CASE STUDY

Westgate, Oxford

GEOFEM

"Geofem have always provided high quality analysis and been very responsive to our demands in the fast-changing world of commercial development."
Richard Whitehead, Managing Director, Waterman Structures

The £500 million Westgate Centre redevelopment in Oxford city centre involved a complete rebuilding and extension of the existing shopping centre including a new two-storey basement car park. Being a low-lying site adjacent to a tributary of the River Thames, the high water table and weak alluvial deposits presented significant challenges.

AT A GLANCE

THE CHALLENGE

- Predicted ground movement and deflection of the new steel basement walls were too high.
- Reliable spring stiffness values for the basement raft design were hard to estimate due to ground heave, dewatering and a lack of reliable soil stiffness data.
- The design of the permanent dewatering measures required estimates of groundwater flow rates around the basement walls and through the layered alluvial deposits and Oxford Clay.

THE SOLUTION

- Additional advanced in situ stiffness testing of the Oxford Clay for more accurate displacement predictions in the finite element analysis (FEA) model.
- Revised displacement predictions shown to lie within acceptable limits (as confirmed by subsequent InSAR analysis).
- Raft spring stiffness values obtained from the geotechnical 3D FEA model.
- Groundwater flow modelling by FEA of a range of scenarios was used to estimate pumping rates for permanent basement dewatering options.

THE BENEFITS

- With some additional site investigation and advanced geotechnical FEA, significant time and cost was saved by not needing to change the basement wall design during construction.
- More economy in the basement raft design leading to time, cost and carbon savings through reduced concrete and steel reinforcement volumes.
- Improved groundwater flow cut-off properties of the basement wall leading to savings in pumping energy throughout the life of the development.

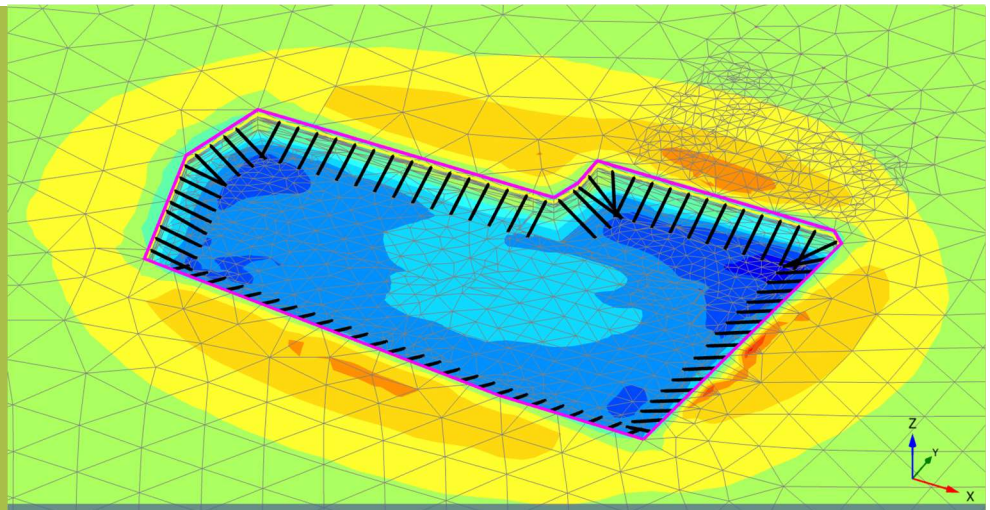
THE CHALLENGES

The design of the permanent steel sheet pile basement wall by conventional analysis methods was unable to demonstrate satisfactory wall deflection and hence adequate protection of the adjacent building foundations, roads and underground services. Differential settlements between new and existing parts of the redevelopment also needed to be assessed.

Ground conditions were challenging and comprised fine and coarse-grained layers of weak alluvium overlying stiff Oxford Clay with a high water table well above basement formation level.

The structural engineers needed coefficients of subgrade reaction (spring stiffness) for the Oxford Clay supporting the basement raft but the heave resulting from basement excavation and the dewatering measures made this difficult to estimate accurately.

Groundwater flow rates through the alluvial layers and Oxford Clay and into the basement for different perimeter wall toe depths and sealing options were difficult to assess by simple analysis methods.



3D finite element analysis (FEA) prediction of excavation-induced ground movement

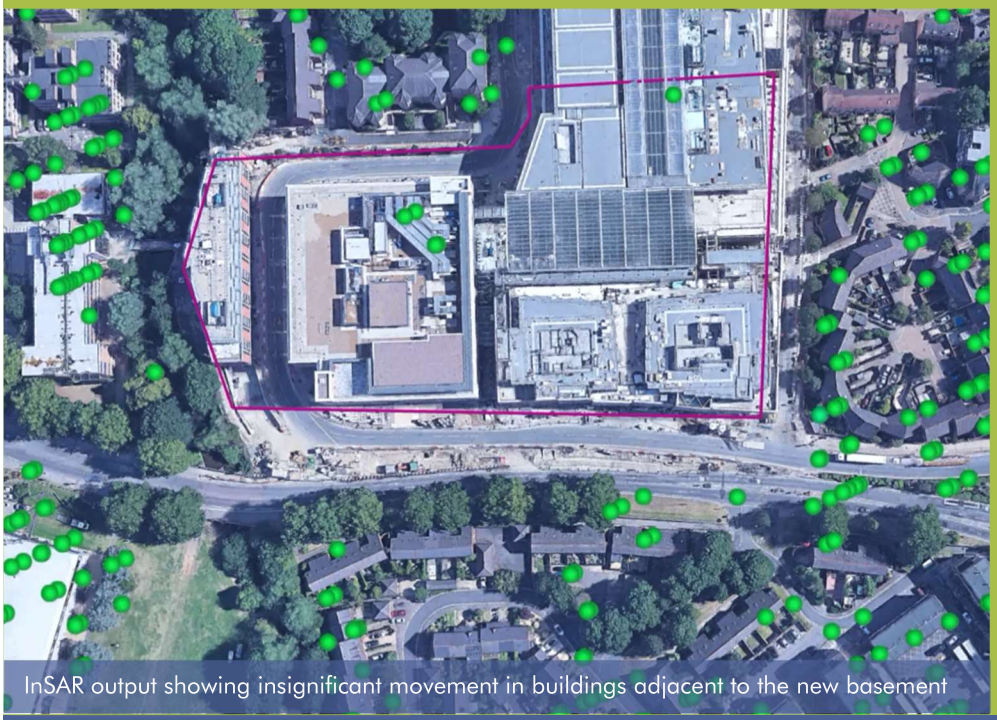
A LITTLE EXTRA

We recommended additional advanced in-situ stiffness testing of the Oxford Clay in the form of downhole seismic testing. The clay's small-strain stiffness was key to improving the accuracy of displacement predictions in the FEA model by means of non-linear stiffness constitutive models.

The predicted ground movement and differential settlement with existing structures decreased to acceptable levels (as confirmed by subsequent InSAR analysis), meaning that the existing wall design could be accepted.

The same 3D FEA model was used to simulate construction of the basement raft and gradual increase of structural loading. Its outputs included spring stiffness values for structural design of the raft that took full account of structural stiffness, ground conditions, displacements and loading.

Groundwater flow modelling in FEA was also undertaken to estimate pumping rates for permanent basement dewatering options including the effects of different wall toe levels and sealing options.


InSAR output showing insignificant movement in buildings adjacent to the new basement

THE BENEFITS

Without our recommended additional site investigation and advanced geotechnical FEA, the 500m long basement wall would have needed strengthening according to the original design. This would have added significant time and cost to basement construction.

More economy in the basement raft design was achieved thanks to the more accurate spring stiffness values provided to the structural engineers, leading to time, cost and carbon savings through reduced concrete and steel reinforcement volumes.

Improved efficiency of the permanent basement dewatering measures thanks to modifications to the perimeter wall led to savings in pumping energy throughout the life of the development.

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