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Discussion: Design of braced excavations to limit ground movements

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Included in this paper is a very interesting section on the use of heave-resisting piles to reduce the wall deflection (and associated settlement) for deep excavations. The section includes a theoretical example of the effect such piles might have had for an actual excavation in Singapore.

How to assess the effect of piles within an excavation was a matter of considerable discussion prior to the collapse of an excavation at Nicoll Highway, as mentioned in the report of the committee of inquiry[22] and also during the subsequent investigations. Most designers in Singapore ignore the beneficial effects of such piles; this is conservative. Where designers do include the piles, this is commonly done in 2D finite element analysis by modelling each line of piles as a wall of equivalent stiffness. This approach is unconservative, as it generally overstates the potential benefit of the piles. It is therefore useful that the authors have proposed another method of assessing the benefits of heave-reducing piles. However, the method proposed could also overestimate the benefits of such piles.

The authors propose that there are two components of resistance provided by the piles, a horizontal component and a vertical component, as shown in equation (6) in the paper. In the paper these components are defined in purely geotechnical terms, and are related to the length of each pile within the moving mass. However, the piles can provide this restraint only if they are anchored below the moving mass of soil such that equal and opposite forces can be derived from the undisturbed soil. The piles must also be capable of taking the tension force induced by the vertical component of the resistance, and the bending moments and shear forces induced by the horizontal component. The components of restraint may therefore be governed by the structural capacity of the piles or the capacity of the anchorage below the moving mass.

For the horizontal component of resistance the piles are acting as cantilevers. For large, deep, excavations in (deeper) soft clay, such as the example given in the paper for Singapore, the depth to the base of the moving mass is large, and so the lever arm is long. Under these circumstances, the bending capacity of the piles is likely to limit the restraining force that the piles can apply to the soil at the base of the excavation. Because of the long lever arm, even large-diameter piles are relatively flexible in the horizontal direction, and this may also limit the restraint that can be obtained.

For the vertical component of resistance, the piles act in tension, and must be reinforced accordingly. They must also be taken to sufficient anchorage below the moving mass of soil. The failure of a section of excavation for the Common Services Tunnel[23,24] was ascribed, in part, to the inadequate anchorage of piles driven below the base of the excavation. However, it takes very little relative movement to fully mobilise the skin friction on the piles. Provided there is adequate reinforcement and anchorage, the vertical component of resistance can be readily mobilised.

The vertical resistance provided by piles in an excavation can be simply derived, but the horizontal resistance is more difficult to estimate. If the horizontal component of resistance is ignored, there are two simple methods of modelling the effect of the vertical resistance provided by heave-resisting piles. These methods have beeen used for excavations in soft clay in Singapore. One method is to introduce a surcharge at the base of the excavation. The magnitude of the surcharge is equal to the total upward force resisted by the piles over the length within the moving mass (see Fig. 13 in the original paper), distributed over the base of the excavation. The alternative method is to model the piles as tension elements with negligible lateral stiffness.

Authors' reply

The authors are grateful to the discusser for his interesting comments on the use of heave-resisting piles to stabilise the base of excavation in soft clay. The authors recognise that they had focused in their paper on the geotechnical question of how to predict ground displacements around excavations, including the beneficial reduction of displacements, by the use of such piles. The discusser has correctly drawn attention to structural behaviour of heave-piles themselves. The designer needs to ensure sufficient tensile resistance to avoid uplift and sufficient flexural rigidity to resist lateral ground movement, if each of these effects is to be included as an extra source of stability. We fully support all the additional considerations recommended by the discusser.

The authors noted in their paper that, in the case of heave-reducing piles, they had produced a calculation method that would always overpredict the influence of these components, precisely because of their assumed rigidity. The authors have aspiration to incorporate the stiffness of all structural elements, as well as the ground, into their mobilisable strength design (MSD) methodology. An earlier attempt to include wall stiffness in calculating lateral movements due to excavation was shown by Osman and Bolton.[2] The authors are therefore most encouraged by the interest shown by the discusser. In common with all design calculations that are simplified so as to be capable of practical application, MSD calculations should be evaluated in carefully monitored field studies or centrifuge tests prior to their use in practice. This evaluation was the objective of the paper.

REFERENCES

22. MAGNUS R., TEH C. I. and LAU J. M. *Report of the Committee of Inquiry into the Incident at the MRT Circle Line Worksite that Led to the Collapse of Nicoll Highway on 20 April 2005*. See http://www.mom.gov.sg/publish/momportal/en/press_room/press_releases/2005/20050513-CommitteeofInquiryconcludesstringofcriticaldesignerrorscausedcollapseatNicollHighway.html (last accessed December 2006).
23. LIM P. C. and TAN T. S. A floating-type braced excavation in soft marine clay. *Proceedings of Underground Singapore 2003*, Singapore, 2003, pp. 326–337.
24 SHIRLAW J. N., TAN T. S. and WONG K. S. Deep excavations in Singapore marine clay: Special lecture. *Proceedings of the 5th International Symposium on Geotechnical Aspects of Underground Construction in Soft Ground, Amsterdam*, 2005