Editorial

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Welcome to this themed edition of *Geotechnical Engineering* on 'Innovation in deep foundation design and construction'. This issue has attracted a large number of high-quality papers from authors around the world, which is a testament not only to the wide readership and status of *Geotechnical Engineering* within the industry, but also to the determination of ground engineers everywhere to further their knowledge and understanding of geotechnical engineering. It is with some regret that many of the submitted papers were not chosen for this issue, primarily due to the limitations of the size of the edition. For those authors, however, their papers will have joined the publication list and may even have been published in earlier editions. Please do delve into other issues of *Geotechnical Engineering*, there are many fascinating papers on a wide range of subjects to enjoy.

This issue contains 11 papers which, true to the theme, cover a wide variety of innovative and topical subjects from research and numerical modelling to laboratory models and field study. We have a truly a global collection, with authors from Italy, India, Spain, Singapore, New Zealand, USA, Ireland, Australia, Germany and of course here in the UK. All of the authors have a common desire to propose new ways of working or demonstrate a furtherance in understanding and how these can be applied to real life situations.

Balancing ground risk with the cost of investigations and accurate and adequate determination of the ground model remains one of the major considerations in construction. As we strive to build deeper, larger, higher and more efficiently, ground engineers everywhere seek to find an edge in understanding of ground conditions to provide more efficiency in design and construction. Our understanding of the ground model and how this interacts with our designed structures is key to this improvement. There is global interest in innovation in deep foundations since project costs can be lower and programmes can be significantly shorter if appropriate novel techniques are applied. Using a new process or model can also improve worker safety, be the driver for more research to improve understanding and be a catalyst for development in difficult conditions. Alongside innovation we must always be aware of the need for caution, checking and corroboration, so that we can demonstrate our understanding of the ground model and ensure safety of installation before execution.

Much has been written regarding the collapse of the Nicoll Highway in Singapore in 2004 and the collapse of a 13-storey

apartment block in Shanghai in 2009. The Nicoll Highway collapse was the result of a fundamental error in understanding of the ground model leading to under-prediction of wall movements and bending moments (Hight *et al.*, 2009). The 'Lotus Riverside' apartment block collapse was caused by a contractor who excavated a 5 m deep open excavation for an underground car park adjacent to the long side of the apartment block. The structure, which was supported in soft alluvial soils on lightly reinforced prestressed hollow-section concrete piles, toppled when the piles suffered tensile cracking as a result of uneven loading due to the excavation on one side and the excavated soil piled up to 10 m high on the opposite side of the building (Chai *et al.*, 2013). Both of these high-profile cases were fundamentally caused by a lack of understanding of the ground model or changes to the ground model during construction, be that by the designer or the constructor. We should be mindful of the need to communicate our designs fully, stating limitations and assumptions where necessary, include for independent checking where appropriate and understand the construction process to ensure the efficacy of the design through all stages of construction and operation.

The subject of innovation in deep foundations is particularly important in the current economic climate, with many developed and developing nations making their way out of the global down-turn in the late 2000's and earlier this decade; governments and developers are looking for innovation to minimise cost and shorten delivery times. We very much hope that the papers in this edition will help that process by highlighting some areas of current research and proposing some novel approaches to old problems.

Many of the 11 papers in this edition concern pile foundations, but of a wide variety and in several different situations with case studies and models represented. We have two papers that challenge current practice in respect of the specification of concrete and adhesion factors in London Clay. We also have contributions concerning the long-term behaviour of structures using a unique opportunity during a break in construction, and a paper on suction caissons, important for the renewable sector and the proliferation of structures near shore.

Our first paper, by O'Leary *et al.* (2016), discusses several sites in Dublin but focusses on the performance of a secant pile retaining wall that remained in place for a number of years following construction, owing to project suspension due the

world economic down-turn. The wall apparently behaved as predicted by the Frew analysis during the construction phase prior to cessation of the project in 2008; however, when measurements were resumed nearly 3 years later it was found that movements had increased to more than 50% higher than the model prediction and the wall was still moving. The implication of this finding for the long-term performance of temporary works is discussed. An interesting outcome of the research also has implications on wall design efficiency. This paper has provided a seldom-seen insight to long-term behaviour of retaining structures and the results of the analyses should enable efficient designs to be created and to allow for the unexpected. It would have been interesting to see how the long-term integrity of the wall behaved had this research and remedial measures not been implemented.

The second paper, authored by *Geotechnical Engineering* editorial panel member and co-editor of this edition, John Gannon (2016), reviews current practice for specification of pile concrete for secant pile walls and determines that the requirement for long-term strength can contradict early strength requirements for male pile construction. He proposes a novel method to determine a window of opportunity between upper and lower limits of concrete strength as a more suitable way to control concrete strength. He also suggests that the current UK specification for concrete may not be applicable in certain pile situations. This paper shows a clear insight into the application of specifications in real situations and reinforces the sentiment that, as ground engineers, we should fully understand the design and continue to challenge the status quo where real progress and innovation can be made. Proposals in this paper, if adopted, could have a significant cost benefit on the installation of secant pile walls.

Our third paper, by Martin *et al.* (2016), challenges the pre-conception that a 'one-size-fits-all' approach for the adhesion factor for bored piles in London Clay is appropriate for all sites in London with deep foundations. By doing so, supported by the evidence gained through pile testing and back analysis, the designers were able to justify using a higher factor. As a consequence of this approach piles could be shorter and installation time and cost lower than the initial design suggested. The conclusions of this research also support the value of adopting preliminary test piles to validate pile behaviour and the expected ground model, and once more prove the benefits of testing to corroborate design, in contrast to adopting standardised methods.

The next two papers consider different aspects of group pile design for large structures. Kumar and Choudhury (2016) present a field study of dynamic soil–structure interaction (DSSI) for an oil tank supported on deep piles in weak soils in a seismically active area. They use three-dimensional (3D) non-linear finite-difference analysis within Flac3D to model the soil–structure interaction, corroborated by field pile load

test results. The DSSI analyses highlight the importance of numerical modelling in complex soil–structure interaction designs and they propose that the model developed can be used in similar situations elsewhere.

Maheetharan *et al.* (2016) describe a practical method that can be used to attain optimum pile configuration under piled rafts to cater for total and differential settlement and bearing capacity. They describe the design and construction of twin 31-storey towers with a five-storey podium connecting the towers. Initial review of the scheme indicated greater than acceptable differential settlements between the tower cores and the podium between the twin towers. For this reason the raft areas were enlarged and piled foundations used to limit total settlement of the core structures and a rigid joint between the tower structures and the podium completed at a later time during construction. They used an iterative method adopting readily available software to model the pile/soil/raft interactions to achieve an optimum design layout and then checking with the structural model. Although this might be considered to be a time-consuming or complicated approach it allowed the different lengths, diameters and spacing of piles to be modelled easily to achieve a satisfactory layout to cater for both serviceability and ultimate limit states relatively quickly. This paper provides a great example of how a versatile model of soil–structure interaction can be achieved using a straightforward and accessible approach.

The paper by Doherty *et al.* (2016) presents the results of a laboratory study of the shear and compression behaviour of carbonate sands and of carbonate sand/cement grout mixtures. Since carbonate sands are liable to grain crushing at engineering stresses, the use of driven piles is restricted in these soils because they behave in a contractant manner during shearing and this leads to low shaft friction resistance. The laboratory study shows that the geotechnical and structural behaviour of two Irish sands mixed with 15% to 35% of cement grout at a water:cement ratio of 0.4 can produce a material with similar properties to siliceous sand grouts. This suggests the mix-in-place MIDOS piling technique could be suitable in carbonate sands.

Justo *et al.* (2016) report the results of field load tests with optical fibre strain gauges and 3D finite-element modelling of 400 mm square hollow precast concrete piles extended by 145 mm dia. drilled micropiles. This composite pile type is used to overcome the problem faced by simple precast concrete piles, which is their inability to penetrate hard soil layers or rock and low characteristic tension resistance. Maximum static loads of 4000 kN vertical and 125 kN horizontal were applied to a 20.5 m long pile installed in a sequence of silt, sand, clay, sand and gravel, and hard marly clay. Dynamic vertical load tests were also performed on the driven pile. Plaxis 3D was employed to model the pile response using a hardening soil model in conjunction with Plaxis 'embedded piles' and

'volume piles'. The paper compares and discusses the field and analytical results and the modelling limitations.

The paper by Pender and Rogers (2016) examines the lateral loading response of timber poles embedded by 1.5 m to 2.0 m depth into stiff residual clay of intermediate plasticity. Due to the small depth of embedment, bending effects in the poles are not significant (termed 'short pole behaviour') and therefore the conventional published formulations for the ultimate lateral capacity of the soil do not accurately model the stress distributions observed. Using 250 mm dia. timber poles either in direct contact with the soil or embedded in a 450 mm dia. concrete surround installed in a circular array about a central larger-diameter reaction pole, the instrumented lateral load test results are analysed. The soil pressure distribution that best describes the observed response is found to depend on the embedment length to diameter (L/D) ratio with a simple ultimate resistance profile of $3s_u$ suggested where $L/D < 3.5$ and other distributions better fitting the test data where embedment is greater.

Valentino and Stevanoni (2016) describe and interpret the installation and static load testing of 2.3 m to 5.6 m long polyurethane-steel-reinforced micropiles. A novel construction technique, which makes use of lightweight and compact equipment, consists of boring a hole using an impact mole, expanding the hole using a hydraulic packer, installing the resin using injection pressures up to 1 bar (100 kPa) and then inserting a hollow steel thread-bar. Compression tests on 13 piles at six sites and tension tests on three piles at two sites from northern and central Italy are described. Limiting pile loads of between 25 kN and 165 kN are shown for these piles installed in silt and clay soils with standard penetration test N values typically < 20 . A method of evaluating the limit load is presented in which the quality of the injection process and the effective diameter of the pile are explicitly taken into account. The method of Fleming (1992, 1993) is adapted, using an additional dimension amplification factor parameter, to obtain the pile load-displacement response.

Hamidi *et al.* (2016) present and discuss the concept, design philosophy and behaviour of controlled modulus columns (CMCs). While at first sight appearing to be unreinforced concrete piles, CMCs are shown to be ground improvement inclusions with load sharing between the column and the surrounding soil. The paper provides a useful description of the plant, equipment, materials and methods used to form the columns and then presents a review of European methods of load transfer and distribution calculation which have culminated in a design method arising from a long-term French research project 'Asiri'. To demonstrate an application, claimed world record 42 m long CMCs, 400 mm in diameter, installed on a 1.7 m to 2.5 m spacing to support an imposed pressure load of 120 kPa from oil and water tanks in New Orleans, USA are described. The columns at this site have been installed in challenging ground conditions comprising very soft

and soft deep alluvial clays. The settlement performance of the CMC-improved ground is outlined.

The final paper, by Guo *et al.* (2016), describes and presents the results of an experimental laboratory study of six model suction caissons, 180 mm to 200 mm in diameter with a wall thickness of 10 mm, installed in kaolin clay normally consolidated from a slurry at effective pressures of 41 kPa, 106 kPa and 216 kPa in a 1.4 m tall $\times$ 1.0 m dia. steel tank. In contrast to previous published laboratory studies where steel caissons with a low wall thickness-to-diameter ratio have been used, this study focusses on concrete caissons where the thickness-to-outside diameter ratio is about 5% and where the soil consolidation stress is maintained while the vacuum is applied to the caisson interior. The undrained shear strength of the clay is of the order of 10 to 60 kPa – that is, very soft to firm. A key parameter identified in the analysis is m , the ratio of the internal soil plug volume and the volume of soil displaced by the caisson wall. A linear relationship is shown between m and soil undrained shear strength. The model tests also show that soil displacement is proportional to caisson wall thickness and that the suction pressure required to effect penetration is proportional to soil preconsolidation stress and stiffness. These observations enable estimates to be made of the suction pressures required to install concrete caissons in similar clay soils.

As you come to the end of this edition, we hope you have taken some useful and relevant information from the papers that have been included. If you would like to comment on any issues raised in this edition please consider contributing to the journal in the form of a discussion piece. Instructions on preparation and submission are included at the end of each paper. If you are inspired to submit a paper to the journal for publication please refer to the 'Instructions to authors' which can be found on the 'Aims and scope' page at the start of this issue.

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