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Editorial

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This expanded issue of *Geotechnical Engineering* is dedicated to the theme 'Geotechnical Challenges for Renewable Energy Developments'. Such developments are taking place worldwide and while our publishing Institution is UK-based our call for papers specifically for this issue attracted attention internationally. We include here 11 papers that we hope will be read by and of interest to an international audience.

The field of renewable energy development involves geotechnical engineers in a range of site investigation and foundation problems. Work reported here arises indirectly from power generation from wind, tidal current and tidal barrage schemes, but also in more direct terms from the abstraction of energy from the ground itself – energy piles and high-temperature geothermal schemes in dry or saturated rocks.

Developments in wind turbine technology, both onshore and offshore, which have variable application in western Europe and elsewhere, in the UK mainly use large mono-pile foundations with an increased interest being shown in alternative foundation forms. While much has been learned over the last 40 years about the behaviour of large piles for offshore oil and gas exploitation the wind turbine foundation throws up a different range of loading envelopes, the effects of which are at present less well understood. For example, long-term research projects at Imperial College London, UK, and the University of Western Australia have resulted in improved design methods to estimate the axial resistance of offshore piles. However, in a review paper to this journal Gavin *et al.* (2011) highlight residual uncertainties when these design approaches are applied to the offshore wind industry. These include the effects of cyclic dynamic loading and ageing effects, which are considered in a number of papers in this issue.

Wave, current and tidal plants each have their attractions – better predictability and energy density than wind are available for power generation – but they also present the engineer with severe problems often linked to very harsh environments. Work in this area lags somewhat behind that in the wind-farm industry, but one paper here (Maynard *et al.*, 2013) addresses some of the issues.

Abstraction or injection of heat from/to the ground at the shallow depths associated with energy piles is increasingly widespread although there are significant regional and national variations even in western Europe (Kalantidou *et al.*, 2012). Research continues to put this technology on a more robust scientific basis and interactions between thermal and mechanical behaviour are still the subject of uncertainty.

Abstraction of higher-grade energy from hot rocks at greater depth is currently of limited application around the globe but the search for more exploitable renewable energy will undoubtedly lead to increased activity in this field. Twenty years ago the Institution of Civil Engineers Energy Board was debating 'Hot dry rocks – a renewable energy resource' (Parmee, 1991) while recently in the *New Civil Engineer* Nicholson (2012) has discussed wider opportunities. Worldwide there are likely to be significant research programmes and developments of the resources in this field over the next decade.

Some nations will be better provided with renewable energy resources than others but all will be searching for power supply security, as with water supplies. Cross-boundary energy trade and transmission brings its own technical challenges and it is perhaps surprising that there is no input to this issue in this area. Similarly, site investigation for some of the development areas brings difficult challenges associated with drilling and sampling in areas with high seabed water velocities and in rocks at high temperatures.

The 11 papers contained in this issue fall into a number of subsets, namely

- tidal power
- pile design and performance, principally related to wind turbine installations
- thermal properties of ground and energy piles
- geothermal energy extraction on a large scale.

Maynard *et al.* (2013) describe investigations for a commercial fixed seabed tidal turbine substructure in Maine, USA. Site investigation and analysis indicate the viability of using suction caissons with shallow skirts to resist the environmental horizontal and vertical loadings applied. Such developments parallel interest in using similar structural forms in offshore wind-farm projects where mono-pile foundations have been the norm in northern Europe.

A group of papers look at various aspects of pile design and behaviour – principally, but not exclusively, in the context of wind-farm development. Sim *et al.* (2013) report an investigation using high-quality, advanced triaxial testing on sands to advance the understanding of offshore piles, in conjunction with laboratory model and field-scale tests. Gavin *et al.* (2013) present results from tests on 7m long, open-ended pipe piles in sand in Ireland to assess the post-installation ageing effects on static capacity, comparing behaviour with previous results obtained by

the Imperial College Geotechnics group. The latter (Rimoy *et al.*, 2013) address the displacement performance of pipe piles in a marine sand in France under static/cyclic load combinations showing the critical effect of both mean and cyclic load levels. Klinkvort and Hededal (2013) use centrifuge model tests on mono-piles in dense homogeneous sand under both monotonic and cyclic loading to develop design predictions of cumulative displacements and overall stiffness changes.

Bhattacharya *et al.* (2013) use small-scale laboratory models to assess the dynamic effects of both mono-piles and tetra-pod suction caissons used as alternative foundation types for offshore wind turbines. In contrast to the group of papers above they consider both uniform sand and kaolin clay test beds, and investigate true dynamic effects rather than the effects of cyclic loadings, in the current absence of long-term field observations of these structural forms.

Papers by Bourne-Webb *et al.* (2013) and by Loveridge and Powrie (2013) consider aspects of the behaviour of energy piles while Loveridge *et al.* (2013) look at thermal response testing of the Chalk aquifer beneath London in a 150 m deep borehole. There is rapidly increasing interest within the UK in thermal properties of the ground and in the use of energy piles for buildings, at least in part because of the Géotechnique Symposium in Print in 2009. It is hoped that this group of papers will contribute to increased understanding and use of these technologies.

The final two contributions by Bromley *et al.* (2013) and Pender *et al.* (2013) are twinned papers describing aspects of the assessment of settlements at a regional scale associated with long-term abstract of hot fluids from the Wairakei–Tauhara area of New Zealand. While there have been many publications, largely in the southern hemisphere, relating to this geothermal energy project it is relatively unknown in the north and this review of the current state of knowledge and of the advanced investigations into soil–rock behaviour is especially welcomed. This is not a technology exploited in most of Europe but as the search for renewable energy sources is national, regional and indeed global this should be exposed to the widest audience.

Our thanks go to all contributing authors and to the members of the *Geotechnical Engineering* Advisory Panel who have been involved with this particular issue and to the reviewers who have been pressed to respond to deadlines in order to get these papers to print. We would also like to offer thanks to all the industrial partners who have been associated with the many projects described in the issue. Without their willingness to contribute information and make data available to others this Journal and the profession generally would be impoverished.

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We hope you find this issue interesting and stimulating. If you would like to raise any particular points regarding the papers published in the issue please consider contributing to the Journal in the form of a discussion piece. Instructions on the preparation and submission of a discussion are included at the end of each paper.

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