

# Performance Monitoring and Numerical Modelling of a Deep Circular Excavation

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For the design of deep excavations, codes and standards advise to base estimates of wall deflections and ground movements on empirical data. Due to the limited number of case studies on circular excavations it is nearly impossible to find comparable projects under similar conditions. Therefore designers have to adopt conservative approaches, which predict larger ground movements than probably occur in reality and thus lead to more expensive structures and protective measures.

Further uncertainty is induced for diaphragm wall shafts. The discontinuous nature of the wall due to the joints between the individual panels may cause anisotropic wall behaviour. There is a complete lack of understanding if, and how, the design of diaphragm wall shafts should consider anisotropic wall stiffness.

The construction of Thames Water's Abbey Mills shaft in East London provided a unique opportunity to monitor the structural performance and the ground movements of one of the largest shafts ever built in the UK. The 71 m deep excavation penetrates a typical London strata and one third is in unweathered medium to hard Chalk. The monitoring scheme included distributed fibre optic strain sensing instrumentation and conventional inclinometers in the shaft wall to measure bending and hoop strains, as well as wall deflections during several construction stages. Further inclinometers and extensometers were installed around the shaft to monitor surface and sub-surface ground movements. The monitoring results were then compared to the initial PLAXIS design predictions. A further numerical investigation was conducted in FLAC2D which allowed a more flexible parametric study.

The measured bending moments during shaft excavation exceeded the predictions mainly in the wall sections in the Chalk group. It was found that this was caused by assigning a low cohesion to the Chalk to induce conservative ground movements, so that the Chalk yielded in the analysis. In reality however, it remained elastic and hence induced larger bending moments in the wall. For future excavations in Chalk it is recommended to investigate the effect of a low and a high cohesion of the Chalk on the wall bending moment.

The hoop strain measurements indicate that the shaft has undergone a three-dimensional deformation pattern during a dewatering trial prior to shaft excavation.

The parametric study on wall anisotropy suggests that the shaft wall behaved like a cylindrical shell with isotropic stiffness, where the joints between the panels do not reduce the circumferential stiffness.

Further numerical simulations varied the shaft wall thickness and the at rest lateral earth pressure coefficient in the Chalk. The results showed that the wall thickness has a minor influence on its deflection and hence thinner walls might be feasible for future shafts. The at rest lateral earth pressure coefficient of the Chalk appeared to be appropriately picked with 1.0 in the initial design.

Above all, it was shown that wall deflections were very small with less than 4 mm. Correspondingly small ground movements were measured throughout shaft excavation. Empirical formulas on the other hand predict large settlements between 40 and 105 mm. Numerical predictions were much closer to the measurements and showed that small heaves occurred due to soil swelling caused by removal of overburden pressure. For future shaft designs it is hence advised against the use of empirical formulas derived from case studies under different conditions. It may furthermore not be necessary to implement expensive large-scale monitoring schemes, as it has been confirmed that ground movements around diaphragm wall shafts are minimal and that risks are low.

The findings from this study provide valuable information for future excavations, which can be applied to the shafts constructed for the forthcoming Thames Tideway Tunnel project.