MetroLink

Response to EARLDEV submission made 29.02.24

P01

2024/03/04

MetroLink

Project No: 32108600
Document Title: Response to EARLDEV submission made 29.02.24
Document No.:
Revision: P01
Date: 2024/03/04
Client Name: Transport Infrastructure Ireland
Client No:
Project Manager: Paul Brown
Author: John Kinnear
File Name: Response to EARLDEV submission made 29.02.24

Jacobs Engineering Ireland Limited

Merrion House
Merrion Road
Dublin 4, D04 R2C5
Ireland
T +353 1 269 5666
F +353 1 269 5497
www.jacobs.com

Document history and status

Revision	Date	Description	Author	Checker	Reviewer	Approver
01	04/03/2024	For Information	JK	MG	MG	PB

Response to EARLDEV submission made 29.02.24

The settlement analysis completed and process set out in Appendix 5.17 of the EIAR is in line with industry practice and uses a conservative 3 phase approach, that is then refined through each subsequent phase as the design and construction methods are progressively finalised. This approach is such that the predicted impacts are conservative at this current phase 2 and there is a credible expectation that they can reduce further as the details are confirmed in the later phases of the project. It is a robust conservative process with a predictable outcome and provides a progressive method of establishing and predicting the impacts of ground movement.

This process set out by Mair, Taylor and Burland[1] is used globally in the industry including in the USA. In the USA, their early phase projects generate a "construction impact assessment" which is completed prior to a Record of Decision. To support the impact assessment, an empirical evaluation of ground movements is completed and stresses and strains imposed on structures and utilities within the Zone of Influence are used to identify anticipated damage categories, along with recommendations for follow-up work during the next phase of the project. This same process was also used on projects in Copenhagen[2], the United Kingdom included Tideway, Crossrail, and HS2 prior to their respective Development Consent Orders or Hybrid Bills. In addition, the same process TII is following on Metrolink was also used here on the Dublin Port Tunnel.

The phase 1 assessment involves drawing contours of ground surface settlement using methods set out by Peck[3] and refined by O'Reilly and New[4]. This is a filter to identify buildings potentially at risk[5] and eliminating all buildings falling outside the 10mm contour after checking no eliminated building experiences a slope exceeding 1/500.

The phase 2 assessment calculates the maximum tensile strains induced in the assumed structure without inherent stiffness. The maximum tensile strain calculated is used to obtain the corresponding potential damage category. The approach is usually conservative, because the building is assumed to have no stiffness and to conform to the greenfield settlement profile. In reality, the inherent stiffness of the building will tend to reduce both the deflection ratio and the horizontal strains. In most cases, therefore, the derived category of damage in the second stage assessment refers only to the possible level of damage.

The Phase 3 is a detailed evaluation and undertaken for those buildings classified in the phase 2 assessment as being at risk of *moderate* damage or greater, protected structures, deep basements, piled structures and proximity to the excavation. The sequence and method of tunnels and full account of 3-dimensional aspects of the tunnel layout in relation to each specific building is taken into consideration within the Phase 3 assessment in collaboration with the building owner.

A strength of the process is that it does not purport to identify conclusions that cannot be substantiated and requires buildings like the Arthur Cox building to be moved to a Phase 3 assessment irrespective of the damage category predicted by the greenfield settlement. A phase 3 assessment of the Arthur Cox building was committed to in the EIAR and repeated in our Response to the Observers submission.

It may be helpful to clarify what the damage categories are and what they mean. The system of classification is based on "ease of repair" of the visible damage. Thus, in order to classify visible damage it is necessary, when

[1] Mair, R.J., Taylor, R.N. & Burland, J.B. (1996). Prediction of ground movements and assessment of risk of building damage due to bored tunnelling. Proceedings of the International Symposium on the Geotechnical Aspects of Underground Construction in Soft Ground. London 1996, Mair & Taylor (eds), Balkema, Rotterdam, 1996.

[2] Eskesen, S.D., Whittles, D., Krogh, J., Graygaard, J.H., (2011) The Copenhagen Metro Circle Line—Tunnelling and Station Construction Challenges in Urban Conditions, RTE, San Francisco, 2011

[3] Peck (1969). Deep excavations and tunnelling in soft ground. In Proc. 7th Int. Conf. Soil Mech. Found. Engineering, 345–352, Stockholm

[4] O'Reilly, M.P. and New, B.M. (1982). Settlements above tunnels in the United Kingdom – their magnitude and prediction. Tunnelling '82. Ed Jones, M.J. pp 173-181. London, IMM

[5] Moss, N.A., Bowers, K.H. (2005). The effect of new tunnel construction under existing metro tunnels. Proceedings of the 5th International Symposium Geotechnical Aspects of Underground Construction in Soft Ground. Amsterdam, 2005.

carrying out the survey, to assess what type of work would be required to repair the potential predicted damage both externally and internally. The following important points should be noted:

- The classification relates only to the visible damage at a given time and not to its cause or possible progression which are separate issues.
- The strong temptation to classify the damage solely on crack width must be resisted. It is the ease of repair which is the key factor in determining the category of damage.
- The classification was developed for brickwork or blockwork and stone masonry. It can be adapted for other forms of cladding. Although it is not an intended classification for reinforced concrete the process is still applicable.

The terms *negligible*, *very slight*, *slight* refer to cosmetic damage, *moderate* and *severe* to serviceability and *very severe* to structural damage respectively.

During a phase 2 assessment a greenfield prediction is calculated with movement and slope. Each building is assessed based on its size and position on the slope. The assigned category is a description of the damage that might be witnessed in a brick structure when subject to the predicted potential ground movements. It is not a prediction of crack widths in a reinforced concrete structure which is far more robust. The relationship between maximum tensile strain and category of damage lies at the heart of the methodology for assessing the risk of potential damage due to ground movements induced by tunnelling and excavation. The prediction for the Arthur Cox building from the phase 2 assessment is to classify it in the slight category. This descriptor of severity of damage may not be appropriate, but the categories are still applicable.

The Observer stated that the geology assumed was wrong. While as explained below the exact geology under the Arthur Cox building was not known, the assumptions made were conservative and so remain robust. Our ground model did not include the specific details of the bore holes the observer has provided clustered around this particular location (which as explained we have only now in fact received due to miscommunication between the Observer and TII), but the geological model we used is based on a large number of investigations used to define the overall MetroLink ground model (257), which is wholly appropriate for a project of this type and size. Considering a total alignment length of 19km, the average distance between investigations would be approximately 74m. This distance aligns well with European standard recommendations 6. As the Observer confirmed we have taken a conservative approach in our ground models which has the rock head lower than the level than recorded in their boreholes. This demonstrates the robustness in the damage predictions at this phase, with a higher rock head the impact is expected to reduce. With the information provided the ground model can be updated with the location specific geology, assisting the subsequent phases of assessment.

The process outlined by the Observer, lowering the tunnel and performing a greenfield analysis such that the damage category is at a category which is acceptable to them, is problematic. The reasons greenfield equations are using in phase 2 is to identify whether a Phase 3 assessment would be prudent, not to draw conclusions that are based on assumptions that are deliberately used to assume a conservative case. Where the greenfield movements calculated in the phase 2 result in a potential impact, further refined analysis with site specific parameters, stiffness of the structure and the use of finite element modelling may also be appropriate. Applying the basic greenfield settlement equations for pile toe depth is not recommended. The Observer made frequent reference about the concentrated load effect from the buildings, and suggested an increase in volume loss to account for this, which is unconventional. It also fails to consider that at the level of the tunnel crown, the additional pressure due to the building loading will dissipate by load spread and that the unloading due to basement construction is a greater load. It is therefore their argument about effect due to concentrated load which is technically incorrect. Buildings such as the Arthur Cox building are identified for phase 3 assessments for the reasons set out above. Using the established process we have followed, buildings which need to be taken to further analysis are identified and progress to that stage irrespective of the category of damage assigned. Ekesen (2011) illustrated the sequential approach and included details of the sensitive facades and

---

[6] Eurocode EN 1997

how the contract design and build contract competes the final stage of analysis. The phase 3 assessment will involve a building specific engagement with the Observer.

The Observer noted on 4 occasions the "*very relevant experience*" of the Dublin Port Tunnel and we would like to respond to the relevance of this project.

We concur that the Dublin Port Tunnel was constructed in Dublin in similar ground conditions to those that MetroLink is to be constructed within and, more specifically, in the limestone below the Arthur Cox building.

There the similarities end, as that project was constructed 20 years ago with tunnelling technology and controls on the management of tunnelling that bear little resemblance to the state of the art, full face, pressurised tunnel technology systems proposed for MetroLink. It is reported that on Dublin Port Tunnel that the TBM was operated in "open mode" (i.e. no face pressure) and water ingress rates into the tunnel of up to 300l/sec were reported. These factors absolutely contribute to an increase in ground movement, and MetroLink would not permit such inappropriate control. So the TBM that will be used on Metrolink will produce far less settlement risk.

Importantly, despite the use of that (now outdated) tunnelling technology, the Observer noted that a face loss of 0.5% (in comparable ground conditions) was achieved on Dublin Port Tunnel. This evidence should provide further reassurance that the proposed face loss percentages stated by MetroLink are conservative and readily achievable by the technologies proposed in the EIAR and modelled in the ground movement assessments. Indeed Goto in his 2004 paper "**Dublin Port Tunnel – Excavation of an 11.8m diameter urban motorway tunnel**" reports that in general, face losses of 0.07% to 0.12% were achieved in the area of full limestone cover.

The clearance from the tunnel to the toe of the foundations of Arthur Cox building is more than three meters and MetroLink still assumes a face loss of 0.5% compared to the lower numbers stated above.

The MetroLink assessments are appropriate and remain conservative.

The approach does have limitations in so far as it is conservative and requires a necessitates a further level of assessment for identified buildings. It remains appropriate for deriving categories of damage at phase 2 and will usually be conservative in its estimation. The calculation of tensile strain assumes that the building in question has no inherent stiffness, and that it deforms to the greenfield settlement profile. In reality the stiffness of the building will interact with the supporting ground, and therefore tend to reduce the deflection ratio and horizontal strains. Hence, in the majority of cases, for reinforced concrete buildings like the Arthur Cox building, the likely actual damage will be less than the assessed category.