Discussion: The long-term behaviour of retaining walls in Dublin

Frank O'Leary BEng, MIEI

Geotechnical Engineer, Arup Geotechnics, London, UK; PhD Candidate, Department of Civil Engineering, University College Dublin, Dublin, Ireland

Mike Long BE, MEngSc, PhD, MIEI, MICE, CEng

Senior Lecturer, Department of Civil Engineering, University College Dublin, Dublin, Ireland

Maurice Ryan BE, CEng, MIEI

Principal Engineer, Byrne Looby Partners, Dublin, Ireland

Ria Blackmore MEng (Hons), CEng, MICE

Project Geotechnical Engineer, Coffey Geotechnics Ltd, Manchester, UK

Nabeel Bux MEng (Hons)

Senior Geotechnical Engineer, Coffey Geotechnics Ltd, Harrogate, UK

Andrew Smith MA, PhD, MBA, CEng, FICE, CGeol, FGS

Technical Director, Coffey Geotechnics Ltd, Harrogate, UK

Contribution by R. Blackmore, N. Bux and A. Smith

The authors (O'Leary *et al.*, 2016) are to be congratulated on taking the opportunity to carry out long-term monitoring on walls designed with short-term conditions in mind, and they appear to have obtained some valuable and interesting data.

The Heuston results are particularly interesting as being for an anchored wall. The authors state that they revised the original analysis by raising the water table and decreasing the stiffness of the wall, both of which are plausible. However, a comparison of the original design deflection profile with the measured profile (Figure 5) indicates that some other factors may also have played a part.

- Measured deflections near the toe of the wall were much smaller than indicated by the original design calculation – does this indicate that the soil was stiffer than the design value? Was the same rigid boundary level used for both models?
- Could the increased deflection at the top of the wall result from reduced anchor stiffness (possibly degraded if they were designed only as temporary anchors) in combination with the reduced wall stiffness (0.7EI to 0.5EI)? Was any sensitivity analysis carried out regarding the effects of reducing anchor and wall stiffnesses?

The authors state that there was concern about the bending moments in the wall, given that the deflections were greater than originally predicted. A higher water table (implying a load-controlled problem) would certainly lead to increased moments. However, the problem is also partially displacement controlled (earth pressures should decrease with increased displacement), and to that extent should not the decreased bending stiffness of the wall result in reduced moments?

It would be interesting to know if the nearby listed boundary wall had experienced any movement during the monitoring period.

The results from cantilever walls support the general consensus that embedded wall software tends to overestimate the deflections in such walls, but it does appear remarkable how large the difference reported by the authors is. Do they have any suggestions as to why this might be? One interesting aspect is that the tops of the walls at both Ballycullen (Figure 8) and North Quay (Figure 9) have bent back as if anchored or propped in some way. Were the inclinometers in or behind the walls? If the latter, might a tension crack have formed at the top of the wall? If the former, do the authors have any other suggestions as to why this should have occurred?

Author's reply

The authors are grateful to their colleagues in Coffey Geotechnics for their observations and interesting reflections on the paper.

The authors agree that the analysis carried out underestimates the stiffness of the soil. Oasys FREW and simple finite-element models, typically used in industry, assume a linear elastic stiffness, and thus do not consider the stress-dependent stiffness of the soil. In particular it is clear that at low strains Dublin Boulder Clay (DBC) is extremely stiff, with geophysical testing confirming this (Long and Menkiti, 2007). It is possible that the modelling could be improved by sub-dividing DBC into a number of layers and assigning an increasing stiffness with depth to the layers or using a sophisticated soil model. The same rigid boundary was used for both analyses.

The authors have no evidence that the increased deflections are due to the reduction in performance of the anchors. Although the anchors installed had a design life of 2 years, the potential reduction in cross-sectional area was nominal (expected loss of section <1 mm for up to a 25-year period in these ground conditions). The anchors were inspected and signs of corrosion were not observed. The anchors were also load tested and lift off of the anchor bearing plate did not occur at the design load confirming that the anchors were overloaded.

The authors agree that the decreased bending stiffness of the wall will result in reduced moments; however, the magnitude of the increased displacements was such that there was still a concern over the high bending moments and the potential for these to increase further.

The listed boundary wall was inspected regularly and there is no evidence of movement or obvious signs of distress in the structure.

The authors agree that there is a significant difference between the design predictions and observed behaviour. Walls such as those detailed in the paper tend to be designed on the basis of moderately conservative design parameters rather than most probable parameters. This is done to reduce risk to the client and provide some certainty on programme, rather than employing an 'ab initio' observational method approach. It is clear that there is scope to refine the designs with a more sophisticated analysis approach such as finite-element using a

non-linear soil model, perhaps in conjunction with an observational approach.

The inclinometer access tubes were embedded within the piles and a tension crack was not observed at either site. It is difficult to state with certainty the cause of the deflected shape at Ballycullen Road and North Wall Quay. It is possible that the presence of a very stiff capping beam which is fixed at either end may influence the deflected shape of the wall.

REFERENCES

- Long M and Menkiti CO (2007) Geotechnical properties of Dublin Boulder Clay. *Géotechnique* **57**(7): 595–611.
- O'Leary F, Long M and Ryan M (2016) The long-term behaviour of retaining walls in Dublin. *Proceedings of the Institution of Civil Engineers – Journal of Geotechnical Engineering* **169**(2): 99–109, <http://dx.doi.org/10.1680/jgeen.15.00041>.