CASE STUDY

Richards Bay, South Africa

GEOFEM

The $70 million Richards Bay mounded LPG storage facility was commissioned in October 2020 and has secured the supply of the most environmentally friendly of the fossil fuels across southern Africa. With a 22,600 tonne capacity each, it contains the four largest LPG tanks in the world but they are sensitive to settlement. So they required a 5,600m^2 raft foundation with 1,400 settlement-reducing piles in an ingeneous arrangement thanks to some advanced analysis.

AT A GLANCE

THE CHALLENGE

- The loose sand ground conditions required an expensive foundation solution to minimise differential settlement and hence distortion of the tanks.
- A lower-cost, settlement-reducing piled raft option was available but that required advanced geotechnical expertise and analysis for its design.
- The settlement-reducing piles needed to be arranged in such a way that raft foundation settlements would be near-uniform.

THE SOLUTION

- A large number of preliminary pile load tests on various lengths of the proposed auger displacement piles were undertaken and back-analysed using FEA to obtain accurate pile-ground interaction parameters.
- A 3D FEA model of the ground, piled raft, LPG tanks and mound was created to predict raft settlement during construction, hydrotesting and subsequent operation.
- The pile arrangement was optimised to produce near-uniform foundation settlement.

THE BENEFITS

- Distortion of the LPG tanks during hydrotesting and subsequent operation was minimised, helping to ensure the safe operation of the facility.
- Near-uniform raft settlement was achieved by a softer, settlement-reducing piling approach instead of deep ground improvement or a stiffer structure, giving a more efficient engineered solution.
- Greater efficiency in the design brought time, cost and carbon savings to the project through the use of less construction materials and shallower piles.

THE CHALLENGES

The sheer size of the four largest LPG storage tanks in the world (each 60m long and 16m diameter) made them sensitive to distortion. This required a foundation solution that would keep differential settlements small to avoid straining the tanks. However, ground conditions comprised a loose sand near the surface which would have caused excessive differential settlement.

A large area of deep ground improvement could have been undertaken or, alternatively, deep piles supporting a stiff load transfer structure. Either of these would have been very expensive at this site, so the client's preferred option was a raft with settlement-reducing piles. These are piles that are allowed to settle more than conventional piles, thereby transferring more load to the raft foundation.

The client had an aspirational target of zero differential settlement (i.e. uniform settlement) across the 80m x 70m raft! Some advanced geotechnical analysis and expertise was needed to optimise to such a level the design of this large piled raft with such an unusual loading.

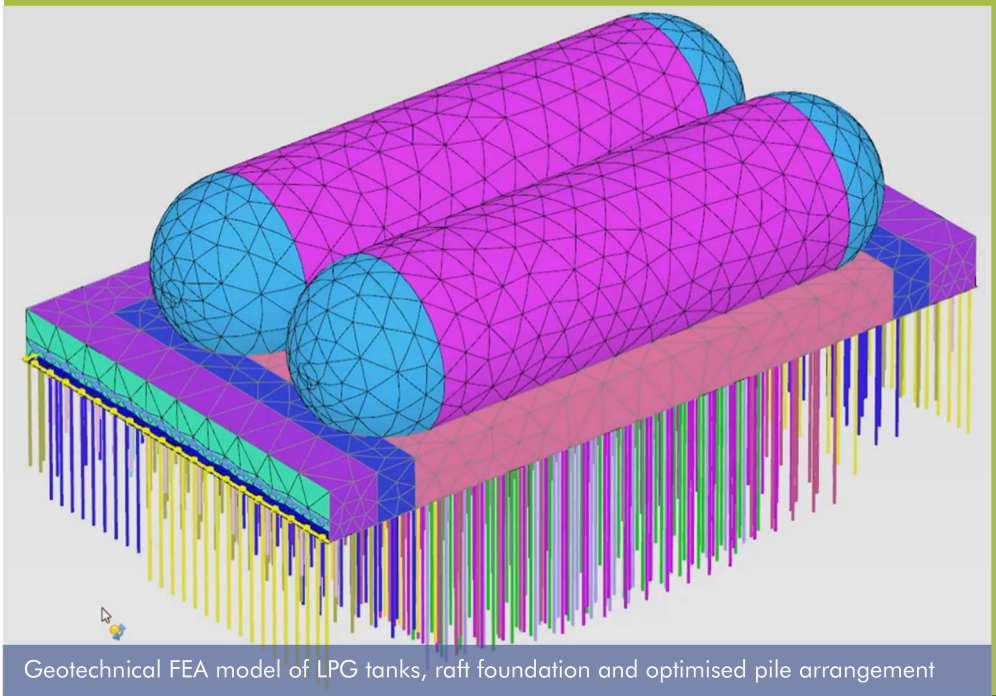
The LPG storage facility during construction

SOME ADVANCED ANALYSIS

A ground investigation was undertaken to obtain stiffness parameters for the upper soil layers and to confirm the existence and condition of the bedrock at around 20m depth. Several load tests on each proposed length of auger displacement pile were performed on preliminary piles installed across the raft footprint. All tests were back-analysed using finite element analysis (FEA) to validate the soil and pile-ground interaction parameters.

A 3D FEA model of the LPG tanks, piled raft foundation and supporting ground was created to predict raft settlement during construction, hydrotesting (the most onerous loading) and subsequent operation.

Several iterations of pile arrangement were analysed, working with the designers of the tanks themselves, to obtain the most uniform settlement during all load cases and thereby minimise distortions of the tanks.



Geotechnical FEA model of LPG tanks, raft foundation and optimised pile arrangement

THE BENEFITS

Distortion of the LPG tanks during hydrotesting and subsequent operation was minimised, helping to ensure the ongoing safe operation of the facility since October 2020.

Rather than adopting a harder, settlement-minimising solution, this softer approach that allowed larger but uniform settlements achieved the goal of low distortions in the tanks with a much more efficient solution.

Significant savings in time, cost and carbon emissions associated with construction of this facility were brought compared with the harder engineering solutions of deep ground improvement or deep piles and a stiffer support structure.

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Satellite analysis with engineering insight

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