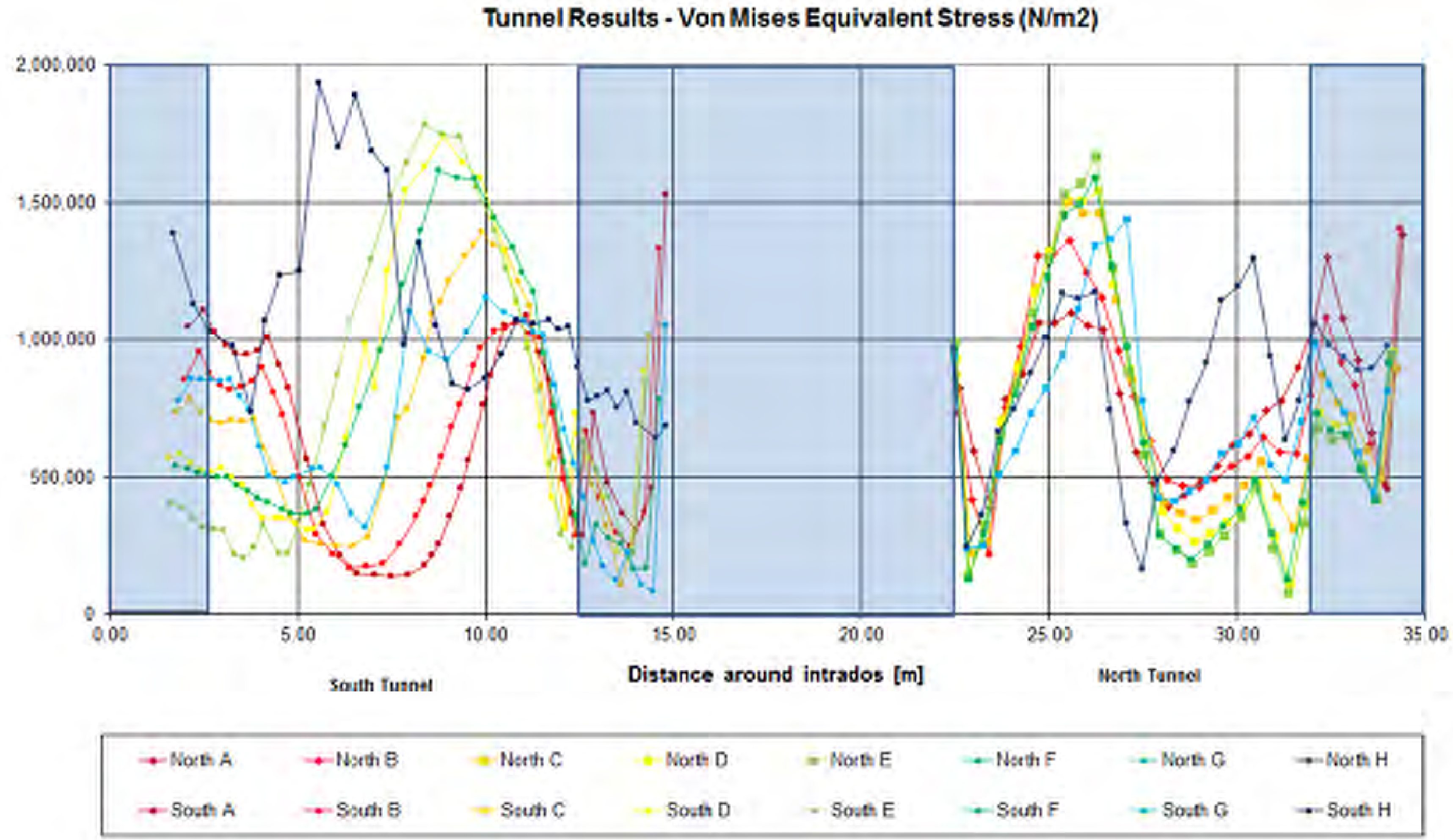


Figure D2. Predicted stress in tunnel intrados – No Building

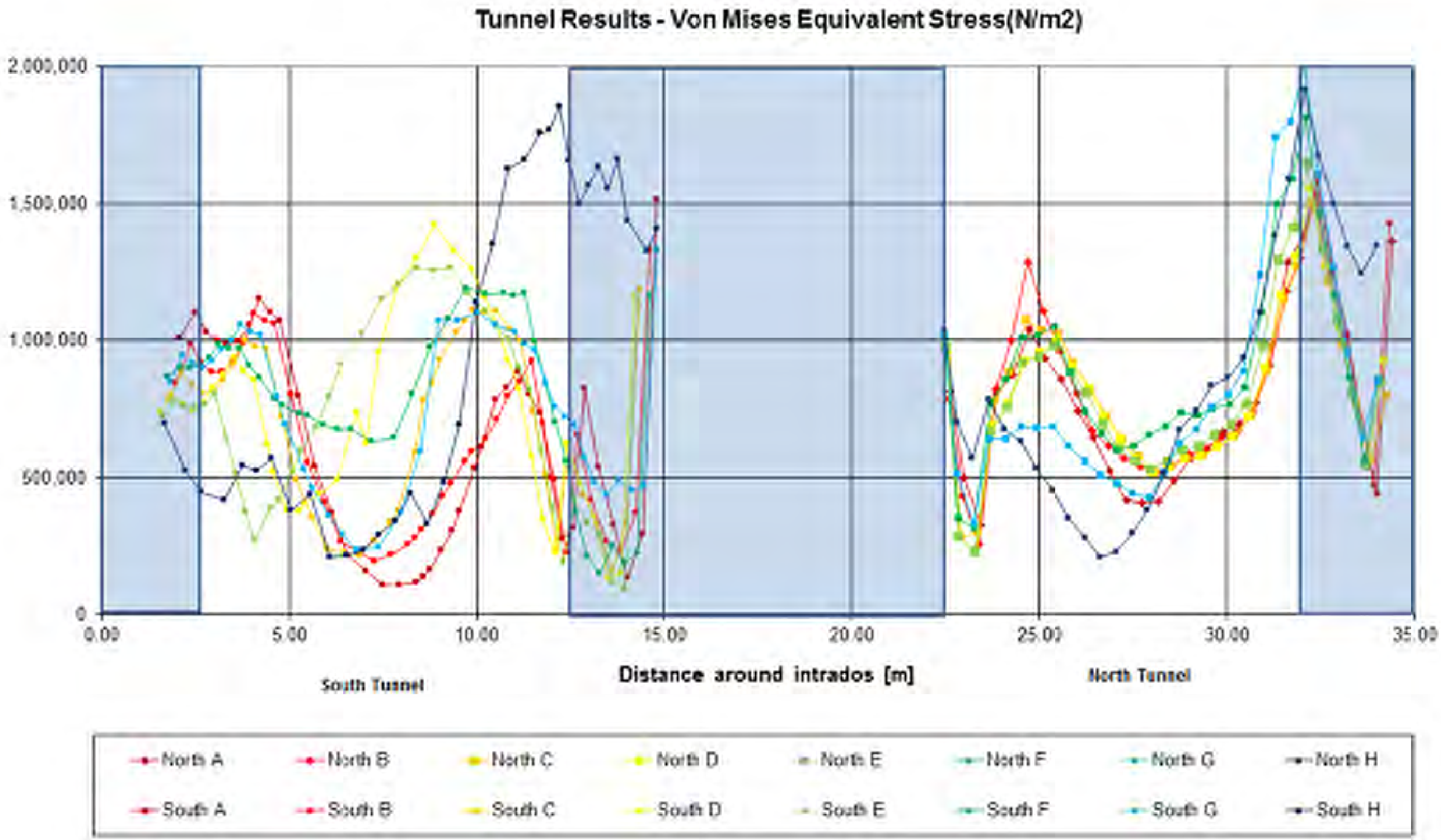


Figure D3. Predicted stress in tunnel intrados – New Building

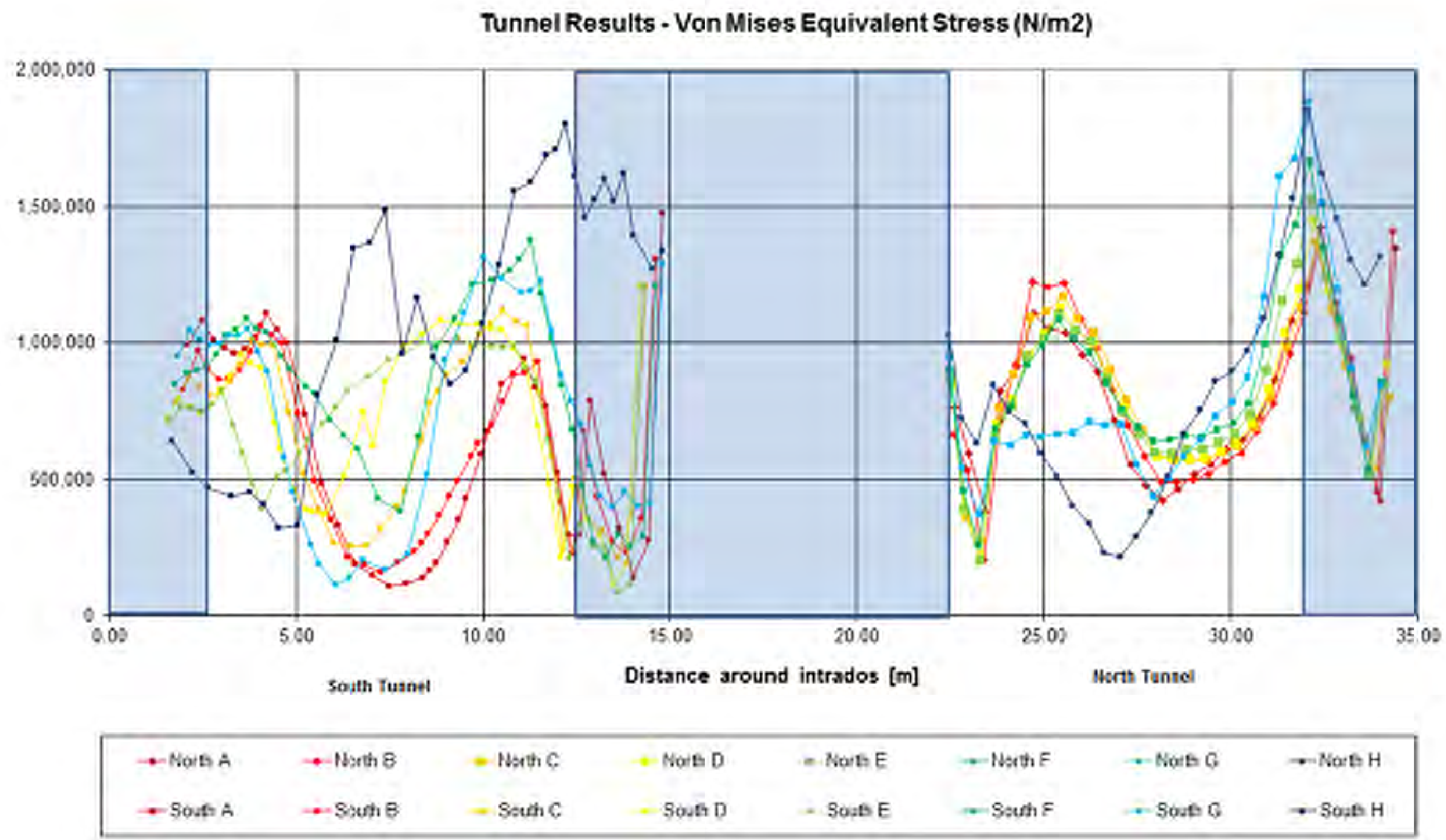


Figure D4. Predicted stress in tunnel intrados– Existing building and Crane Loading

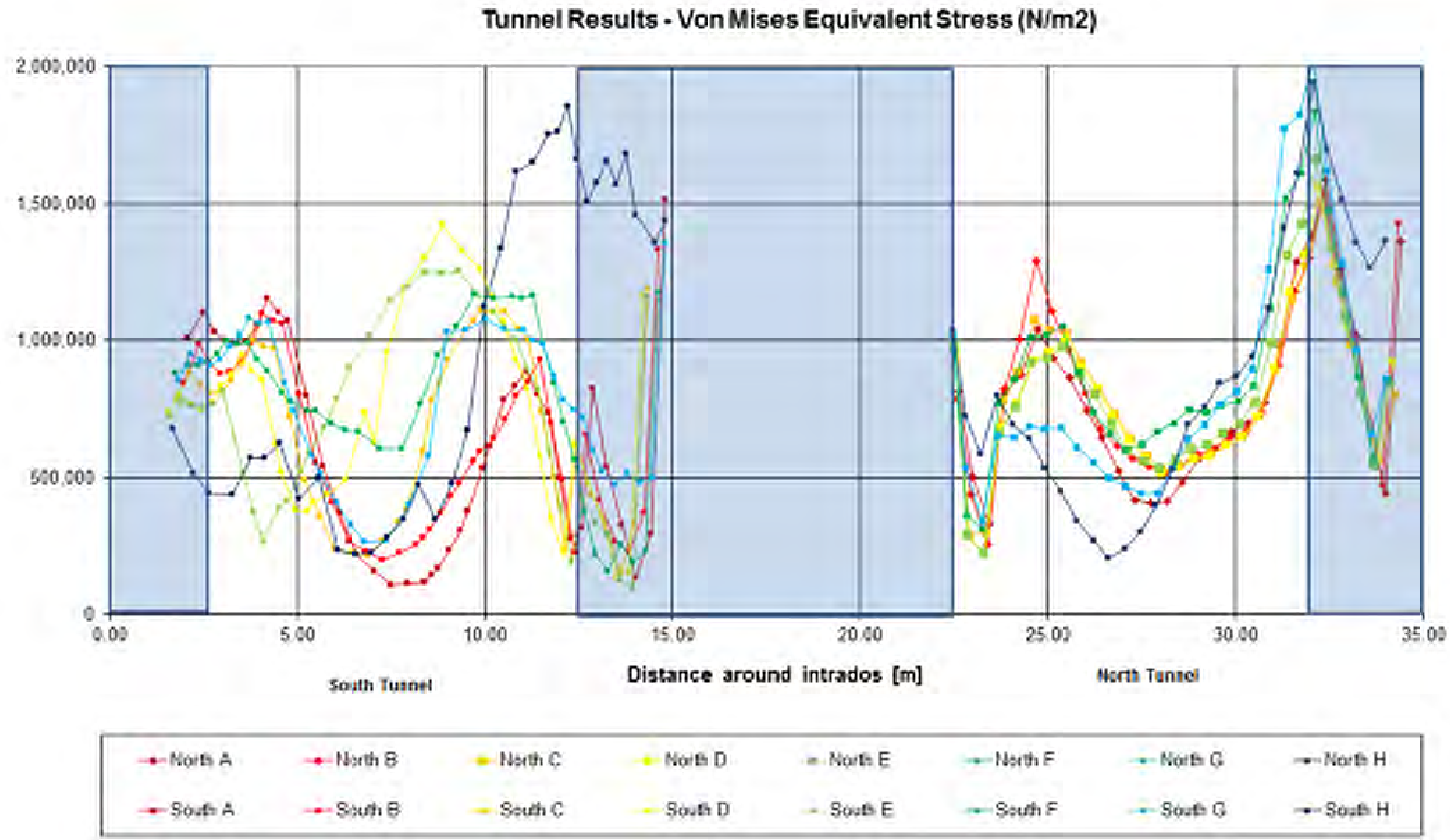


Figure D5. Predicted stress in tunnel intrados – New Building and Lift Impact Loading

Appendix E – AIP and Form A

Report No. 18885/ST/R06
August 2011

KINGS CROSS TRIANGLE LIGHTHOUSE BUILDING

CIRCLE LINE TUNNEL STRUCTURAL ASSESSMENT FOR CAPACITY AND LOADING

TfL London Underground
Infrastructure Protection Engineer,
Capital Programmes Directorate
London Underground, 2nd Floor,
25 Eccleston Place, Victoria,
London SW1W 9NF

KINGS CROSS TRIANGLE LIGHTHOUSE BUILDING

CONTROLLED DOCUMENT

Gifford No:	**18885**/ST/R06		
Status:		*Copy No:*	
	Name	*Signature*	*Date*
Prepared by:	J A Heath/ L Mabon		4.08.2011
Checked:	C Brookes		4.08.2011
Gifford Approved:	J A Heath		4.08.2011

Revision Record					
Rev.	*Date*	*By*	*Summary of Changes*	*Chkd*	*Aprvd*

TfL London Underground
London Underground, 2nd Floor,
25 Eccleston Place, Victoria,
London SW1W 9NF

Gifford
Bankside Studios
76 - 80 Southwark Street
London
SE1 0PN

KINGS CROSS TRIANGLE LIGHTHOUSE BUILDING

CIRCLE LINE TUNNEL STRUCTURAL ASSESSMENT FOR CAPACITY AND LOADING

C O N T E N T S

Page

1. NAME OF SCHEME

Kings Cross Triangle Lighthouse Building.

The Lighthouse Building lies over two masonry lined tunnels. The south tunnel, was opened in 1863 by the Metropolitan Railway and is known as the Circle Line Tunnel. It carries Metropolitan and Circle underground trains and is owned by London Underground Limited (LU).

The north tunnel, was built soon after the first for the Northern Railway and is now known as the City Widened Lines Tunnel. It carries Thameslink Network Rail trains. It is owned by Network Rail Limited. A similar and parallel approvals process is being pursued with Network Rail for the north tunnel.

The scheme is outline in the structural report in Appendix B.

2. NAME OF STRUCTURE

Circle Line Tunnel

2.1 Type of structure

Tunnel

2.2 Obstacle crossed

The tunnel passes under the Kings Cross Lighthouse building and Grays Inn Road

3. STRUCTURE DETAILS

3.1 Description of Structure

The structure is a brick masonry tunnel, opened 1863 by the Metropolitan Railway. It is known as the Circle Line Tunnel and carries Metropolitan and Circle underground trains.

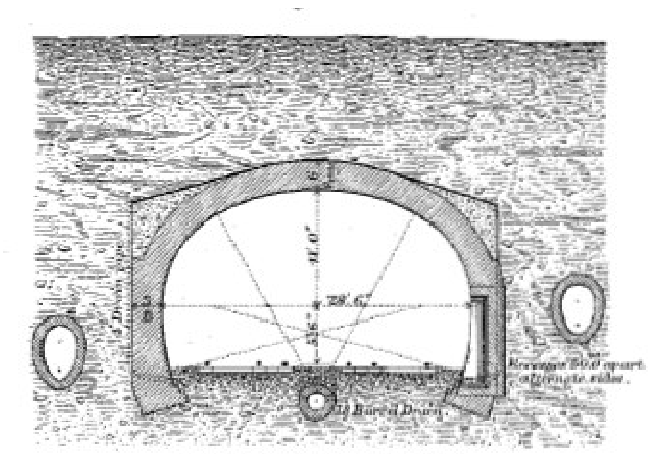
The Lighthouse Building above dates from circa 1875 and lies over this tunnel and the adjacent City Widened Lines tunnel owned by Network Rail Limited.

3.2 Structural Type

Believed to be a cut and cover tunnel.

3.3 Sub-structure and foundations

Foundations assumed to be stepped brick footings. The modelled foundations will be based on The Institution of Civil Engineering. Minutes of Proceedings. Volume 81, Issue 1885, pages 1 - 33 "*The Metropolitan and Metropolitan District Railways*." By Benjamin Baker, which notes the footings are 4feet wide with no concrete beneath. As shown in the image below from this paper:



METROPOLITAN RAILWAY.
TYPE SECTION OF COVERED WAY.

Figure 1 Drawing showing assumed foundation construction (note this does not show the second tunnel or Lighthouse building over

3.4 Span Arrangements

N/A

3.5 Articulation Arrangements

Monolithic construction

3.6 Parapet Type

None

3.7 Material Properties

Characteristic strength of the masonry:

The properties of materials used in the structural analysis have been based on lower bound representative values and based on those given in BD21/01 and BS 5628 as well as those determined during a verification study involving comparisons with full-scale tests of masonry arch bridges, (Proceedings of the Institution of Civil Engineers Engineering and Computational Mechanics 163 September 2010 pp 203-211 *Application of finite/discrete element method to arches* C. Brookes) Reference will also be made to LU Category 2 Standard E3701 Structural Assets – Inspection.

4. ASSESSMENT CRITERIA

4.1 Loading

4.1.1 Assessment Live Loading

Live loading from highway load and rail loads will be not be considered because these remain unchanged.

Unfactored live loads from the building occupation will be in accordance with BS6399

4.1.2 Any special loading not covered here

The initial and permanent stress state will be calculated by modelling the construction of the existing building, then partial demolition and subsequent construction of the new building. Loads will be based on conservative estimates of the existing building loading and design loading from the new building. These will include unfactored dead and imposed loads.

4.2 List of Relevant British European and LU Standards

British Standards, incorporating the latest amendments and corrigenda,

Highways Agency. *Design Manual for Roads and Bridges, BD 21/01, The Assessment of highway bridges and structures*, August 2001

Highways Agency. *Design Manual for Roads and Bridges BA 55/06 Assessment of Bridge Substructures and Foundations, Retaining Walls and Buried Structures*

LU Standard Category 2 Assessment for Safe Loading S-CV-0015 A3

LU Standard Category 2 Standard E3701 Structural Assets – Inspection.

British Standards Institution.1996. *BS 6399 Loading for Buildings Inc amendment No 1*

British Standards Institution. 2002. *BS 5628-1:1992, Code of practice for use of masonry, Part 1: Structural use of unreinforced masonry.*

4.3 Proposed departures from LU standards listed above

None

4.4 Proposed Methods of dealing with aspects not covered by LU standards listed in 4.2

N/A

5. STRUCTURAL ANALYSIS

5.1 Methods of Analysis proposed for the superstructure, substructure and foundations

5.1.1 Objectives

The principal objectives of the tunnel lining and foundation structural analyses are as follows:

i) To predict likely displacements (settlement) that may result in the two tunnel linings arising from proposed alterations in the building. In terms of structural engineering, it is expected that most of the existing diaphragm walls will be removed from the ground floor up, being replaced by some columns. It is understood that details of this refurbishment have not yet been finalised.

ii) To compare predicted maximum displacements with any available acceptable values below which no further assessment is required.

iii) To calculate tunnel lining masonry stresses and compare the results with lower bound representative characteristic strengths.

iv) To compare predicted intrados circumferential strains with any available acceptable values below which no further assessment is required.

In 2006 a preliminary 2D Finite Element model was undertaken (see appendix C) to give an initial understanding of the building - tunnel interactions. Further, more accurate, information regarding the proposed design and loads from the building (drawings appendix D), the position of the tunnels (from surveys) and the tunnel construction (based on trial holes appendix Aand research) mean that a more accurate 3D analysis will now be undertaken.

5.1.2 Analyses Method

A numerical model will be used to undertake structural analysis and to calculate displacements, strains and stresses in the tunnel linings resulting from predicted changes in load distribution from the proposed building alterations. There are two key stages in the structural analysis process as follows:

i) Review available survey data of the tunnels and the Lighthouse Building as listed in section 7 and construct a 3-dimensional geometric model. The relative positions of the two tunnels and the buildings are show in Figure 2

ii) The masonry tunnels including the brick tunnel linings, foundations, fill and overlying structures will be analysed using the Finite Element method and the computer program ANSYS The analysis will be a 3D linear elastic model, using solid elements to represent the tunnel linings and backing, and 3D linear shells to represent the structure above. The model will represent the following load cases:

   a. Existing building with masonry cross walls and traditional roof with timber floors and residential loading.
   b. Key, worse case, intermittent stages in construction, when loads have been reduced as the demolition progresses.
   c. The completed new building with office and retail loads, new floors and roof

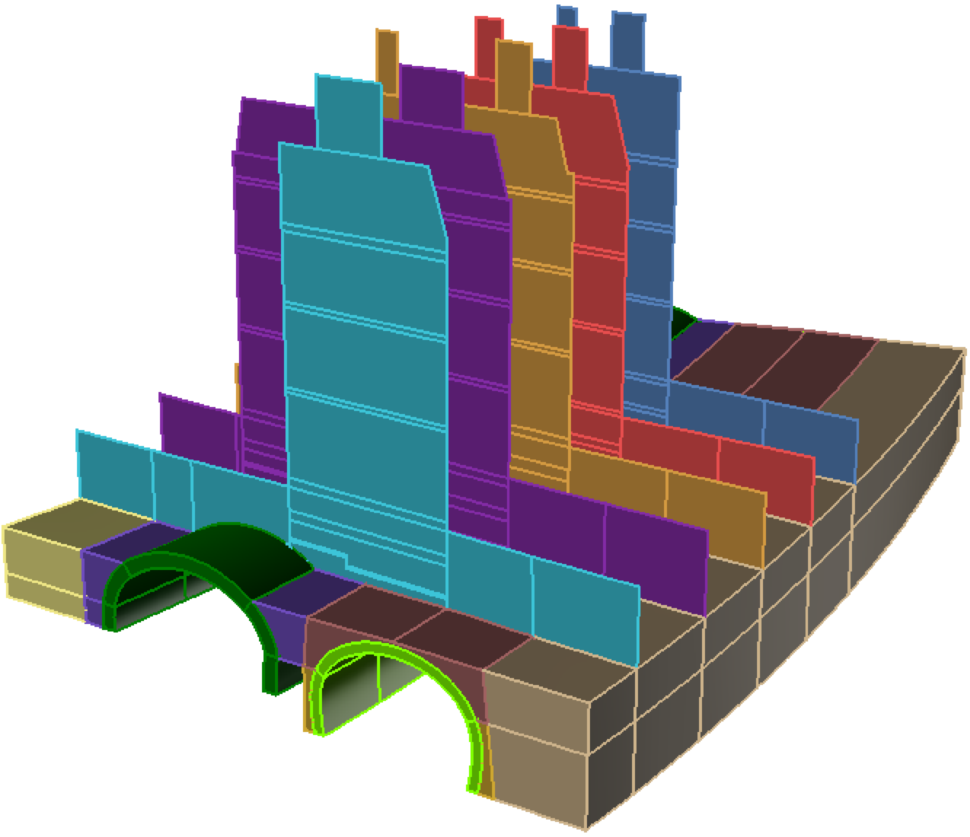


Figure 2 *Coordinated position of tunnels and building*

5.1.3 Stresses

Predicted stresses in the masonry linings will be compared against the masonry characteristic strength. In the absence of any material investigations a lower bound characteristic strength as given in BD 21/01 of 2.5 N/mm^2 is suggested. This is based on brick unit strength of 20 N/mm^2 and 1:3 Lime Mortar joints and which is contemporary with masonry construction of the nineteenth century.

Clearly, predicted stress changes must not result in the tunnel lining masonry exceeding the masonry strength to be acceptable.

5.1.4 Displacements

It is understood that limits on movements to tunnel linings from engineering work on the surface such as building alteration are based on the Deed of Settlement drafted for the London Underground Limited's CTRL works at King's Cross. This deed is concerned with potential building movement arising from tunnelling activities and categorises movement risk, staged assessment and where necessary sets out procedures for compensation. It is concerned with buildings within 30m plan of the tunnel works.

In the deed there are two references to settlement limits summarised as below.

i) In cases where the settlement predicted for a protected property is 5mm or more then an inventory of defects should be made prior to commencement of the tunnelling works.

ii) Any building where the predicted settlement from bored tunnelling is less than 10mm and the predicted slope is less than 1/500 will not be subject to further assessment.

Additionally, building damage classification is categorised according to maximum tensile strain and approximate crack width.

Although this Deed is geared towards tunnel works driving potential damage at the surface it is understood that, for the Lighthouse Building, the same criterion is being used for surface building work influencing existing tunnels. Hence, interpretation of the Deed in this reversed context would suggest that if all predicted tunnel lining displacements remain less than 5mm (Risk Category 0, 0.05% maximum tensile strain, negligible damage, nothing exceeding hairline cracks) levels of settlement are acceptable and further assessment is not required.

TfL will assess the displacement to ensure that it does not interfere with the kinetic envelope for the running of the trains.

6. DRAWINGS AND DOCUMENTS

6.1 List of drawings and other documents accompanying this submission

Drawing/report Number	Title	Year	Originator	
11885/R05	The King's Cross Lighthouse Structural Report	2008	Gifford	Appendix B
11885/02/R03	Tunnel Lining and Foundation Structural Analysis	2006	Gifford	Appendix C
18885-S-001	Basement & Foundation GA	2011	Gifford	Appendix D
18885-S-002	Ground Floor GA	2011	Gifford	Appendix D
18885-S-003	First Floor GA	2011	Gifford	Appendix D
18885-S-004	Second Floor GA	2011	Gifford	Appendix D
18885-S-005	Third Floor GA	2011	Gifford	Appendix D
18885-S-006	Fourth Floor GA	2011	Gifford	Appendix D
18885-S-007	Roof Layout	2011	Gifford	Appendix D

18885-S-009	Roof Sections Sheet 1	2011	Gifford	Appendix D
18885-S-010	Roof Sections Sheet 2	2011	Gifford	Appendix D
18885-S-015	Isometric Views	2011	Gifford	Appendix D

7. REFERENCES

The geometrical relationship of the foundations to the tunnel linings necessary for structural analysis and numerical modelling has been based on the following information.

Drawing/report Number	Title	Year	Originator
11.6713	Trial hole Investigation Report (Included in Appendix A)	2011	Constructive Evaluation
23008-001F-01A	Trial hole survey	2011	Plowman Craven
Lighthouse.ptx	Exterior Building Laser Scan	2011	Plowman Craven
SU-ABA-210120-001-R00	3d Tunnels survey	2010	ABA Surveying
4821/01 Rev C	Basement Floor Plan	2011	Michael Gaille
4821/02 Rev D	Ground Floor Plan	2011	Michael Gaille

8. ACCEPTANCE

8.1 Acceptance

The above is submitted for acceptance

Signed	Title: Associate
Name (Print): J A Heath CEng MICE	Date 04.08.2011
To be signed by the Assessor responsible for the Assessment to AIP stage or other person authorised to sign on behalf of the organisation responsible for the Assessment	

8.2 Acceptance

The above is agreed subject to the amendments and conditions shown below.

Signed	Title
Name (Print)	Date
To be signed by accredited individual	

APPENDIX A

Trial Hole Report Constructive Evaluation 11.6713

APPENDIX B

The Kings Cross Lighthouse Structural Report 11885 ST R05

APPENDIX C

Tunnel Lining and Foundation Structural Analysis 11885 02 R03

APPENDIX D

Structural Drawings

Title of Scheme: *The Lighthouse Building Kings Cross Triangle*			
Location			
ELR *MCL*	**Mileage** *1mlle 62 Chain*	**OS grid ref.**	**Structure No.**

Part 1: Scheme Details

(Note: relevant information should be given under the headings below. The main headings and their numbering should be used for all submissions unless the Designated Project Engineer directs or permits otherwise. Where a heading is not applicable to a particular submission, "not applicable "or "N/A" should be entered. Where a heading is relevant, suitably numbered sub-headings should be used. Information under additional headings may be necessary for certain Schemes.)

(This form may also be used for Outside Party Works.)

1.1 Network Rail Sponsor

Jakeer Mohammad, Construction Manager, Network Rail, Asset Management (LNE)

1.2 External organisation(s) for whose benefit the Scheme is required

UK Real Estate

1.3 **Proposed date for completion of construction**

Start January 2012, completion mid 2013

1.4 **Organisation responsible for Design to AIP stage**

Gifford, part of Ramboll 76-80 Southwark Street, London, SE1 0PN

1.5 Existing conditions

Kings Cross Triangle Lighthouse Building.

The Lighthouse Building dates from circa 1875 lies over two masonry lined tunnels. The north tunnel was built soon after 1863 for the Northern Railway and is now known as the City Widened Lines Tunnel. It carries Thameslink Network Rail trains. It is owned by Network Rail Limited

The south tunnel was opened in 1863 by the Metropolitan Railway and is known as the Circle Line Tunnel. It carries Metropolitan and Circle underground trains and is owned by London Underground Limited (LU).

A similar and parallel technical approval process is being pursued with TfL for the south tunnel.

1.6 Proposed works

The principles of the scheme is outlined in the structural report 11885 R05 in Appendix B.

Structural Drawings are included as Appendix D

1.7 Alternative solutions to the Remit considered

N/A

1.8 Design criteria (underline bridge)

N/A

Title of Scheme: *The Lighthouse Building Kings Cross Triangle*			
Location			
ELR *MCL*	**Mileage** *1mlle 62 Chain*	**OS grid ref.**	**Structure No.**

1.9 Design criteria (overline bridge)
N/A

1.10 Design criteria (footbridge)
N/A

1.11 Design criteria (equipment support structure)
N/A

1.11 **Design criteria (soil-retaining structure)** *(except where part of a bridge structure)*
N/A

1.12 Design criteria (Station platform)
N/A

1.13 Design criteria (Station canopy or building)
N/A

1.14 Design criteria (Earthwork)
N/A

1.15 Design criteria (other Structures)
See below

1.16 Design criteria (Permanent Way)
N/A

1.17 Design life
60 years

1.18 Organisation proposed to be responsible for detailed Design
Gifford, part of Ramboll 76-80 Southwark Street, London, SE1 0PN

1.19 Design standards
British Standards, incorporating the latest amendments and corrigenda, as called up by NR/GN/CIV/025 Issue 3 June 2006 and summarised as follows

British Standards, incorporating the latest amendments and corrigenda,

Title of Scheme: *The Lighthouse Building Kings Cross Triangle*			
Location			
ELR *MCL*	**Mileage** *1mlle 62 Chain*	**OS grid ref.**	**Structure No.**

Highways Agency. Design Manual for Roads and Bridges, BD 21/01, The Assessment of highway bridges and structures, August 2001

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British Standards Institution.1996. BS 6399 Loading for Buildings Inc amendment No 1

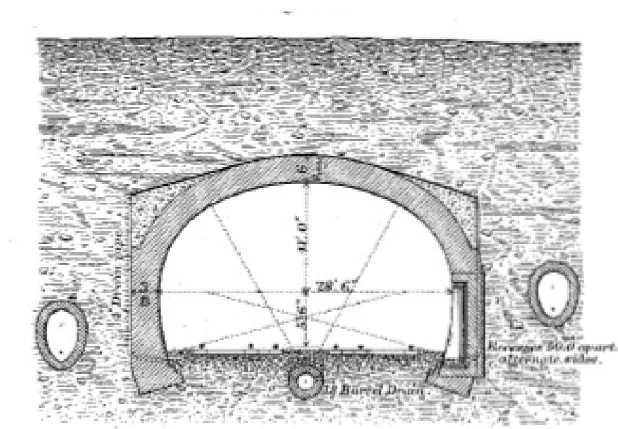
British Standards Institution. 2002. BS 5628-1:1992, Code of practice for use of masonry, Part 1: Structural use of unreinforced masonry.

1.20 Departures from Design standards (with justification)

None

1.21 Geotechnical considerations

Foundations assumed to be stepped brick footings. The modelled foundations will be based on The Institution of Civil Engineering. Minutes of Proceedings. Volume 81, Issue 1885, pages 1 - 33 "The Metropolitan and Metropolitan District Railways." By Benjamin Baker, which notes the footings are 4feet wide with no concrete beneath. As shown in the image below from this paper:



METROPOLITAN RAILWAY.
TYPE SECTION OF COVERED WAY.

Figure 1 Drawing showing assumed foundation construction (note this does not show the second tunnel or Lighthouse building over)

Geotechnical conditions are Made Ground lying over directly overlying the London Clay. A more detailed assessment will be derived from the above paper, trial holes excavated to the tops of the tunnel (Constructive Evaluation Report 11.6713 included in Appendix A) and bore hole date in the area from the British Geological Society boreholes close to the site.

Title of Scheme: *The Lighthouse Building Kings Cross Triangle*			
Location			
ELR *MCL*	**Mileage** *1mlle 62 Chain*	**OS grid ref.**	**Structure No.**

1.22 **Design statement** *(Describe the methodology to be adopted to execute the Design.)*

Methods of Analysis proposed for the superstructure, substructure and foundations

Objectives

The principal objectives of the tunnel lining and foundation structural analyses are as follows:

i) To predict likely displacements (settlement) that may result in the two tunnel linings arising from proposed alterations in the building. In terms of structural engineering, it is expected that most of the existing diaphragm walls will be removed from the ground floor up, being replaced by some columns. It is understood that details of this refurbishment have not yet been finalised.

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In 2006 a preliminary 2D Finite Element model was undertaken (see appendix C) to give an initial understanding of the building - tunnel interactions. Further, more accurate, information regarding the proposed design and loads from the building (drawings appendix D), the position of the tunnels (from surveys) and the tunnel construction (based on trial holes appendix A and research) mean that a more accurate 3D analysis will now be undertaken.

Loading

Live loading from highway load and rail loads will be not be considered because these remain unchanged.

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Title of Scheme: *The Lighthouse Building Kings Cross Triangle*			
Location			
ELR *MCL*	**Mileage** *1mlle 62 Chain*	**OS grid ref.**	**Structure No.**

Analysis Method

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c. The completed new building with office and retail loads, new floors and roof

Title of Scheme: *The Lighthouse Building Kings Cross Triangle*			
Location			
ELR *MCL*	Mileage *1mlle 62 Chain*	OS grid ref.	Structure No.

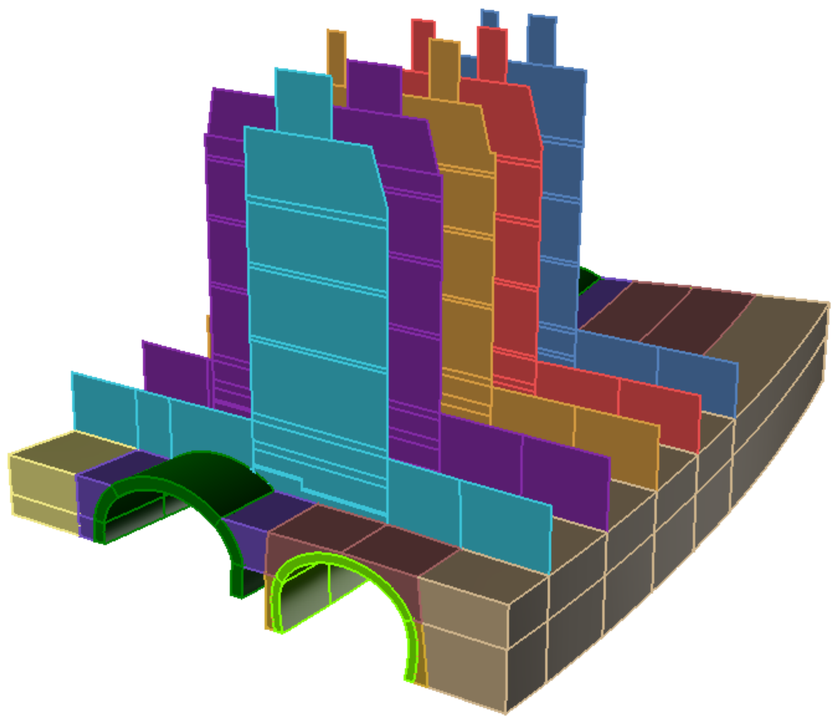

Figure 2 *Coordinated position of tunnels and building*

Stresses

Predicted stresses in the masonry linings will be compared against the masonry characteristic strength. In the absence of any material investigations a lower bound characteristic strength as given in BD 21/01 of 2.5 N/mm^2 is suggested. This is based on brick unit strength of 20 N/mm^2 and 1:3 Lime Mortar joints and which is contemporary with masonry construction of the nineteenth century.

Clearly, predicted stress changes must not result in the tunnel lining masonry exceeding the masonry strength to be acceptable.

Displacements

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Title of Scheme: *The Lighthouse Building Kings Cross Triangle*			
Location			
ELR *MCL*	**Mileage** *1mlle 62 Chain*	**OS grid ref.**	**Structure No.**

In the deed there are two references to settlement limits summarised as below.

i) In cases where the settlement predicted for a protected property is 5mm or more then an inventory of defects should be made prior to commencement of the tunnelling works.

ii) Any building where the predicted settlement from bored tunnelling is less than 10mm and the predicted slope is less than 1/500 will not be subject to further assessment.

Additionally, building damage classification is categorised according to maximum tensile strain and approximate crack width.

Although this Deed is geared towards tunnel works driving potential damage at the surface it is understood that, for the Lighthouse Building, the same criterion is being used for surface building work influencing existing tunnels. Hence, interpretation of the Deed in this reversed context would suggest that if all predicted tunnel lining displacements remain less than 5mm (Risk Category 0, 0.05% maximum tensile strain, negligible damage, nothing exceeding hairline cracks) levels of settlement are acceptable and further assessment is not required.

NWR will assess the displacement to ensure that it does not interfere with the kinetic envelope for the running of the trains.

1.23 Accompanying drawings and other documents

List of drawings and other documents accompanying this submission

Drawing/report Number	Title	Year	Originator	
11885/R05	The King's Cross Lighthouse Structural Report	2008	Gifford	Appendix B
11885/02/R03	Tunnel Lining and Foundation Structural Analysis	2006	Gifford	Appendix C
18885-S-001	Basement & Foundation GA	2011	Gifford	Appendix D
18885-S-002	Ground Floor GA	2011	Gifford	Appendix D
18885-S-003	First Floor GA	2011	Gifford	Appendix D
18885-S-004	Second Floor GA	2011	Gifford	Appendix D
18885-S-005	Third Floor GA	2011	Gifford	Appendix D
18885-S-006	Fourth Floor GA	2011	Gifford	Appendix D
18885-S-007	Roof Layout	2011	Gifford	Appendix D

Title of Scheme: *The Lighthouse Building Kings Cross Triangle*			
Location			
ELR *MCL*	**Mileage** *1mlle 62 Chain*	**OS grid ref.**	**Structure No.**

18885-S-009	Roof Sections Sheet 1	2011	Gifford	Appendix D
18885-S-010	Roof Sections Sheet 2	2011	Gifford	Appendix D
18885-S-015	Isometric Views	2011	Gifford	Appendix D

1.24 **Any other relevant information** *(Give information as appropriate.)*

The geometrical relationship of the foundations to the tunnel linings necessary for structural analysis and numerical modelling has been based on the following information.

Drawing/report Number	Title	Year	Originator
11.6713	Trial hole Investigation Report (Included in Appendix A)	2011	Constructive Evaluation
23008-001F-01A	Trial hole survey	2011	Plowman Craven
Lighthouse.ptx	Exterior Building Laser Scan	2011	Plowman Craven
SU-ABA-210120-001-R00	3d Tunnels survey	2010	ABA Surveying
4821/01 Rev C	Basement Floor Plan	2011	Michael Gaille
4821/02 Rev D	Ground Floor Plan	2011	Michael Gaille

Title of Scheme: *The Lighthouse Building Kings Cross Triangle*			
Location			
ELR *MCL*	**Mileage** *1mlle 62 Chain*	**OS grid ref.**	**Structure No.**

(Form A – continued)

Part 2: Designer Submission

I confirm that the applicable criteria specified in Network Rail Company Specification (NR/SP/CIV/003) formerly (RT/CE/S/003) have been considered, and the Design is submitted for Approval in Principle on behalf of *(name and address of organisation responsible for Design to AIP stage)*.

Signed____________________	Title ASSOCIATE
Name (Print) J A HEATH C ENG MICE	Date 8.08.2011
To be signed by the Designer responsible for the Design to AIP stage or other person authorised to sign on behalf of the organisation responsible for the Design.	

Part 3: Construction organisation acknowledgement of submission by a sub-contract Designer

The organisation named in Part 2 is engaged as a sub-contractor to the organisation stated below. I formally acknowledge the submission of this certificate to Network Rail in support of our contract*/sub-contract* obligation for provision of the AIP stage Design on behalf of *(name and address of organisation responsible for Construction Works)*.

(Delete as applicable - further acknowledgement section(s) shall be completed where there is more than one layer of sub-contract relationship. Insert "not required" if a direct contract with Network Rail.)*

Signed	Title
Name (Print)	Date
To be signed by the Contractor's Responsible Engineer or other person authorised to sign on behalf of the organisation responsible for the Construction Work.	

Title of Scheme: *The Lighthouse Building Kings Cross Triangle*			
Location			
ELR *MCL*	**Mileage** *1mlle 62 Chain*	**OS grid ref.**	**Structure No.**

Part 4: Designated Project Engineer comments

I have considered the submission for the above Scheme and confirm that the information specified in Network Rail Company Specification (NR/SP/CIV/003) formerly (RT/CE/S/003) is included in the submission. My comments on the submission are as shown below.

(Notes:

1. *The Design organisation should leave reasonable space for comments here.*
2. *The Designated Project Engineer's comments may be given on a separate sheet of paper or in a covering letter if more convenient. In such cases the comments must be identified clearly with the Scheme and Form A to which they relate and must be signed.)*

Signed	Title
Name (Print)	Date
To be signed by the Designated Project Engineer.	

Title of Scheme: *The Lighthouse Building Kings Cross Triangle*			
Location			
ELR *MCL*	**Mileage** *1mlle 62 Chain*	**OS grid ref.**	**Structure No.**

Form A (continued)

Part 5: Civil Engineer comments

I have considered the submission for Approval in Principle of the above Scheme in order to be satisfied that the Designer has adequately addressed the applicable criteria specified in Network Rail Company Specification (NR/SP/CIV/003) formerly (RT/CE/S/003), and confirm that:

The Design of the permanent works shall be checked as **category** ………. **.** *(Insert 0, I, II or III as appropriate.)*

The Design of the Temporary Works shall be checked as **category** ………. **.** *(Insert 0, I, II or III as appropriate, or delete if not applicable.)*

The Scheme does*/does not* require endorsement by Network Rail's Professional Head of Track*/Structures* Engineering in accordance with Network Rail Company Specification (NR/SP/CIV/003) formerly (RT/CE/S/003).

(Delete as applicable. *Part 7 of Form A is to be completed where endorsement is required.)*

My comments on the submission are as shown below. Provided these comments are adequately addressed, I hereby give Approval in Principle to the Scheme.

(Notes:
1. *The Design organisation should leave reasonable space for comments here.*
2. *The Civil Engineer's comments may be given on a separate sheet of paper or in a covering letter if more convenient. In such cases the comments must be identified clearly with the Scheme and Form A to which they relate and must be signed.)*
3. *The "comments" space and signature box must be repeated where more than one person is to sign, with a clear statement as to who is signing for what (e.g. for a Property Scheme, a non-technical person might sign for items (a), (b), (c) and (m) in Clause 6.4.1 and the Civil Engineer for the other items).*
4. *In the case of equipment-supporting Structures, insertion of an additional signature box is recommended, with suitable wording to record acceptance by or on behalf of the Asset Engineer for the relevant equipment (see Clause 6.5.3).*

Signed	Title
Name (Print)	Date
To be signed by the Civil Engineer.	

Signed	Title
Name (Print)	Date
To be signed by other responsible person *(if applicable)*.	

Title of Scheme: *The Lighthouse Building Kings Cross Triangle*			
Location			
ELR *MCL*	**Mileage** *1mlle 62 Chain*	**OS grid ref.**	**Structure No.**

(Form A – Continued)

Part 6: Asset Engineer Endorsement (Schemes for existing infrastructure only)

I have considered the submission for the above Scheme and confirm that the information specified in Network Rail Company Specification (NR/SP/CIV/003) formerly (RT/CE/S/003) is included in the submission. My comments on the submission are as shown below.

(Notes:
1. *The Design organisation should leave reasonable space for comments here.*
2. *The Asset Engineer's comments may be given on a separate sheet of paper or in a covering letter if more convenient. In such cases the comments must be identified clearly with the Scheme and Form A to which they relate and must be signed.)*

Signed	Title
Name (Print)	Date
To be signed by the Asset Engineer.	

Part 7: Endorsement by Network Rail Professional Head of Track*/Structures* Engineering *(* Delete as applicable.)*

I have considered the submission for Approval in Principle of the above Scheme as required by Network Rail Company Specification (NR/SP/CIV/003) formerly (RT/CE/S/003) in order to be satisfied that the applicable criteria specified in Network Rail Company Specification (NR/SP/CIV/003) formerly (RT/CE/S/003) have been adequately addressed by the Designer, and my comments on the submission are as shown below.

Provided these comments are adequately addressed I hereby endorse the Approval in Principle submission.

(Notes:
1. *The Design organisation should leave reasonable space for comments here.*
2. *The Professional Head's comments may be given on a separate sheet of paper or in a covering letter if more convenient. In such cases the comments must be identified clearly with the Scheme and Form A to which they relate and must be signed.)*

Signed	Title
Name (Print)	Date
To be signed on behalf of Network Rail's Professional Head of Track*/Structures* Engineering. *(* Delete as applicable.)*	