

OPTIMISATION OF DIAPHRAGM WALL DESIGN BY INCLINOMETER-BASED BENDING MOMENT ANALYSIS: A CASE STUDY

A.K.H. Karunathilaka, L.I.N. de Silva *

Department of Civil Engineering, University of Moratuwa, Moratuwa

Accurate finite element modelling (FEM) of diaphragm walls in deep excavations remains a challenging task due to uncertainties in assigning reliable soil parameters, often limited by the availability of accurate field data. This study explores a practical approach to determine realistic unloading–reloading modulus (E_{ur}) values for FEM analysis, based on back-analysis of lateral displacement measurements obtained from inclinometer data. This approach enables an accurate representation of wall behaviour and enhances the reliability of numerical models.

Two deep excavation projects in Sri Lanka were analysed as a part of this research. The lateral wall displacements were monitored using inclinometer systems installed within the diaphragm walls to capture the wall deformation profiles throughout the excavation stages. The measured displacement profiles were processed using the least squares method with high degree polynomial fitting to obtain continuous functions of wall movement along the depth. This approach provided a good approximation of the actual field behaviour. Some local variations were observed near the top and bottom of the walls during second order differentiation, reflecting the sensitivity of polynomial differentiation at boundaries. Nevertheless, the method yielded reliable and consistent bending moment profiles in the central wall regions, allowing for a meaningful calibration of the numerical model against field data.

Finite element models were developed using a two-dimensional plane strain analysis framework, employing the Mohr-Coulomb soil model to simulate sequential excavation stages, wall construction, and prop installation. The models were calibrated by varying E_{ur} relative to the initial secant modulus (E_{50}). Through iterative back-analysis, it was determined that increasing E_{ur} to approximately two to three times E_{50} provided displacement and bending moment predictions that closely matched the field monitored values, significantly improving the reliability of the numerical models without excessive conservatism. Alongside numerical modelling, empirical methods were used to estimate prop forces and bending moments. The Terzaghi and Peck apparent earth pressure diagram and the Distributed Prop Load (DPL) method were applied, assuming sandy soil behaviour. Both methods consistently predicted higher bending moments across the excavation depth compared to FEM calibrated results. This confirms that while empirical methods are useful for preliminary design, they tend to overpredict wall forces and moments due to their simplifying assumptions.

The main conclusion of this study is that selecting E_{ur} values between two to three times E_{50} provides a conservative and realistic basis for finite element modelling of diaphragm walls. Future research should aim to expand the database by analysing field-monitored excavation projects across a wider variety of soil conditions and excavation geometries, thereby enabling further refinement of stiffness adjustment recommendations and enhancing the overall reliability and general applicability of diaphragm wall performance predictions.

Keywords: Back analysis, Deep excavation, Elastic modulus, Finite element analysis

* Correspondence: nalinds@uom.lk

OPTIMIZATION OF DIAPHRAGM WALL DESIGN BY INCLINOMETER-BASED BENDING MOMENT ANALYSIS: A CASE STUDY

Problem statement

Idealized diaphragm wall designs overlook local soil behavior, leading to overdesign and increased costs.

Objective

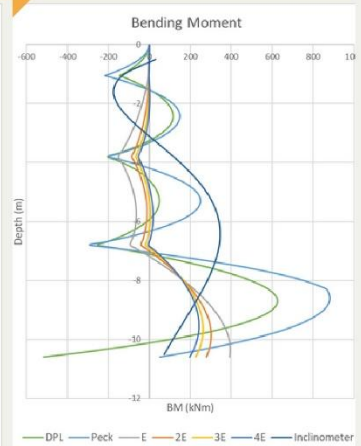
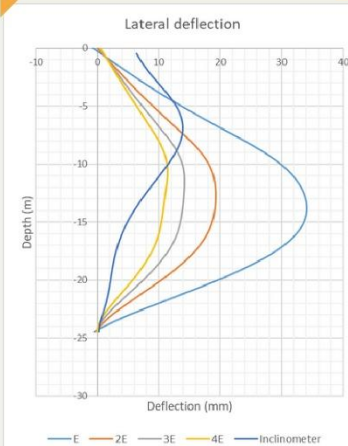
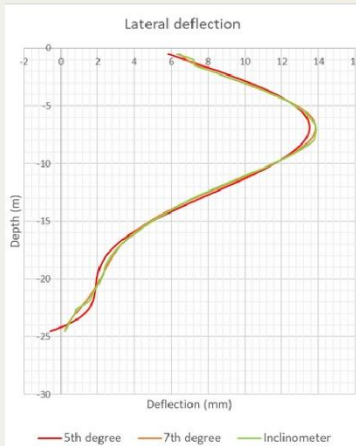
Propose a method for selecting appropriate unloading-reloading modulus (E_{ur}) values for FEM analysis, based on a back-analysis technique using inclinometer data.

Methodology

Fit inclinometer data into a continuous function using least square method

Obtain displacement profiles with varied E_{ur} values in the FEM and compare with actual displacement values

Obtain bending moment profiles using inclinometer data, FEM and empirical methods and compare them



Results & Conclusions

- Using $E_{ur} = 2-3 \times E_{50}$ in FEM provides a conservative and realistic basis for diaphragm wall design.
- Further studies recommended to expand field-monitored databases and refine stiffness adjustment guidelines.