Geotechnical Consultancy for Thames Marshland Construction

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The development of former marshland presents a number of significant challenges, not least of which is geotechnical. Whilst detailed and accurate site investigation is vitally important, the analysis of the data produced, the subsequent design of engineering works, and ongoing monitoring are also key to the success of any such venture.

STATS was recently contracted to provide geotechnical investigation and consultancy services for a housing development near Gravesend. The site is being developed by Barrratt Homes, and lies within the 'Thames Gateway'.

The Thames Gateway is identified in Regional Planning Guidance for the South East as a national priority for regeneration and growth and in the Sustainable Communities plan as one of the four growth areas for new housing in the South East. This area extends for 40 miles along the River Thames from the London Docklands to Southend in Essex and Sheerness in Kent.

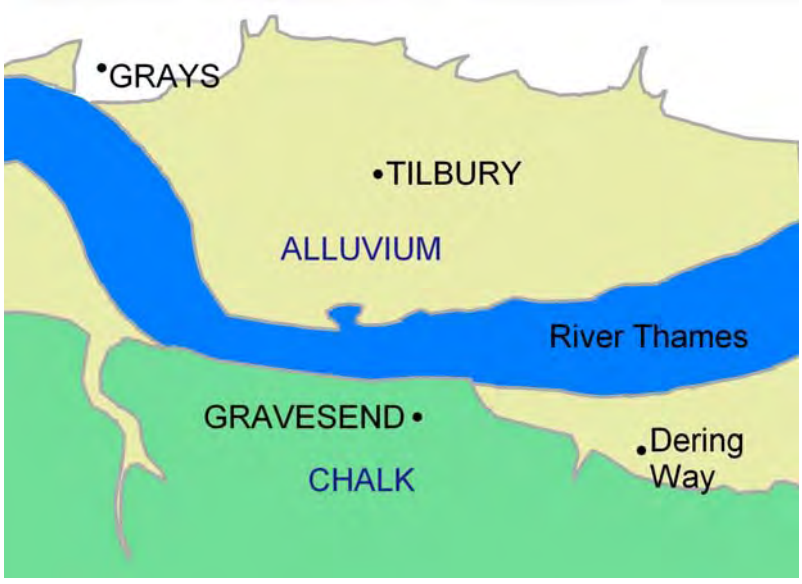

Figure 1

The development is located at Dering Way near Gravesend and lies on the southern margin of the Thames floodplain (see Figure 1). The geological map of the site implies an increasing thickness of alluvium from the south to the north of the site with chalk bedrock

beneath. The chalk bedrock is indicated to outcrop just to the south of the site. Prior to development the site was occupied by marshland with a number of drainage ditches running across it. Over much of the site ground levels have been raised by approximately 2m in order to bring it safely above predicted flood levels. Building works have included the construction of 147 residential units with associated infrastructure and an embankment to the north of the site, varying in height from 3.85m to the west to 1.5m in the east, to carry a distributor road (see Figure 2). As well as the current site this will also feed further housing developments proposed to the north and east.

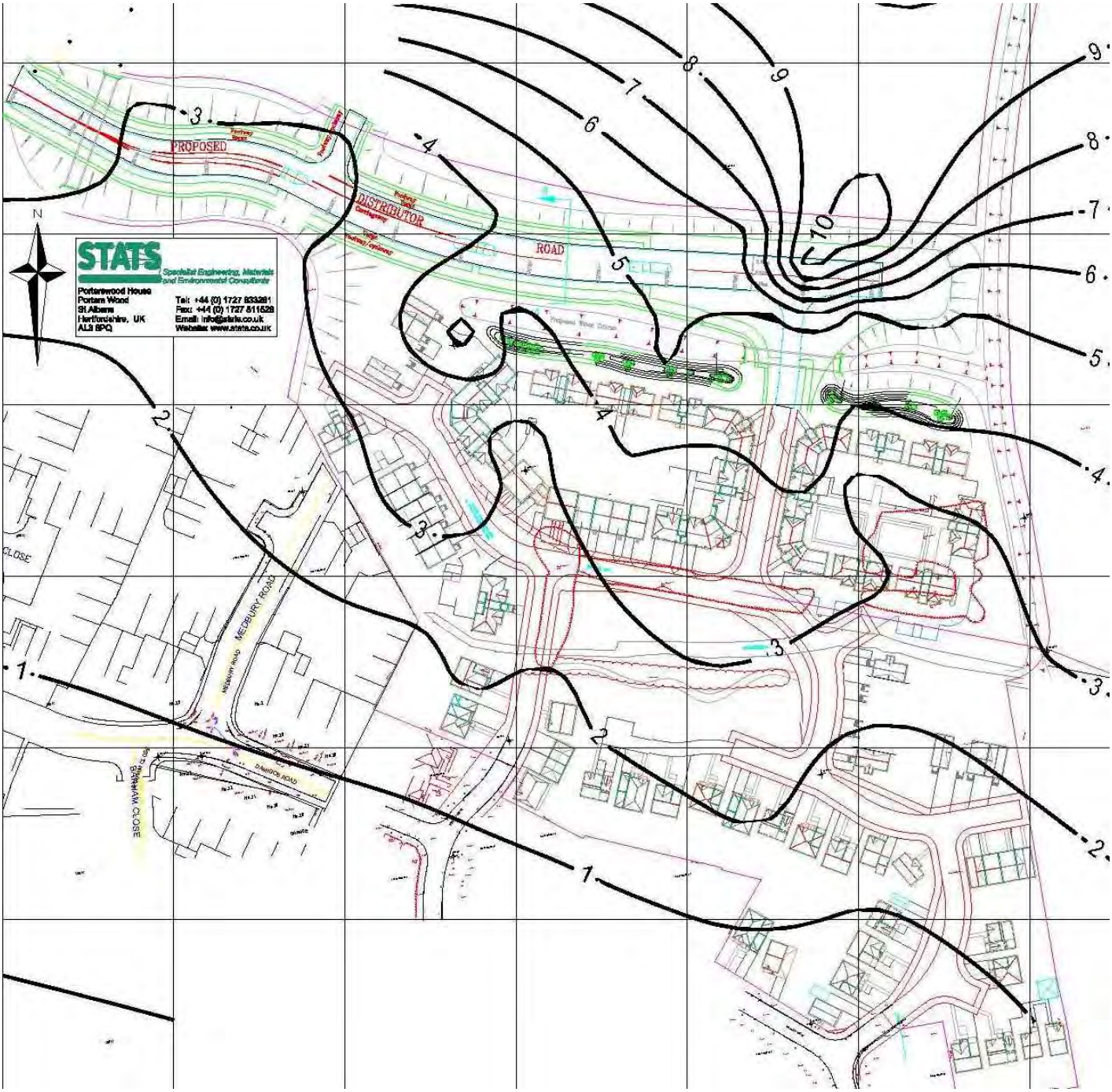

Figure 2

In recognition of the importance of technical expertise in the development of land lying within a floodplain, STATS were commissioned to perform a full geotechnical review of the site to include:

- collation of existing site investigation data
- a detailed geotechnical investigation of the site
- a feasibility study of the available techniques for the construction of foundations to both roads and housing
- final design of distributor road embankment and foundation, including band drains, surcharging, basal reinforcement and specification of fill material and its compaction
- prediction of primary and secondary settlement of soft alluvial soils beneath the proposed distributor road embankment and areas of housing
- monitor actual settlement rates for the embankment and pore water pressures in the underlying soft alluvium to validate predictions

Site Investigation

Site investigation works included a limited number of shell and auger boreholes, trial pits and window sampler holes primarily for the purpose of obtaining samples for geotechnical testing. In addition to this a comprehensive cone penetrometer testing (CPT) survey of the entire site was carried out to delineate the extent and thickness of the soft alluvial deposits and the condition of the underlying chalk. This indicated that the soft alluvial deposits varied between 2m in depth to the south and ten metres in depth to the north east (see Figure 2).

Laboratory triaxial, oedometer and Rowe cell testing was carried out in order to determine a range of soil settlement parameters for the soft alluvial deposits including the coefficients of volume compressibility (M_v), consolidation (C_v and C_h) and secondary settlement (C_{sec}). Given the highly organic nature of the alluvial deposits the latter of these coefficients (C_{sec}) was particularly important as it allowed future secondary settlements to be estimated. This coefficient is less commonly used than the other settlement coefficients but is simply the slope of the secondary settlement curve (normally straight) per unit thickness of sample on a log time plot as illustrated in Figure 3.

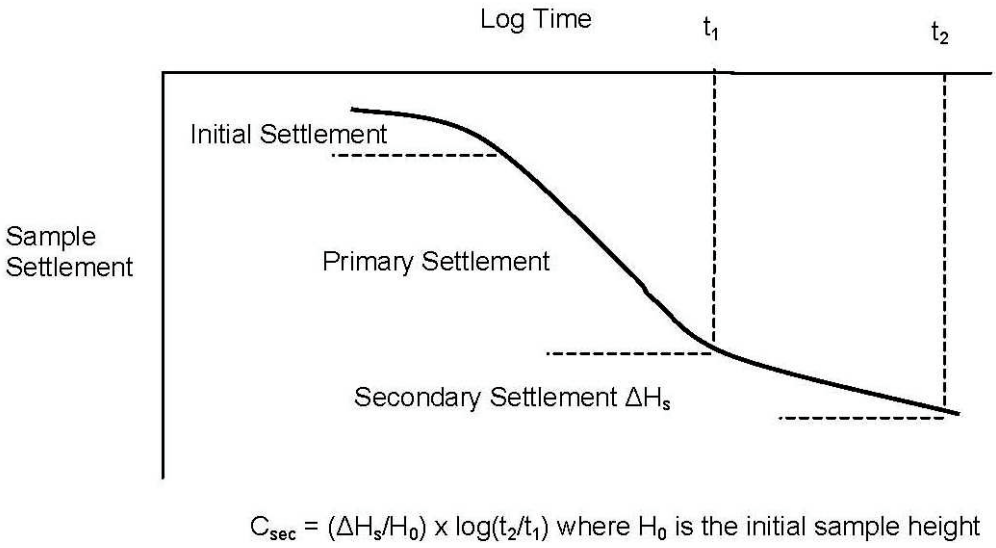

Figure 3

Feasibility Study

On completion of the site investigation the feasibility study of potential embankment foundations was performed which considered the following options (See Figure 4);

1. Adoption of a piled solution with geotextile reinforcement in the base of the embankment the piles being taken down into chalk bedrock

2. Adoption of a vibro concrete column (VCC) solution (insufficient confining stress for stone columns) with geotextile reinforcement in the base of the embankment the VCC's being founded on the surface of the chalk bedrock

3. Use of lightweight fill material, such as expanded polystyrene, in conjunction with excavation beneath the footprint of the road embankment to balance vertical loads and limit long term settlements

4. Installation of band drains through soft alluvial deposits down to the permeable chalk bedrock and subsequent surcharging to accelerate consolidation and possibly secondary settlement

A review of the above options was submitted to Barratts in September 2003, and as a result it was agreed that the band drain and surcharge option should be adopted. The rationale behind this decision was based on the fact that this method provided the most economic solution to the problem while at the same time allowing the surcharged embankment to act as a haulage route onto the site for building materials and plant.

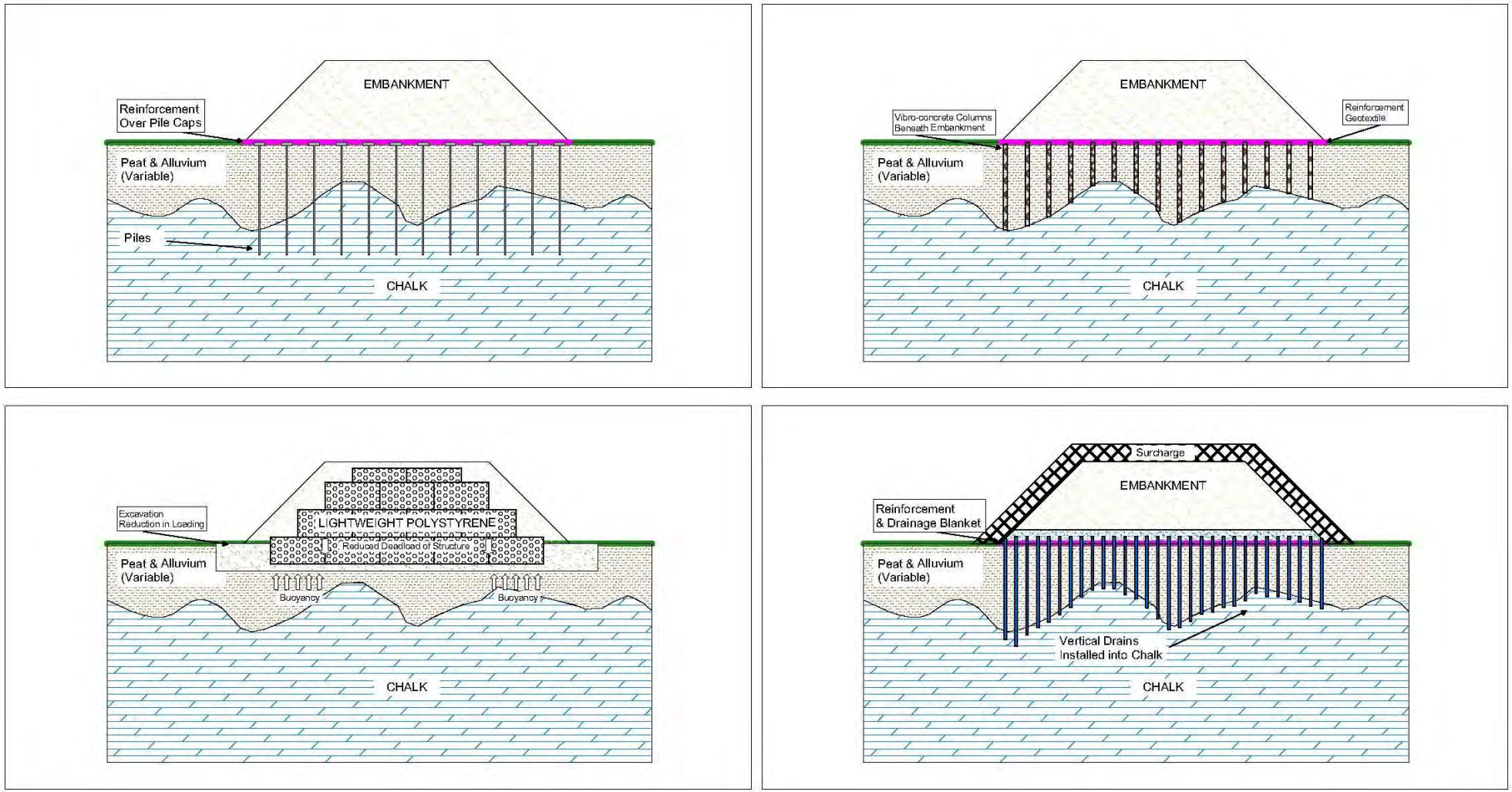
EMBANKMENT
Reinforcement
Over Pile Caps
Peat & Alluvium
(Variable)
Piles
CHALK
EMBANKMENT
Vibro-concrete Columns
Beneath Embankment
Reinforcement
Geotextile
Peat & Alluvium
(Variable)
CHALK
Excavation
Reduction in Loading
LIGHTWEIGHT POLYSTYRENE
Reduced Deadload of Structure
Peat & Alluvium
(Variable)
Buoyancy
Buoyancy
CHALK
Surcharge
EMBANKMENT
Reinforcement
& Drainage Blanket
Peat & Alluvium
(Variable)
Vertical Drains
Installed into Chalk
CHALK

Figure 4

Design

In February 2004 the design recommendations were finalised. This provided specific details regarding the spacing of band drains and depth of surcharge required to achieve 95% primary consolidation within the desired time scale of 8 months. Various options were presented as the rate at which consolidation occurs can be modified by adjusting either the thickness of surcharge or band drain spacing. The latter of these is particularly important, as the rate of consolidation is proportional to the square of the drainage path length. Clearly band drains can significantly reduce the drainage path length and thus markedly accelerate settlement. For the purpose of analysis a spreadsheet was produced which combined Terzaghi's theory of one dimensional consolidation with Barrons's theory of radial consolidation.

In general band drain spacings of 1m and 1.5m were adopted beneath roads and housing areas respectively, in each case a triangular grid pattern being used. A surcharge thickness of 2m above final ground level was utilised to accelerate settlements. A total of 29,692 band drains have been installed - an operation which took approximately 14 weeks to complete with between 1 and 2 rigs on site.

Based on the above spacing and surcharge, predicted settlements across the site of between 100 and 400mm were estimated after 8 months of surcharging depending on the thickness of alluvial deposits. Along the distributor road, settlements were estimated to be between 200 and 400mm.

Further to this a detailed assessment of estimated secondary settlement over the following 25years was also made based on secondary settlement coefficients derived from laboratory testing. From this it was predicted that secondary settlements of between 10 and 40mm could be expected to occur over the next 25 years after removal of surcharge. The lower bound value is based on work by Mesri et al (1997) which indicates that surcharging of peat can limit future secondary settlement. The upper bound value assumes that future secondary settlement is not influenced by surcharging.

Details relating to the design of the distributor road embankment were also provided including specification of suitable fill materials (6F1) and their compaction, safe shoulder angles and basal reinforcement (Basetex 200/50 Geotextile) required to provide embankment stability in the short term while the underlying soft alluvial deposits consolidated. Further basal reinforcement (SS40 Geogrid) was also provided to facilitate the construction of a working platform/drainage blanket from which the band drains could be installed.

Monitoring

In order to monitor the ongoing performance of the band drains and surcharge, settlement plates founded close to the base of the fill and vibrating wire piezometers were installed across the site predominately along the route of the distributor road. The instrumentation was monitored on a fortnightly basis using a precise level and invar staff, providing data with an accuracy of between 0.1 and 1mm. Vibrating wire peizometers were installed to measure the transient increase in porewater pressure after the application of surcharge and its subsequent reduction as consolidation of the soft alluvial deposits occurred.

In general the measured settlements are much as expected. Figure 5 shows the measured settlements at various points along the distributor road up to approximately one year after the placement of surcharge, at which stage the surcharge is still in place. From this it is seen that settlements range between 120 and 300mm. Towards the west (SP01 and SP02) of the road where less organic material was present it can be seen that little secondary settlement is occurring. To the east however, where there is a considerable thickness of organic material, significant secondary settlement is occurring. The secondary settlement coefficients back analysed from these measurements is within 20% of that estimated by laboratory testing. The vibrating wire piezometers reacted much as expected but provided little additional information to that provided by the level survey.

In conclusion the monitoring satisfactorily verified the initial design allowing construction to progress in line with the required program of works.

Comments

Brand Leonard Consulting Engineers were responsible for designing the estate roads and the housing. Julian Brown, one of the Brand Leonard consultants involved in Gravesend, believes “it is essential that a high level of geotechnical expertise is deployed in developments for which a level of uncertainty exists over the likely behaviour of foundation materials”

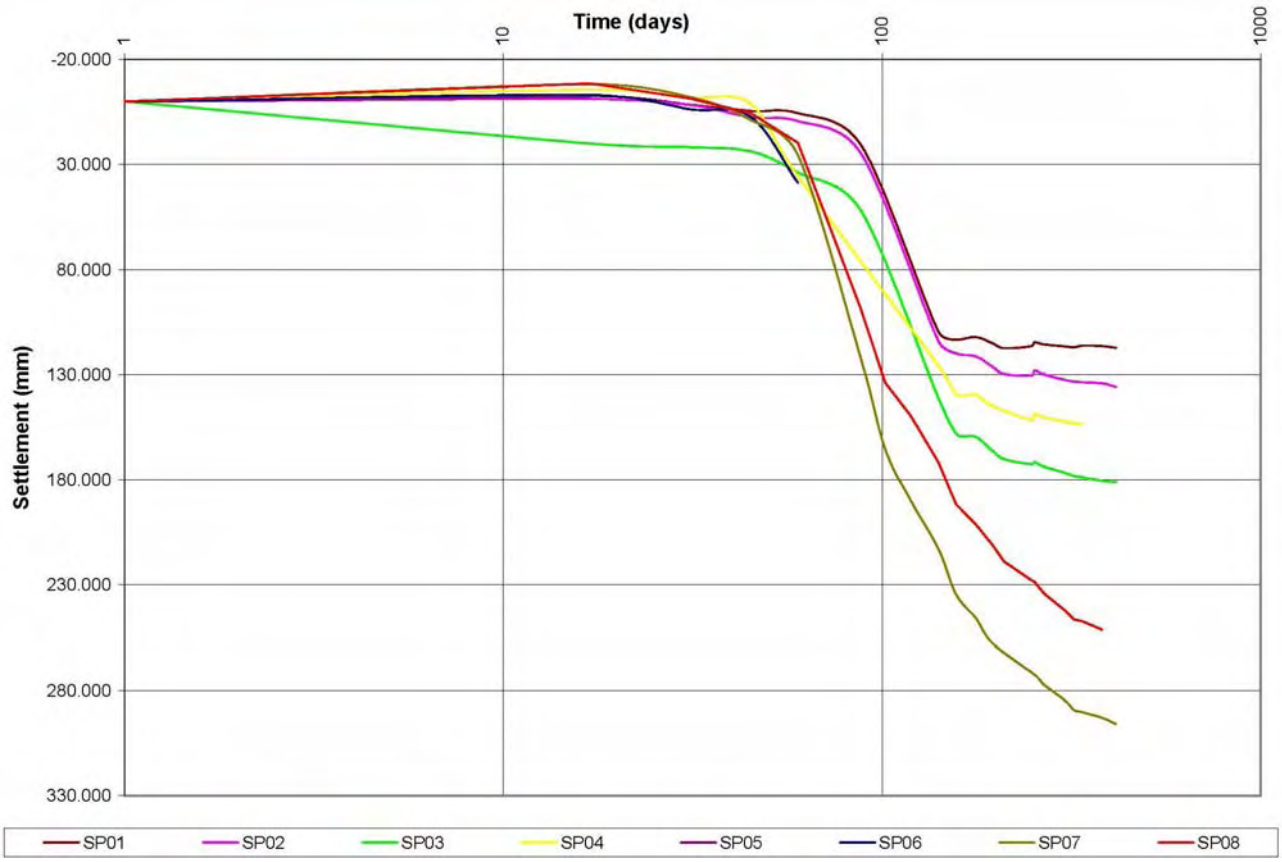

Figure 5

Summary

The key to the successful planning and design of construction projects in areas with soft underlying soils, lies in the engagement of geotechnical engineers that are able to both accurately survey the site, provide detailed recommendations for design, and monitor the site in order to check the validity of geotechnical predictions.

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