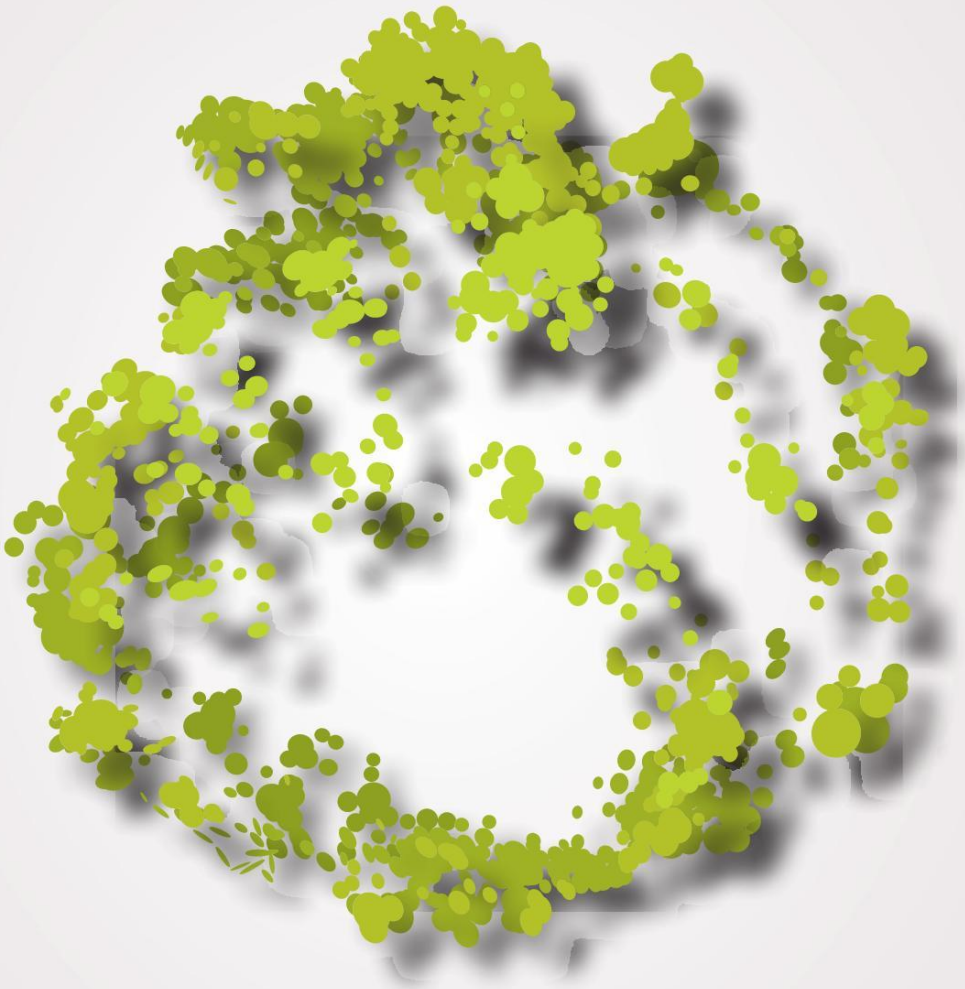

4190- The Fitzrovia

Ground Movement Assessment due to Crossrail 2 construction

Rev 0 - March 2021

Consulting Structural and Civil Engineers

Ground Movement Assessment due to CRL 2

PROJECT NAME: The Fitzrovia

PROJECT NO: 4190

DOCUMENT TITLE: Ground Movement Assessment due to Crossrail 2 construction.
DOCUMENT VERSION: Rev 0
PREPARED BY: OH
DATE: March 2021

Contents

Appendices

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Revision	**Date**	**Status**
Prepared by:	Olivia Houghton, Design Engineer	
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Approved by:	Dimitrios Selemetas, Technical Director	

1. INTRODUCTION

This document has been produced by AKT II on behalf of our Client – M&G Real Estate Limited – to summarise the proposed works for The Fitzrovia, above one of the new Crossrail 2 tunnels running below the site and the analysis undertaken to establish the effect of tunnelling onto the structure.

This document is intended to provide information on the influence of Crossrail 2 tunnelling onto the The Fitzrovia site. The ground movement analysis undertaken will show the settlement induced by the proposed Crossrail 2 tunnels onto the building and asses the building damage category.

The site is located between Goodge Street and Tottenham Court Road stations. The site is bounded by Tottenham Court Road to the west, Bayley Street to the north, Morwell Street to the east and retail and residential buildings to the south.

The site occupies approximately 1800m^2. The National Grid reference for the site is TQ 29749 81552, Latitude 51.517996 and Longitude -0.13139770. The post code is W1T 7QZ.

Figure 1 shows the location of the site together with the reference to the proposed alignment of the Crossrail 2 bored tunnel.

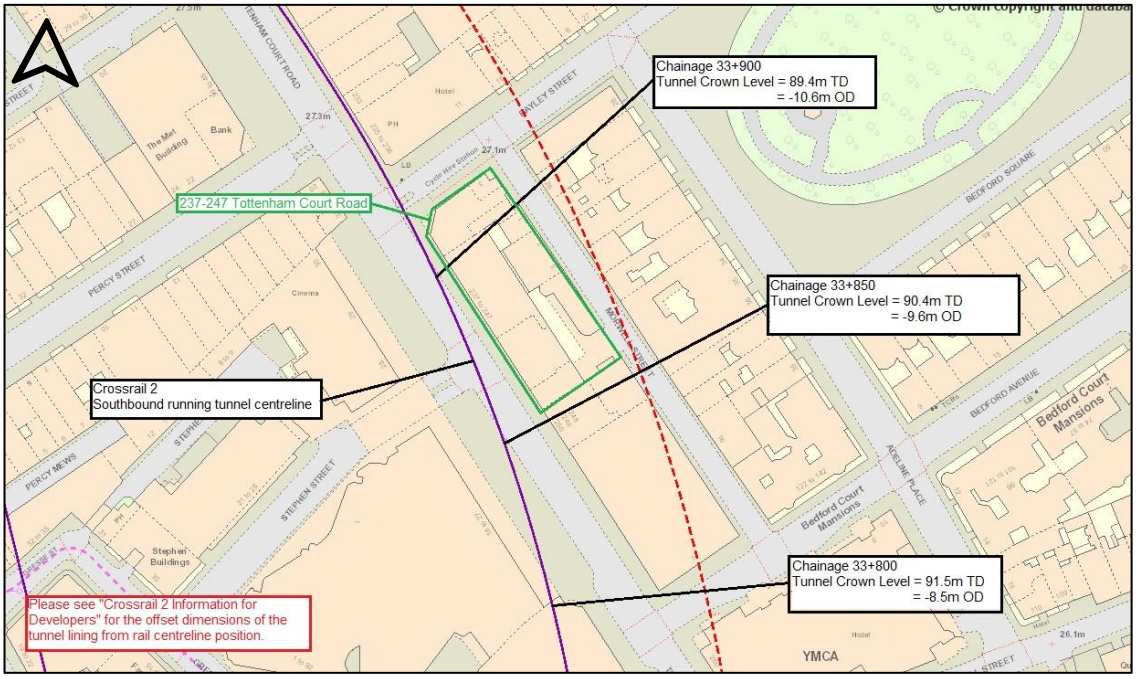


Figure 1: Site Location Plan

2. PROPOSED SCHEME

The site is currently occupied by multi-storey offices and retail stores. The existing ground level varies from North to South from approximately +27.5mOD to +26.9mOD respectively. Throughout the site an existing basement has been assumed down to approximately +24.1mOD. The proposed development comprises of a multi-storey building of mixed uses. An extension of the existing basement (to approximately +22.2mOD) is currently proposed for most of the site and an additional two levels of basement (to approximately +17.2mOD) are currently considered for the rest of the site. The redevelopment is proposed to be founded on a raft foundation. An embedded piled retaining wall is currently proposed to extend to 5m below the maximum basement level to a maximum of around +12mOD to satisfy stability requirements based on preliminary calculations. It is assumed that 2 props will be used at the double basement and a single prop will be used for the single basement. Whilst the piling works have been assumed to be carried out from existing ground level, the excavation works have been assumed to be carried out from existing basement level. Detailed temporary works arrangements shall be confirmed with a competent Contractor as the scheme progresses further.

The proposed basement layout is presented in Figure 2 and a section showing the tunnel below the site relative to the basement is presented in Figure 3.

The future Crossrail 2 asset consists of twin bore running tunnels with the southbound tunnel approximately 11m below the site. The northbound tunnel is located further to the west and its zone of influence is not considered to reach the proposed development, therefore not assessed. The tunnel closest to the site that is being assessed runs along the southwestern boundary of the site in a southeast to northwest direction. Any temporary works associated with the stability of the ground, and/or adjacent building, and/or infrastructure required as a result of the demolition/construction works are outside the scope of the current assessment, and hence not covered in this report.

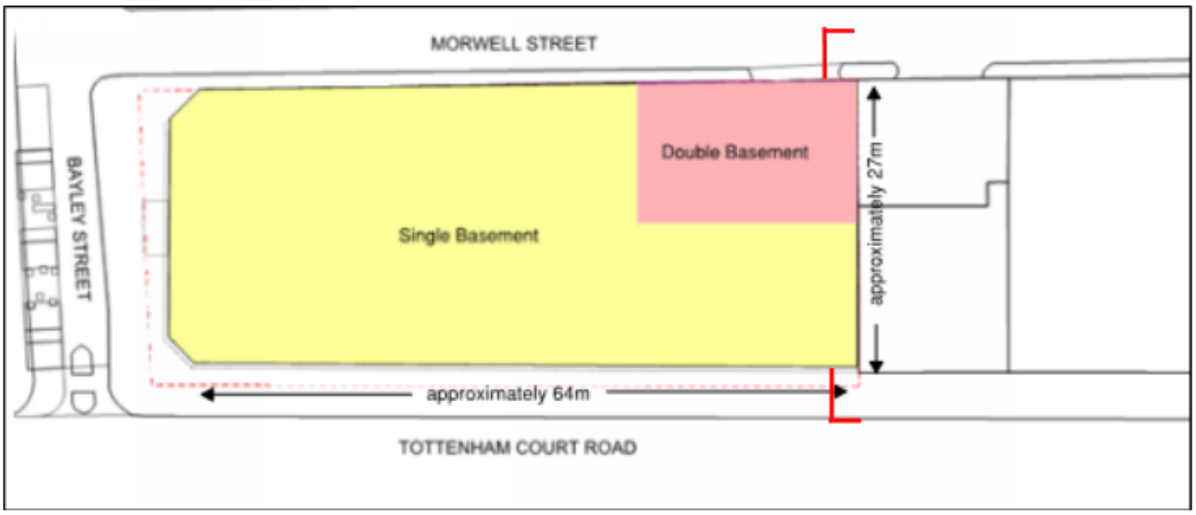


Figure 2: Proposed basement layout

The site is located in close proximity to buildings to the south that contain retail at low level with office and residential use above. It is understood this building also incorporates one basement level.

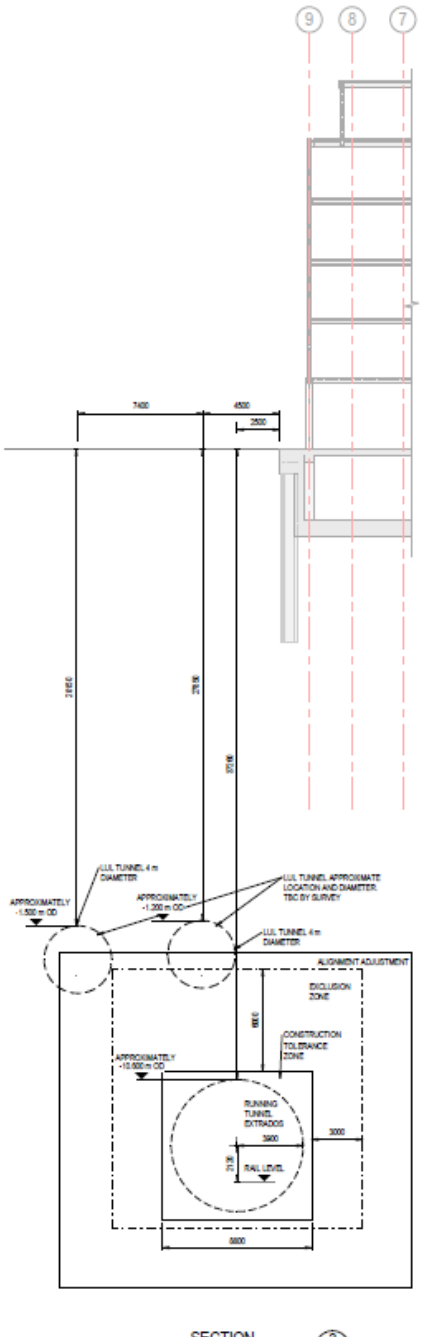


Figure 3: Crossrail tunnel relative to the proposed building

3. GROUND MODEL & ANALYSIS PARAMETERS

3.1 GROUND MODEL

A ground model and a set of geotechnical parameters have been put together using publicly available information (BGS archive), information from nearby sites and draft borehole log information from the recent preliminary Site Investigation carried out by Geotechnical and Environmental Associates (GEA) in October 2020.

The ground conditions on site are expected to follow the typical London geology with Made Ground underlain by River Terrace Deposits, London Clay, Lambeth Group, Thanet Sand and Chalk.

The ground model and the assumed geotechnical parameters used in the analysis are summarised in Table 1.

Table 1: Summary of Ground Conditions

Soil type	Top of Stratum level (mOD)	Undrained Young's Modulus	Drained Young's Modulus
		Eu (MPa)	E' (MPa)
Made Ground	27.2	-	10000
Lynch Hill Gravel	22	-	40000
London Clay	19	30000+3000z	24000+2400z
Lambeth Group	-6	200000	160000
Thanet Sand	-16	-	300000

Notes:

- E' = 0.8Eu, for cohesive soils, following elasticity theory.
- Assumed global Poisson's ratio 0.5 and 0.2 for undrained and drained analysis respectively.
- z refers to m below top of stratum.
- The basement level used for the ground movement analysis is +22.2mOD

3.2 PARAMETERS FOR SETTLEMENT ANALYSIS

To undertake the ground movement assessment due to tunnelling the following parameters were adopted:

- Overall Tunnel Diameter: 7.8m (CRL2 Information for Developers)
- Depth of tunnel axis to foundation: 15m (AKT AIP V6)
- Volume Loss due to TBM tunnelling: 1.2% (CRL2 Information for Developers)
- K parameter for soil at tunnel level: 0.5

4. PHILOSOPHY & ANALYSIS

4.1 PHILOSOPHY

The ground movement analysis for The Fitzrovia Development due to construction of the proposed Crossrail 2 Tunnel presented in Figure 1 has been undertaken using Oasys XDisp 20.1 software that uses the Gaussian curve distribution and includes the 3D effect with the longitudinal settlement trough present in front of the tunnel during excavation. The settlements calculated are all greenfield and do not take into account any effects of the building foundation stiffness. The tunnels are more than 2D apart therefore no increase in volume loss for the second tunnel excavation was included.

Three analyses were conducted to account for the effects of simplified staged excavation of the tunnel on the proposed building. The analyses included the following:

1. Tunnel T1 fully excavated
2. T1 partially excavated - SE end (includes an S wave longitudinal settlement in front of the tunnel)
3. T1 partially excavated - NW end (includes an S wave longitudinal settlement in front of the tunnel)

These analyses capture the effects of both the transverse and longitudinal settlement curves, caused by the excavation of the proposed Crossrail 2 bored tunnel, on the newly constructed building.

Based on the above listed analyses a building damage assessment has been carried out in Oasys XDisp 20.1 according to the Burland Building Damage Assessment.

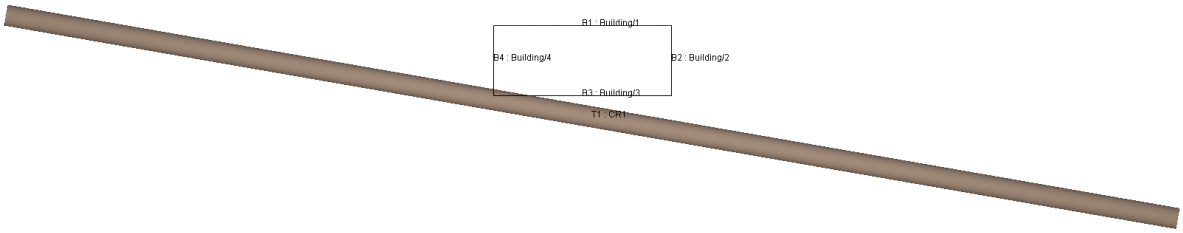
4.2 ANALYSIS

The ground movement analyses listed in the section above were undertaken to better understand the settlement profile under the building due to excavation of the proposed Crossrail 2 tunnel. The three geometry configurations of tunnels were analysed and are presented in Figure 4.

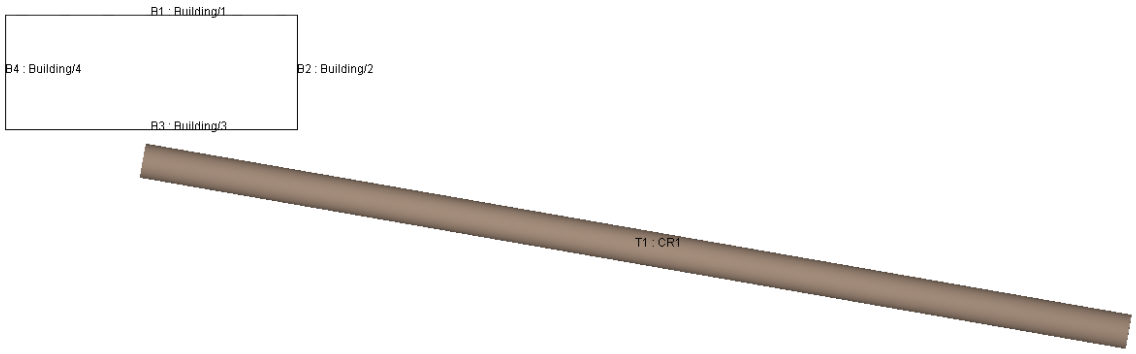
The first analysis contains the fully constructed tunnel under the building, that creates a settlement trough with the highest movement above the axis tunnel. The second and third analyses incorporates the tunnel excavated halfway through the building. This configuration creates a three-dimensional settlement as the longitudinal settlement trough is also present.

The range of analyses aim to find the worst-case scenario for the building damage assessment described in Section 6.

Analysis 1 = Fully constructed



Analysis 2 = 0.5 Tunnel (SE end)



Analysis 3 = 0.5 Tunnel (NW end)

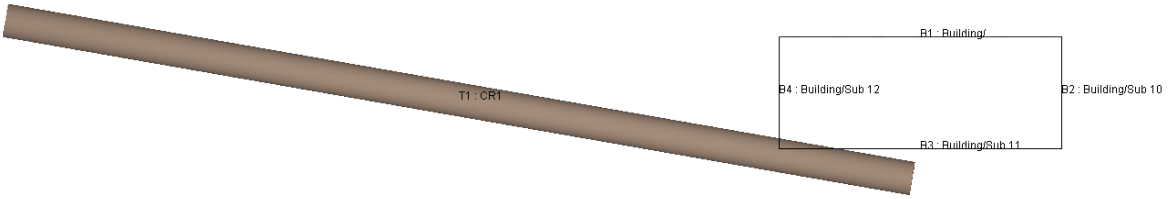


Figure 4: Summary of analyses types.

5. RESULTS

The analyses undertaken resulted in settlement troughs presented in Figure 5 to Figure 8. The maximum settlement predicted due to Crossrail 2 tunnelling construction is 13.8mm located above the tunnel axis.

Analysis 1 shows that the highest settlement of 13.4mm is located at the northwest corner of the building which is the closest to the tunnel. The middle of the building experiences movements ranging from 2.5mm to 10mm and the southeast corner furthest from the tunnel experiences the lowest movements ranging from 0 – 2.5mm.

In Analysis 2 where half the tunnel is constructed starting from the southeast corner and stops within the middle of the building the highest settlement is approximately 10mm in the south-eastern corner. The middle of the building experiences a settlement of around 2mm with the eastern side becoming 0mm.

Analysis 3 is similar to Analysis 2 where only half the tunnel is constructed however, it starts from the middle of the building and runs in the northwest corner. The highest settlement of 13.4mm is located at the northwest corner of the building which is the closest to the tunnel. With the middle of the building experiencing similar movement to Analysis 2.

These results inform the building damage assessment described in the next section.

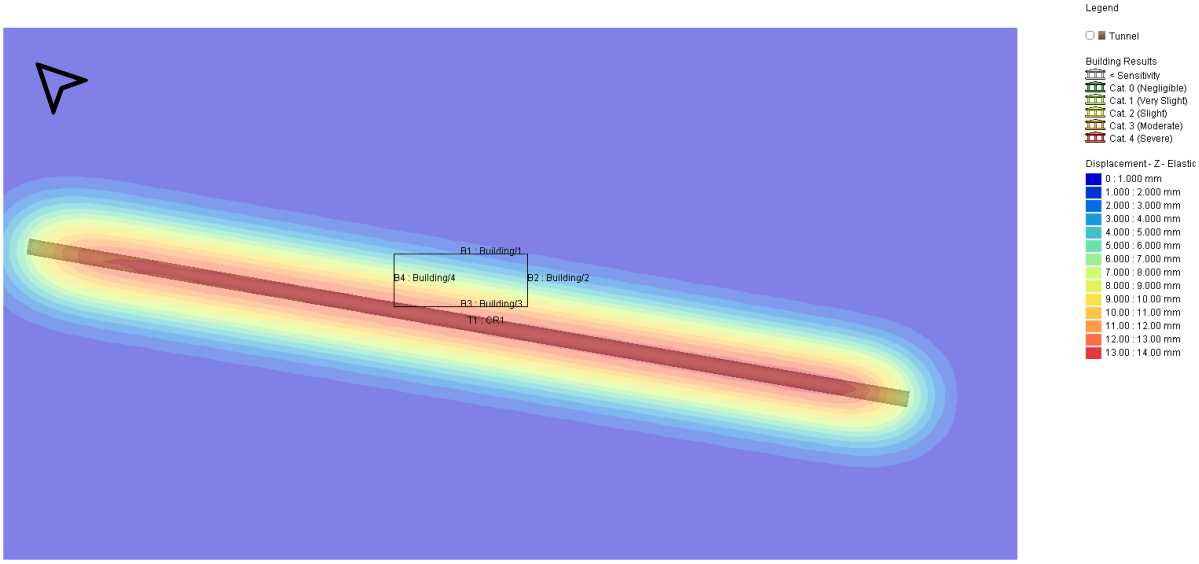


Figure 5: Analysis 1 - Displacement results for the fully excavated tunnel

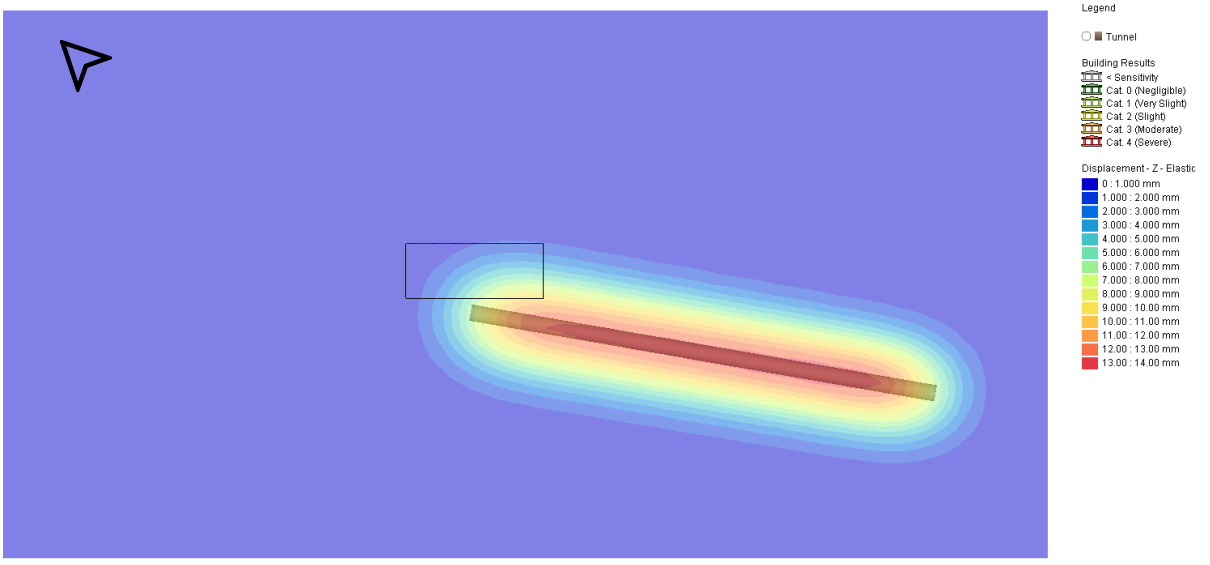


Figure 6: Analysis 2 displacement results 0.5 tunnel (SE end)

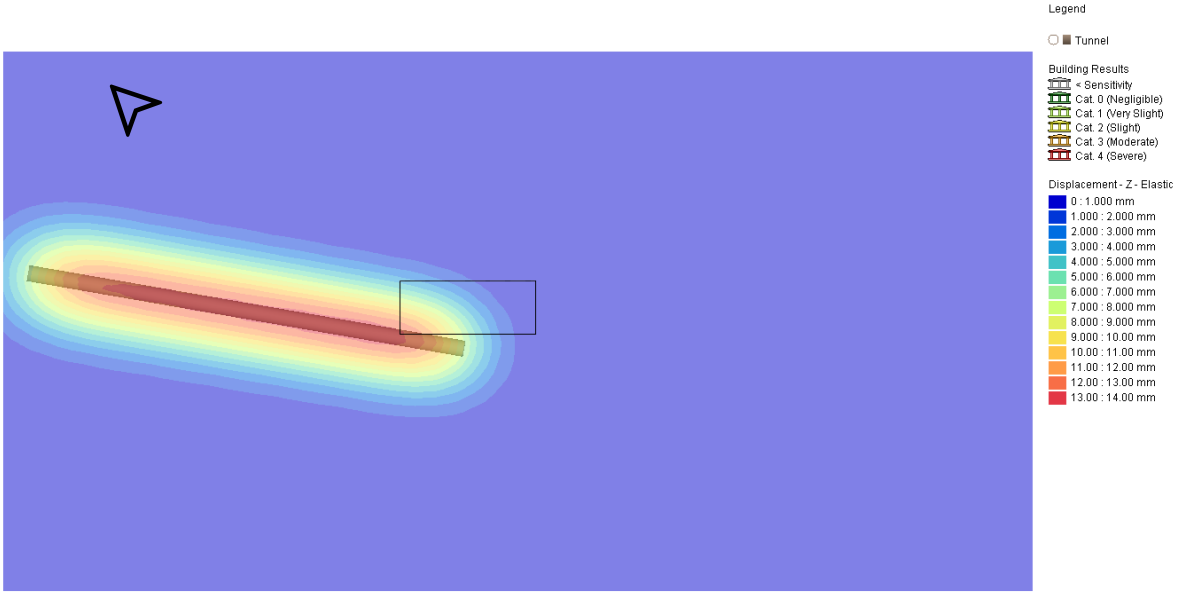


Figure 7: Analysis 3 displacement results for 0.5 tunnel (NW end)

6. BUILDING DAMAGE ASSESSMENT

The building damage assessment has been undertaken based on the movements presented above. The perimeter walls of the building were defined and the height of 25m was assigned to the structure from B1 level.

4No. walls were identified for the assessment and are presented in Figure 8. Each of these walls were assessed in XDisp separately to calculate the displacement and then strains on which basis the Burland's damage category is assigned.

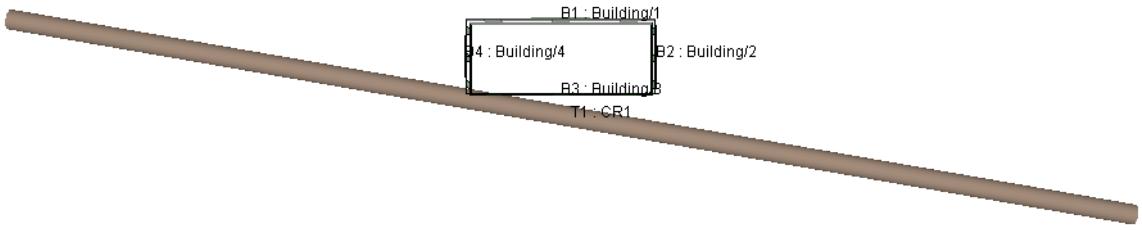


Figure 8: 247 The Fitzrovia walls identified for the building damage assessment.

For each of the three analysis scenarios a building damage assessment was undertaken and predicted negligible damage category due to proposed Crossrail 2 tunnel excavation. A summary for each analysis is presented in Table 2 to Table 5. A graphical output of the damage assessment results is presented in Appendix A.

Table 2: Analysis 1 - Building Damage Assessment Summary of Critical Segments

Sub-building Name	Deflection Ratio	Average Horizontal Strain	Max Slope	Max Settlement	Max Tensile Strain	Max Gradient of Horizontal Displacement Curve	Max Gradient of Vertical Displacement Curve	Min Radius of Curvature (Hogging)	Min Radius of Curvature (Sagging)	Damage Category
	[%]	[%]		[mm]	[%]			[m]	[m]	
1	5.82E-04	4.76E-04	6.15E-05	2.9	1.11E-03	-6.27E-06	6.15E-05	-	-	0 (Negligible)
2	8.01E-03	1.54E-02	-6.32E-04	10.7	2.00E-02	-2.13E-04	-6.32E-04	32235	-	0 (Negligible)
3	1.19E-03	-9.30E-04	-1.07E-04	15.3	8.04E-04	1.39E-05	-1.07E-04	-	-	0 (Negligible)
4	6.81E-03	-0.03E-02	6.21E-04	15.3	1.74E-02	4.56E-04	6.21E-04	-	-	0 (Negligible)

Table 3: Analysis 2 - Building Damage Assessment Summary of Critical Segments

Sub-building Name	Deflection Ratio	Average Horizontal Strain	Max Slope	Max Settlement	Max Tensile Strain	Max Gradient of Horizontal Displacement Curve	Max Gradient of Vertical Displacement Curve	Min Radius of Curvature (Hogging)	Min Radius of Curvature (Sagging)	Damage Category
	[%]	[%]		[mm]	[%]			[m]	[m]	
1	6.54E-04	-7.18E-04	-2.55E-05	0.8	7.30E-04	1.22E-05	-2.55E-05	-	-	0 (Negligible)
2	7.34E-03	1.47E-03	-5.96E-04	10.5	1.89E-02	-2.00E-04	-5.96E-04	35071	-	0 (Negligible)
3	6.10E-03	-7.63E-03	3.20E-04	10.9	1.00E-02	1.16E-04	3.20E-04	76569	60962	0 (Negligible)
4	4.10E-05	-3.04E-04	1.26E-05	0.3	2.45E-04	5.76E-06	1.26E-05	-	-	0 (Negligible)

Table 4: Analysis 3 - Building Damage Assessment Summary of Critical Segments

Sub-building Name	Deflection Ratio	Average Horizontal Strain	Max Slope	Max Settlement	Max Tensile Strain	Max Gradient of Horizontal Displacement Curve	Max Gradient of Vertical Displacement Curve	Min Radius of Curvature (Hogging)	Min Radius of Curvature (Sagging)	Damage Category
	[%]	[%]		[mm]	[%]			[m]	[m]	
1	7.05E-04	8.90E-04	6.49E-05	2.7	1.90E-03	-1.42E-05	6.49E-05	-	-	0 (Negligible)
2	9.77E-06	-2.63E-04	-4.24E-06	0.1	5.28E-05	2.79E-06	-4.24E-06	-	-	0 (Negligible)
3	2.67E-03	-8.03E-03	-4.32E-04	15.5	1.39E-02	-1.21E-04	-4.32E-04	55063	57603	0 (Negligible)
4	7.12E-03	-2.76E-02	6.46E-04	15.5	1.88E-02	4.77E-04	6.46E-04	-	-	0 (Negligible)

7. CONCLUSION

The ground movement assessment undertaken calculates the greenfield ground displacements at the level of the basement of The Fitzrovia building due to the proposed Crossrail 2 bore tunnel excavation.

Three Oasys XDisp models were created and analysed with different tunnel excavation stages to incorporate the 3D effect of tunnel excavation and to identify the worst-case scenario for the building damage assessment.

The analyses resulted in a maximum predicted settlement of 13.8mm occurring above the axis of the tunnels. The settlement troughs from the tunnel excavations cover almost entirely the footprint of the new building and therefore the building is subject to differential settlement at different stages of excavation. To check the building will resist these settlements a building damage assessment was conducted.

The building damage assessment for The Fitzrovia was based on the settlement analysis. All the perimeter walls were analysed in XDisp for the three analyses and the results were damage category 0 and therefore, negligible. The risk of Crossrail 2 excavation to damage the new building is considered low.

In conclusion, the ground movement analysis and the building damage assessment showed that the settlements cause low risk to the proposed building.

8. REFERENCES

1. Oasys XDisp 20.1 User's Manual.
2. Crossrail 2 - Information for Developers June 2019

APPENDIX A – Building Damage Assessment Plots

Ground Movement Assessment due to CRL 2

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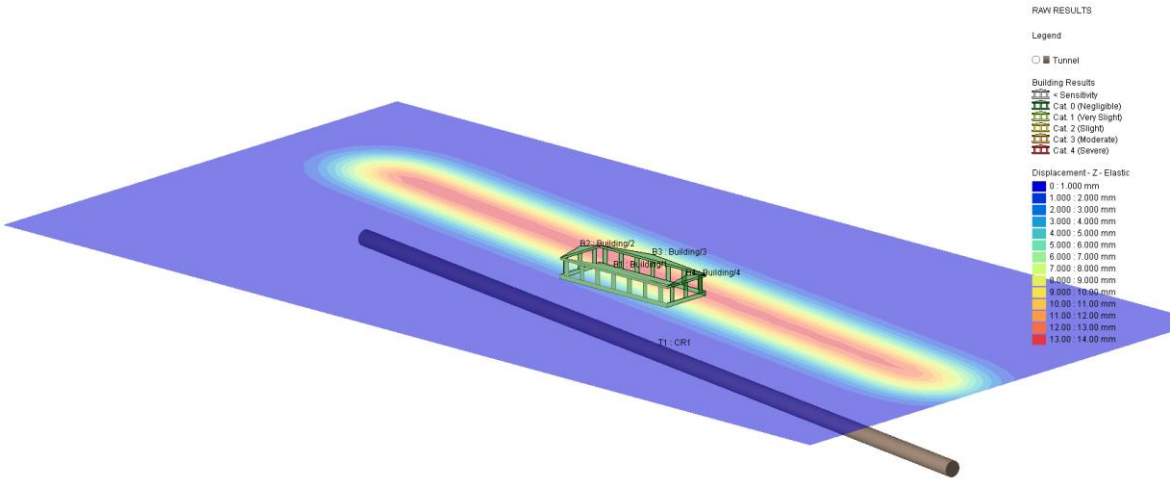
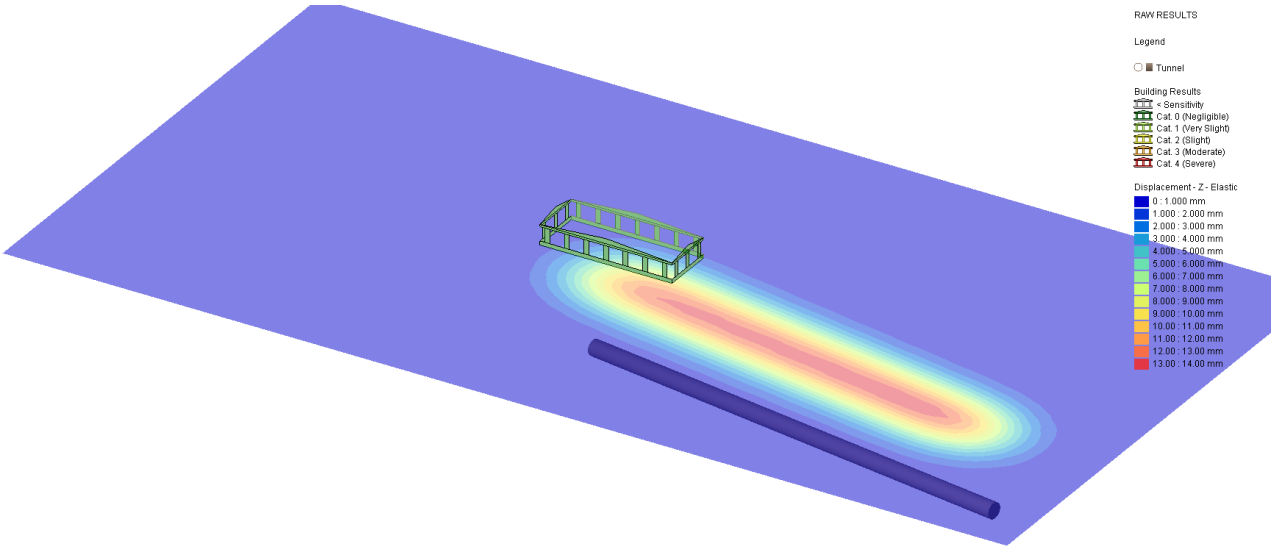


Building Damage Assessment Results for Analysis 1



Building Damage Assessment Results for Analysis 2

Ground Movement Assessment due to CRL 2

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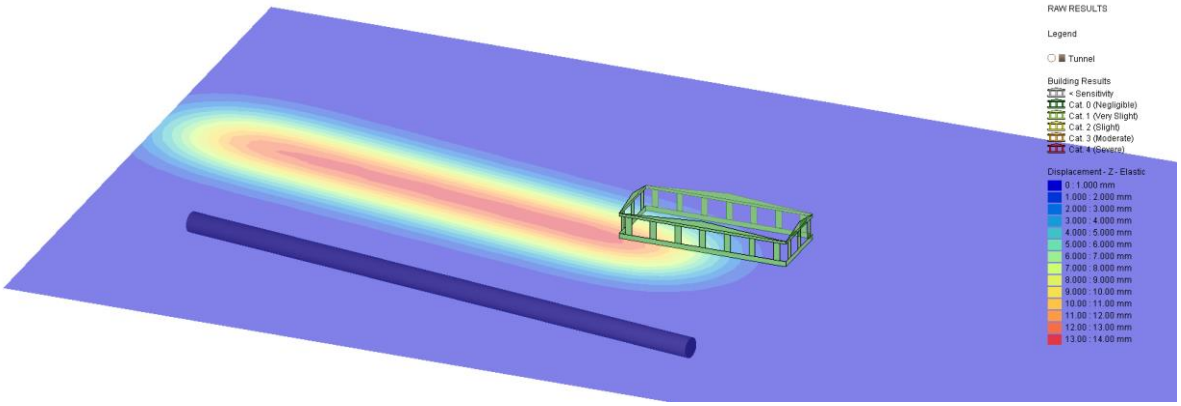

Building Damage Assessment Results for Analysis 3