11.2

(3)

Project Metrolink Railway Order
Estuary to Charlemont via Dublin Airport
(ABP-314724-22)

Oral Hearing

Statement of Evidence

on

Tunnelling Induced Ground Movements & Building Damage Assessment

by Mr. Conor O'Donnell

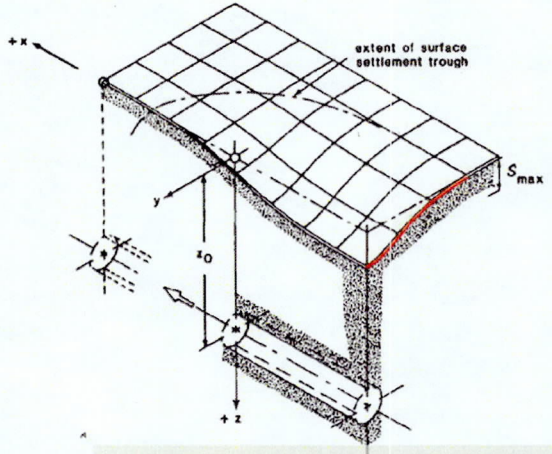
29th February, 2024

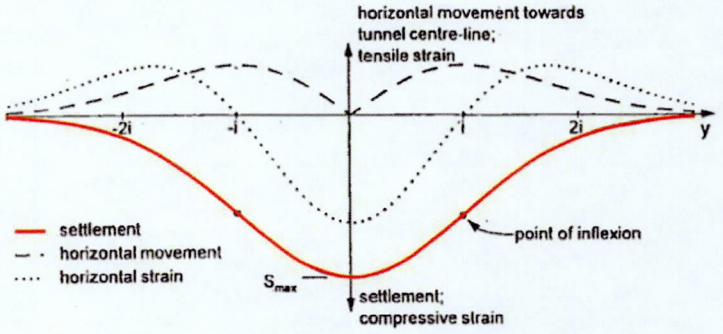
Project Metrolink:
Refined Phase 2a Building Damage Assessment (BDA) for Arthur Cox Building, Earlsfort Terrace

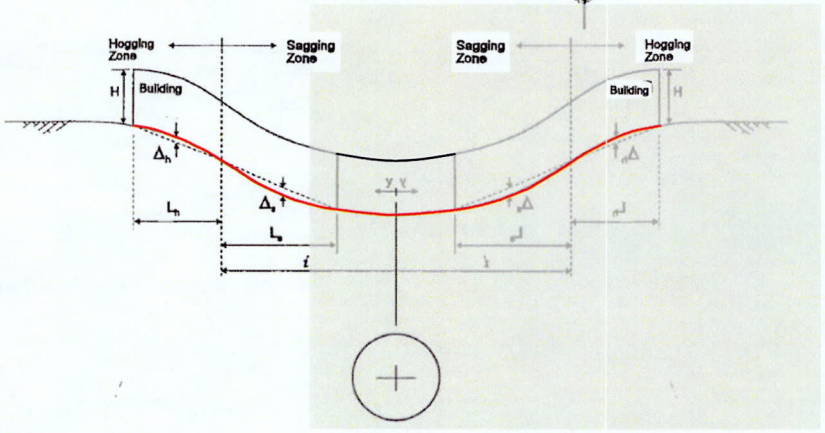
Arthur Cox Building, Earlsfort Terrace

Phase 2a BDA– Arthur Cox Building:

Phase 2a Assessment in Building Damage Report (Appendix A5.17 EIAR):







- Profile of greenfield settlements due to ground loss calculated at building foundation level *("the settlement trough")*
- Building damage assessed as a function of max settlement, ground slope, and the corresponding maximum tensile bending/shear strains due to building distortion.

Phase 2a Assessment in Building Damage Report (Appendix A5.17 EIAR):

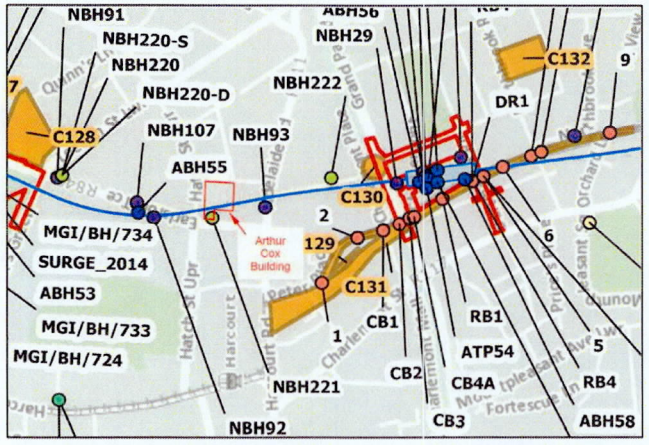


Figure 4-1 Site Investigation Location Plan [from Figure 20.6 (Sheet 7 of 8) in Chapter 20 of the EIAR]

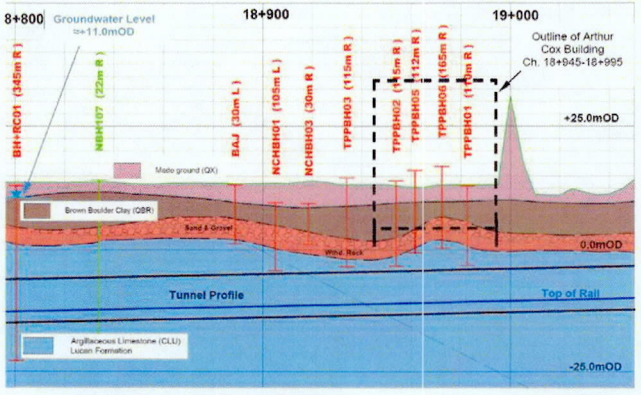


Figure 4-2 Geological Cross-Section [Sheet 26 of 28 from Appendix A20.9 to Chapter 20 of the EIAR]

- Arthur Cox Building (B-238): Case B "Special Building"
  - 8.1m deep basement
  - Height = 40m (7 Floors + 2 Basement Levels)
  - Ch. 18+945 to 18+995 (50m)
- Ground Loss Parameters (Conservative):
  - **0.75%** (Tunnel in rock with >0.5D rock cover): *Ch.18+960 to Ch.18+980*
  - **1.50%** (Tunnel in rock with <0.5D rock cover): *<Ch.18+960 & >Ch.18+980*
  - Trough Width Parameter, **K = 0.40**
- Profile shows building and secant pile wall supported in glacial till over weathered rock.
- Boreholes not included in EIAR – notable omission
- Boreholes NBH-92 and NBH-93 mislabeled or not carried out – no logs.

Phase 2a BDA– Arthur Cox Building: Results (EIAR)

Analysis	Details	Depth to Tunnel Axis (z_o)/ Cover to Foundation Subgrade (m)	Lower Bound (V_l = 0.75%)				
			Lim. (Max) Tensile Strain ε_{tmax} (%)	Max Ground Slope m_{max} (%)	Max Settlement S_{max} (mm)	Risk Category	Degree of Damage
EIAR Results (Jacobs/ Idiom BDA)	Ch. 18+980 Internal RC Structure (incl Basement) Design Vertical Alignment	z_o = 13.4m Cover= 8.7m	-0.09%	0.35%	37	2	Slight

- Carried out @ design tunnel profile based on greenfield settlements at basement level (8.1mBGL) for 40m high building (H)
- Structural properties for a masonry structure (E/G = 2.6) [=Young/s Modulus/Shear Modulus]
- Analysis carried out at lower bound 0.75% ground loss for tunnelling in rock (not stated in BDR)
- Risk Category 2 (Slight Damage) considered to be "Acceptable" threshold of damage => no Refined Phase 2a Analysis required.
- Does not consider raised (or lowered) tunnel profile within proposed Limits of Deviation (LoD)
- Does not consider concentrated foundation loads or likelihood of TBM hitting secant pile wall at original upper limit of vertical LoD.

Building and Structure Damage Classification (after Burland et al (1977) and Boscarding and Cording (1989))					Approximately Equivalent Ground Settlements and Slopes (after Rankin 1988)	
Risk Category	Degree of Damage	Description of Typical Damage and Likely Forms of Repair for Typical Masonry Buildings	Approx. Crack Width (mm)	Limiting Max Tensile Strain (%)	Max Slope of Ground	Maximum Settlement of Building (mm)
0	Negligible	Hairline cracks	<0.1	Less than 0.05		
1	Very Slight	Fine cracks easily treated during normal redecoration. Perhaps isolated slight fracture in building Cracks in exterior brickwork visible upon close inspection	0.1 to 1	0.05 to 0.075	Less than 1:500 (<0.5%)	Less than 10
2	Slight	Cracks easily filled. Redecoration probably required. Several slight fractures inside building. Exterior cracks visible some re-pointing may be required for weather tightness. Doors and windows may stick slightly	1 to 5	0.075 to 0.15	1:500 to 1:200 (0.2-0.5%)	10 to 50
3	Moderate	Cracks may require cutting out and patching. Recurrent cracks can me masked by suitable linings. Re-pointing and possibly replacement of a small amount of extent brickwork may be required. Doors and windows sticking. Utility services may be interrupted. Weather tightness often impaired	5 to 15 or a number of cracks greater than 3	0.15 to 0.3	1:200 to 1:50 (0.5-2.0%)	50 to 75
4	Severe	Extensive repair involving removal and replacement of sections of walls, especially over doors and windows required. Windows and frames distorted. Floor slopes noticeably. Walls lean or bulge noticeably, some loss of bearing in beams. Utility services disrupted.	15 to 25 but also depends on number of cracks	Greater than 0.3	1:200 to 1:50 (0.5-2.0%)	Greater than 75
5	Very Severe	Major repair required involving partial or complete reconstruction. Beams lose bearing, walls lean badly and require shoring. Windows broken by distortion Danger of instability	Greater than 25 but also depends on number of cracks	Greater than 0.3	Greater than 1:50 (>2.0%)	Greater than 75

Wider Effects Report (WER) in Appendix 5.19 of the EIAR

- WER assesses if deviating the tunnel alignment within the proposed Limits of Deviation alters the predicted significant impacts reported in the EIAR
- Original LoD proposed in Article 6 (Deviation) of Part 2 of the Draft Railway Order [6.1(d)]:
  - +5.0m vertically upwards
  - -10.0m vertically downwards
  - ±15.0m on horizontal alignment
- Report gives high level qualitative assessment of impact of implementing LoD for relevant Chapters of the EAIR.
- Notably, building damage due to tunnelling not specifically addressed for Chapter 5 of EIAR [Metrolink Construction Phase]
- i.e. Building Damage Assessment is Appendix A5.17 of the EIAR

Wider Effects Report (WER) in Appendix 5.19 of the EIAR

- Report concludes that raising the tunnel alignment will have
  - "*no potential for significant additional impacts*" in relevant sections of the EIAR (e.g. Soils & Geology.) &
  - "*there would be no change to the required mitigation measures, or to the residual impacts arising from the application of the mitigation measures set out in the EIAR.*"
- Does not include any constraints on raising the vertical alignment under the Arthur Cox Building.
- Does not identify that raising the alignment could have significant adverse impacts on the building – including increased settlements/building damage, or TBM hitting the toe of the secant pile wall.
- Does not properly assess the *positive* impact of lowering the tunnel alignment and the mitigating effect on building damage.
- No constraint on lowering tunnel level at Charlement Station

Refined Phase 2a Building Damage Assessment

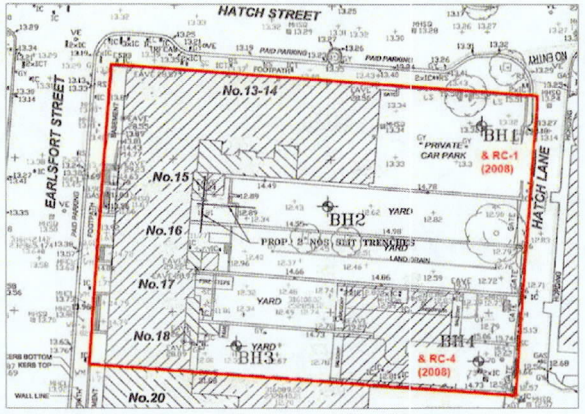


Figure 4-3 SI Location plan for 2008 Ground Investigation for Michael Punch & Partners

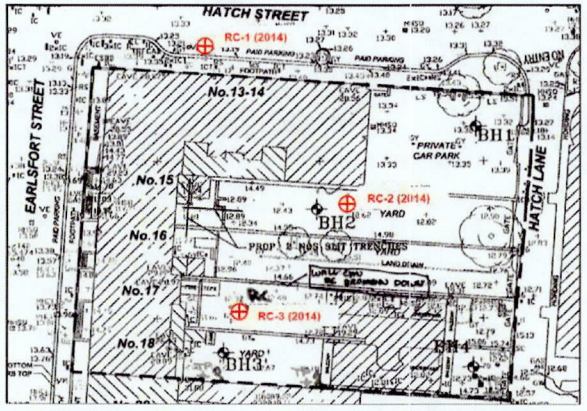
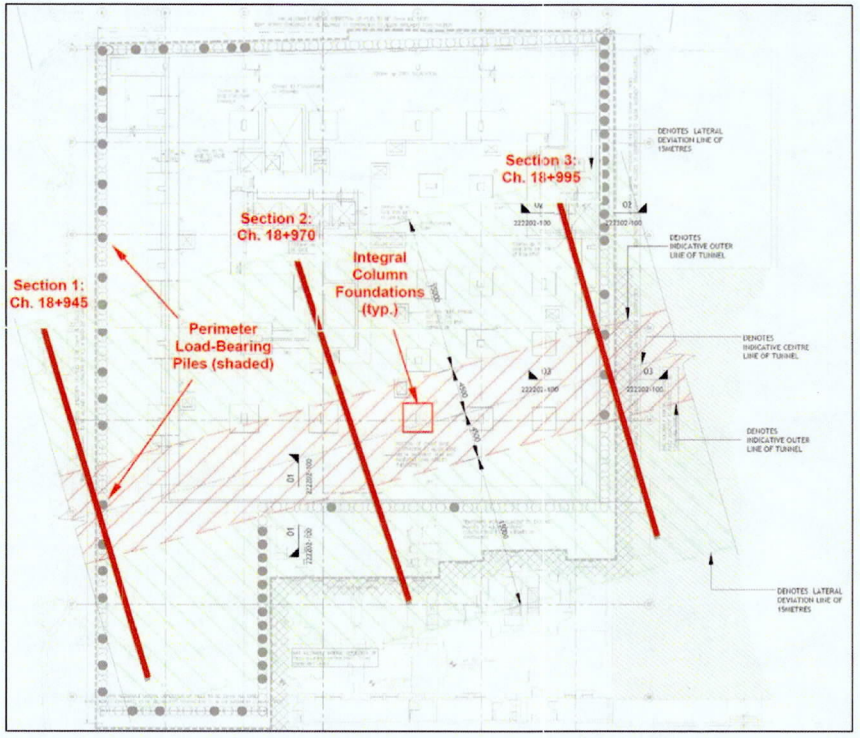


Figure 4-4 SI Location plan for 2014 Supplemental Ground Investigation for Punch Consulting

- Site specific SI information: building is on rock and secant pile wall is socketed 3.5-4.0m into rock below the basement => geological profile in EIAR is incorrect.
- Use *Refined* Phase 2a Ground Loss Parameters from BDR:
  - **0.5%**: Tunnel in rock with >0.5D rock cover
  - **1.0%**: Mixed soil/rock or rock with<0.5D rock cover
- Representative of modern tunnelling equipment & control systems.
- Consistent with experience on Dublin Port Tunnel.
- 0.5% ground loss most relevant to tunnelling in rock under Arthur Cox Building
- Does not account for concentrated foundation loads => calculations for 1.0% ground loss included as upper bound to assess sensitivity of analysis.

Refined Phase 2a BDA– Arthur Cox Building:



**Vertical deviation limited to 3.9m for Section 1 to keep TBM min. 1.0m below toe of secant pile wall*

- 3 No. Sections across building:
  - Section 1 (Ch.18+945): Case 1 - Secant Pile Wall
  - Section 2 (Ch.18+970): Case 2 - Interior RC Frame
  - Section 3 (Ch. 18+995): Case 3 - Basement Floor Slab
- 3 No. Tunnel Profiles
  - Case 1A/2A/3A: Design Profile
  - Case 1B/2B/3B: Raised Profile (+5.0m Max*)
  - Case 1C/2C/3C: Lowered Profile (-5.0m)

	Section 1 Ch. 18+945	Section 2 Ch. 18+970	Section 3 Ch. 18+995
Top of Rail (ToR) Level (mOD)	-11.05mOD	-10.60mOD	-10.15mOD
Tunnel Axis Level (mOD)	-8.98mOD	-8.53mOD	-8.08mOD
Foundation Level (mOD)	+0.65mOD (Pile Toe Level)	+4.80mOD (Slab Subgrade Level)	+4.80mOD (Slab Subgrade Level)
Depth to Tunnel Axis from Foundation Level, z_0 (m)	9.63m	13.33m	12.88m
Tunnel Crown Level (TBM Cutter Head) (mOD)	-4.22mOD	-3.77mOD	-3.32mOD
Clearance to Foundation Subgrade from Tunnel Crown (m)	4.87m	8.57m	8.12m

Refined Phase 2a BDA– Arthur Cox Building: Results (AGL)

Analysis	Details	Depth to Tunnel Axis (z_0)/ Cover to Foundation Subgrade (m)	Lower Bound (V_l = 0.5%)					Upper Bound (V_l = 1.0%)				
			Lim. (Max) Tensile Strain ε_{tmax} (%)	Max Ground Slope m_{max} (%)	Max Settlement S_{max} (mm)	Risk Category	Degree of Damage	Lim.(Max) Tensile Strain ε_{tmax} (%)	Max Ground Slope m_{max} (%)	Max Settlement S_{max} (mm)	Risk Category	Degree of Damage
Design Tunnel Profile												
Case 1A	Ch. 18+945 (Hatch St.) Secant Pile Wall/Bldg. Façade **Design Vertical Alignment**	z_0 = 9.6m Cover= 4.9m	-0.15%	0.58%	37	2/3	Slight to Moderate	-0.30%	1.16%	74	3/4	Moderate to Severe
Case 2A	Ch. 18+970 (Centre) Internal Building RC Frame **Design Vertical Alignment**	z_0 = 13.3m Cover= 8.6m	-0.08%	0.30%	27	2	Slight	-0.16%	0.61%	53	3	Moderate
Case 3A	Ch. 18+995 (South Side) Basement Floor Slab **Design Vertical Alignment**	z_0 = 12.9m Cover= 8.1m	-0.10%	0.32%	28	2	Slight	-0.21%	0.65%	55	3	Moderate
Raised Tunnel Profile (Max. Proposed Vertical Deviation = + 5.0m)												
Case 1B	Ch. 18+945 (Hatch St.) Secant Pile Wall/Bldg. Façade Raised Vertical Alignment (+3.87m)	z_0 = 5.7m Cover= 1.0m	-0.43%	1.63%	62	4/3	Severe to Moderate	-0.85%	3.25%	124	4/5	Severe to Very Severe
Case 2B	Ch. 18+970 (Centre) Internal Building RC Frame Raised Vertical Alignment (+5.0m)	z_0 = 8.3m Cover= 3.6m	-0.20%	0.78%	43	3/2	Moderate to Slight	-0.41%	1.55%	85	4	Severe
Case 3B	Ch. 18+995 (South Side) Basement Floor Slab Raised Vertical Alignment (+5.0m)	z_0 = 7.9m Cover= 3.1m	-0.32%	0.87%	45	3	Moderate	-0.64%	1.74%	90	4	Severe
Lowered Tunnel Profile (Max. Proposed Vertical Deviation = - 5.0m)												
Case 1C	Ch. 18+945 (Hatch St.) Secant Pile Wall/Bldg. Façade Lowered Vertical Alignment (-5.0m)	z_0 = 14.6m Cover= 9.9m	-0.07%	0.25%	24	1/2	Very Slight to Slight	-0.13%	0.50%	49	2	Slight
Case 2C	Ch. 18+970 (Centre) Internal Building RC Frame Lowered Vertical Alignment (-5.0m)	z_0 = 18.3m Cover= 13.6m	-0.04%	0.16%	19	1	Very Slight	-0.08%	0.32%	39	2	Slight
Case 3C	Ch. 18+995 (South Side) Basement Floor Slab Lowered Vertical Alignment (-5.0m)	z_0 = 17.9m Cover= 13.1m	-0.05%	0.17%	20	1	Very Slight	-0.10%	0.34%	40	2	Slight

Building and Structure Damage Classification (after Burland et al (1977) and Boscarding and Cording (1989))					Approximately Equivalent Ground Settlements and Slopes (after Rankin 1988)	
Risk Category	Degree of Damage	Description of Typical Damage and Likely Forms of Repair for Typical Masonry Buildings	Approx. Crack Width (mm)	Limiting Max Tensile Strain (%)	Max Slope of Ground	Maximum Settlement of Building (mm)
0	Negligible	Hairline cracks	<0.1	Less than 0.05		
1	Very Slight	Fine cracks easily treated during normal redecoration. Perhaps isolated slight fracture in building Cracks in exterior brickwork visible upon close inspection	0.1 to 1	0.05 to 0.075	Less than 1:500	Less than 10
2	Slight	Cracks easily filled. Redecoration probably required. Several slight fractures inside building. Exterior cracks visible some re-pointing may be required for weather tightness. Doors and windows may stick slightly	1 to 5	0.075 to 0.15	1:500 to 1:200	10 to 50
3	Moderate	Cracks may require cutting out and patching. Recurrent cracks can me masked by suitable linings. Re-pointing and possibly replacement of a small amount of extent brickwork may be required. Doors and windows sticking. Utility services may be interrupted. Weather tightness often impaired	5 to 15 or a number of cracks greater than 3	0.15 to 0.3	1:200 to 1:50	50 to 75
4	Severe	Extensive repair involving removal and replacement of sections of walls, especially over doors and windows required. Windows and frames distorted. Floor slopes noticeably. Walls lean or bulge noticeably, some loss of bearing in beams. Utility services disrupted.	15 to 25 but also depends on number of cracks	Greater than 0.3	1:200 to 1:50	Greater than 75
5	Very Severe	Major repair required involving partial or complete reconstruction. Beams lose bearing, walls lean badly and require shoring. Windows broken by distortion Danger of instability	Greater than 25 but also depends on number of cracks	Greater than 0.3	Greater than 1:50	Greater than 75

Empirical degree of damage thresholds in table are for masonry structures and are not representative of characteristics of Arthur Cox Building (e.g. façade and basement waterproofing).

Results (RC = Damage Risk Category):

- **Design Tunnel Profile:**
  - Potential for Slight Damage (RC-2) for building & Slight to Moderate Damage (RC-2/3) for secant pile wall and façade (v_l=0.5%) – exceeds building tolerances;
  - Possibly increases to Moderate (RC-3) or Moderate to Severe (RC-3/4) due to concentrated loads, particularly for façade/secant pile wall (v_l=1.0%);
- **Raised Tunnel Profile (+5.0m, or 1.0m below toe secant pile wall):**
  - Potential for Severe (RC-4) or Severe to Very Severe Damage (RC-4/5) due to low cover of rock and building foundations (v_l=1.0%).
  - TBM will hit piles at +4.0m – potential for very severe damage to façade & TBM intervention required.
- **Lowered Tunnel Profile (-5.0m):**
  - Potential damage likely reduces to Very Slight (RC-1) for building & Very Slight to Slight (RC-1/2) for secant pile wall and façade (v_l=0.5%);
  - Potential to comply with limting thresholds of damage for building façade and basement waterproofing system.

Revised Upward Limit of Deviation

- During Oral Hearing – Upward LoD revised by TII to Max. **+1.0m** due to concerns of increased impact on buildings if the original limit was permitted.

  (Ref: Statement of Evidence – Mr. Ronan Hallissey, p7, 19th Feb, 2024)

- No change to Downward or Horizontal LoD.

Refined Phase 2a BDA– Arthur Cox Building: Results (AGL)

Analysis	Details	Depth to Tunnel Axis (z_o)/ Cover to Foundation Subgrade (m)	Lower Bound (V_l = 0.5%)					Upper Bound (V_l = 1.0%)				
			Lim. (Max) Tensile Strain ϵ_{max} (%)	Max Ground Slope m_{max} (%)	Max Settlement S_{max} (mm)	Risk Category	Degree of Damage	Lim.(Max) Tensile Strain ϵ_{max} (%)	Max Ground Slope m_{max} (%)	Max Settlement S_{max} (mm)	Risk Category	Degree of Damage
Design Tunnel Profile												
Case 1A	Ch. 18+945 (Hatch St.) Secant Pile Wall/Bldg. Façade **Design Vertical Alignment**	z_o = 9.6m Cover= 4.9m	-0.15%	0.58%	37	2/3	Slight to Moderate	-0.30%	1.16%	74	3/4	Moderate to Severe
Case 2A	Ch. 18+970 (Centre) Internal Building RC Frame **Design Vertical Alignment**	z_o = 13.3m Cover= 8.6m	-0.08%	0.30%	27	2	Slight	-0.16%	0.61%	53	3	Moderate
Case 3A	Ch. 18+995 (South Side) Basement Floor Slab **Design Vertical Alignment**	z_o = 12.9m Cover= 8.1m	-0.10%	0.32%	28	2	Slight	-0.21%	0.65%	55	3	Moderate
Raised Tunnel Profile (Max. Proposed Vertical Deviation = + 1.0m)												
Case 1B	Ch. 18+945 (Hatch St.) Secant Pile Wall/Bldg. Façade Raised Vertical Alignment (+1.00m)	z_o =8.6m Cover= 3.9m	-0.19%	0.70%	41	3/2	Moderate to Slight	-0.38%	1.40%	82	4/3	Severe to Moderate
Case 2B	Ch. 18+970 (Centre) Internal Building RC Frame Raised Vertical Alignment (+1.0m)	z_o = 12.3m Cover= 7.6m	-0.09%	0.40%	29	2	Slight	-0.19%	0.70%	58	3	Moderate
Case 3B	Ch. 18+995 (South Side) Basement Floor Slab Raised Vertical Alignment (+1.0m)	z_o = 11.9m Cover= 7.1m	-0.13%	0.40%	30	2	Slight	-0.25%	0.80%	60	3	Moderate
Lowered Tunnel Profile (Max. Proposed Vertical Deviation = - 5.0m)												
Case 1C	Ch. 18+945 (Hatch St.) Secant Pile Wall/Bldg. Façade Lowered Vertical Alignment (-5.0m)	z_o = 14.6m Cover= 9.9m	-0.07%	0.25%	24	1/2	Very Slight to Slight	-0.13%	0.50%	49	2	Slight
Case 2C	Ch. 18+970 (Centre) Internal Building RC Frame Lowered Vertical Alignment (-5.0m)	z_o = 18.3m Cover= 13.6m	-0.04%	0.16%	19	1	Very Slight	-0.08%	0.32%	39	2	Slight
Case 3C	Ch. 18+995 (South Side) Basement Floor Slab Lowered Vertical Alignment (-5.0m)	z_o = 17.9m Cover= 13.1m	-0.05%	0.17%	20	1	Very Slight	-0.10%	0.34%	40	2	Slight

BDA for Modified Upward LoD of +1.0m

Building and Structure Damage Classification (after Burland et al (1977) and Boscarding and Cording (1989))					Approximately Equivalent Ground Settlements and Slopes (after Rankin 1988)	
Risk Category	Degree of Damage	Description of Typical Damage and Likely Forms of Repair for Typical Masonry Buildings	Approx. Crack Width (mm)	Limiting Max Tensile Strain (%)	Max Slope of Ground	Maximum Settlement of Building (mm)
0	Negligible	Hairline cracks	<0.1	Less than 0.05		
1	Very Slight	Fine cracks easily treated during normal redecoration. Perhaps isolated slight fracture in building Cracks in exterior brickwork visible upon close inspection	0.1 to 1	0.05 to 0.075	Less than 1:500	Less than 10
2	Slight	Cracks easily filled. Redecoration probably required. Several slight fractures inside building. Exterior cracks visible some re-pointing may be required for weather tightness. Doors and windows may stick slightly	1 to 5	0.075 to 0.15	1:500 to 1:200	10 to 50
3	Moderate	Cracks may require cutting out and patching. Recurrent cracks can me masked by suitable linings. Re-pointing and possibly replacement of a small amount of extent brickwork may be required. Doors and windows sticking. Utility services may be interrupted. Weather tightness often impaired	5 to 15 or a number of cracks greater than 3	0.15 to 0.3	1:200 to 1:50	50 to 75
4	Severe	Extensive repair involving removal and replacement of sections of walls, especially over doors and windows required. Windows and frames distorted. Floor slopes noticeably. Walls lean or bulge noticeably, some loss of bearing in beams. Utility services disrupted.	15 to 25 but also depends on number of cracks	Greater than 0.3	1:200 to 1:50	Greater than 75
5	Very Severe	Major repair required involving partial or complete reconstruction. Beams lose bearing, walls lean badly and require shoring. Windows broken by distortion Danger of instability	Greater than 25 but also depends on number of cracks	Greater than 0.3	Greater than 1:50	Greater than 75

Empirical degree of damage thresholds in table are for masonry structures and are not representative of characteristics of Arthur Cox Building (e.g. façade and basement waterproofing).

Results (RC = Damage Risk Category):

- **Raised Tunnel Profile (+1.0m):**
  - Restricts TBM from hitting toe of secant piles now **3.0 to 4.0m** above raised tunnel crown.
  - Potential for Slight Damage (RC-2) for building & Moderate to Slight Damage (RC-3/2) for secant pile wall and façade (v_l=0.5%);
  - Possibly increases to Moderate (RC-3) or Severe to Moderate (RC-4/3) due to concentrated loads, particularly for façade/secant pile wall (v_l=1.0%);
- Slight increase on damage for design tunnel level;
- Still exceeds threshold tolerances for building façade and basement waterproofing system.

Conclusions:

- EIAR does not adequately assess likely significant impacts of ground movements due to tunnelling on the Arthur Cox Bldg., i.e.:
    - Phase 2a assessment indicates that impact of ground movements on Arthur Cox Building for the design tunnel profile will result in Slight Damage (Risk Category 2).
    - This was considered acceptable by Jacobs/IDOM so that no further assessment was required. However, damage criteria exceeds the structural tolerances of the building façade and basement waterproofing system.
    - Building Damage Report (BDR) does not assess the impact of concentrated foundation loads, the lower level of the perimeter secant pile wall, or the impact of raising/lowering the tunnel alignment within the proposed Limits of Deviation (LoD).
    - The impact of implementing the LoD on ground movements and building damage (Ch.5 of EIAR) has also not been assessed in the Wider Effects Report (WER), which is a notable omission.
    - The report does not include any constraints on raising the vertical alignment under the Arthur Cox Building.
    - The WER concludes that by implementing the LoD for the tunnel alignment "*there would be no change to the required mitigation measures, or to the residual impacts arising from the application of the mitigation measures set out in the EIAR.*"
    - The likely significant *positive* impact of lowering the tunnel alignment has not been assessed.

Conclusions (Contd.):

- The refined Phase 2a analyses carried out by AGL with the lower ground loss parameters (0.5%/1.0%) indicates that:
    - At the **design tunnel profile**, the damage to the perimeter secant pile wall could increase to Slight to Moderate [RC-2/3] under the façade due to the lower level of the toe of the secant pile wall (4-5m above the tunnel).
    - The damage level could rise to Moderate [RC-3] or Moderate to Severe [RC-3/4] if the concentrated loads from the building foundations have a significant impact on ground movements.
    - At the **raised tunnel profile** (+1.0m), there is only a slight increase in the estimated levels of building damage. However, the damage criteria still exceeds the structural tolerances of the façade and basement waterproofing.
    - At the **lowered tunnel profile (-5.0m)** there is a significant reduction in the estimated level of building damage, potentially reducing to Very Slight (RC-1) for the building, and Very Slight to Slight (RC-1/2) for the secant pile wall and façade.
    - At this level there is greater potential to comply with the limiting thresholds of damage for the building façade and basement waterproofing system.

Recommendations:

- Lower level of tunnel by Min. 5.0m
- Update Wider Effects Report to include constraint on upward deviation of *revised* vertical alignment
- Carry out Phase 3 analytical assessment of ground movements and building response to verify building damage and ground movement thresholds.
- Jacobs/Idom & TII to co-ordinate with structural designers to confirm acceptable thresholds of building distortion/damage
- Risk assessment to be carried out for potential ground loss of 0.25% to 0.50% in Phase 3 assessment.
- Stipulate condition to ensure tunnel is designed to support additional building loads for future development (designed for extra floors).

Note: Building is on rock so lowering alignment is most effective mitigation i.e. possibly limited potential for compensation grouting or jacking.

Additional Information from TII during Oral Hearing:

Technical Note by Jacobs/IDOM to assess Implementation of Revised LoD on Building Damage (Doc. No. ML1-JAI-GEO-ROUT_XX-RP-Y-00034, dated 10th Nov. 2023)

- Assessment does not adequately assess the impacts on the Arthur Cox Building, i.e.:
  - Generic site-wide assessment based on original conclusions of Building Damage Report – based on each Damage Risk Category (i.e. RC-1, RC-2, RC-3)
  - Carried out for LoD of +1.0m upward *and* 15.0m horizontally – not separately.
  - Concludes that no increase in damage category level for any of the RC-2 buildings, which includes the Arthur Cox Bldg. => no change to mitigation measures in EIAR.
  - No information on methodology, criteria and results included.
  - Critically, conclusions are still based on acceptable damage level at Risk Category 2, which exceeds the tolerances of the façade and basement waterproofing of the Arthur Cox Bldg.
  - Does not adequately assess the likely significant *positive* impacts of lowering the tunnel alignment.

Additional Information from TII during Oral Hearing:

DRAFT Preliminary Phase 3 Assessment for Arthur Cox Building by Jacobs/IDOM (Doc. No. ML1-JAI-GEO-ROUT_XX-RP-Y-00036 - undated)

- Assessment would not constitute a Phase 3 assessment because the building is not included in the analytical model so it does not account for the structural characteristics or concentrated foundation loads.
- It is based on the incorrect geological profile from the EIAR.
- Models the response of the ground and tunnel structure to an idealised excavation/construction sequence without ground loss.
- Underestimates ground movements that could occur in the best-case scenario.
- Conclusions on resulting building damage levels are incorrect – suggests damage level reduces to Risk Category 0 for 0.2% ground loss.
- AGL analyses indicate that for 0.25% ground loss damage level reduces to:
    - RC-1/2 [Very Slight to Slight] at design tunnel level – still exceeds design tolerances for A.Cox Bldg.
    - RC-0/1 [Negligible to Very Slight] at the lowered tunnel level [-5.0m] – within structural tolerances

Additional Information from TII during Oral Hearing:

TII Comments on 0.2% Ground Loss from draft Phase 3 assessment to justify Design Tunnel Profile

- TII comments on draft Phase 3 report indicates that they rely on lower level of ground loss to justify lower level of damage at the design tunnel profile.
- Not consistent with the building damage assessment in the EIAR, i.e.:
  - Current assessment is based on 0.75% ground loss and acceptable damage level of RC-2.
  - Building Damage Report states that less conservative 0.50% ground loss for tunneling in rock for refined Phase 2a assessment is "*compatible with the values experienced using the modern tunnelling equipment and control systems that are expected to be used on the Metrolink Project*".
  - Not supported with case study references in Building Damage Report: Generally 0.3-1.0% for EPBM, albeit limited data in rock;
- Not supported by methodology of Draft Phase 3 assessment – numerical modelling of idealized tunnel construction without ground loss.
- Still results in damage category that could exceed structural tolerances of façade and basement waterproofing system [RC-1/2].

Additional Information from TII during Oral Hearing:

TII Comments on 0.2% Ground Loss from draft Phase 3 assessment to justify Design Tunnel Profile (Contd.)

- Values of ground loss up to 0.5% reported for tunnelling in rock on Dublin Port Tunnel (e.g. Gillarduzzi, 2014)
- Ground loss also depends on type of TBM, ground conditions, workmanship, ground conditions.
  - EIAR states that type of TBM "*not mandated*" through the contract [Appendix A5.12 – Tunnelling]
  - Alignment drawings show incorrect geological profile and borehole records
  - Limited SI data (1 No. corehole) and SI layout drawings include mislabelled coreholes that don't exist.
- Value of 0.25% considered best-case scenario.
- Phase 3 Building Damage Assessment should consider risk assessment for 0.25%-0.50% ground loss potential.
- Needs to be recognized that lowering the level of the tunnel is the primary mitigation measure for the Arthur Cox Building (i.e. supported on rock – limited potential for compensation grouting).
- Is it intended to specify lower limit in the contract? – Could cause contractual difficulties if exceeded.