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Discussion: Ground heave induced by installing stone columns in clay soils

Bryan McCabe PhD, CEng, MIEI
Lecturer, College of Engineering and Informatics, National University of Ireland, Galway, Ireland

Daniela Kamrat-Pietraszewska MSc, PhD
Research Associate, Department of Civil and Environmental Engineering, University of Strathclyde, Glasgow, UK; formerly Geotechnical Engineer, Keller Foundations, Coventry, UK

Derek Egan PhD, CEng, MICE
Technical Director, Keller Ltd, Coventry, UK

César Sagaseta PhD
Professor, Group of Geotechnical Engineering, Department of Ground Engineering and Materials Science, University of Cantabria, Santander, Spain

Jorge Castro PhD
Lecturer, Group of Geotechnical Engineering, Department of Ground Engineering and Materials Science, University of Cantabria, Santander, Spain

Contribution by C. Sagaseta and J. Castro

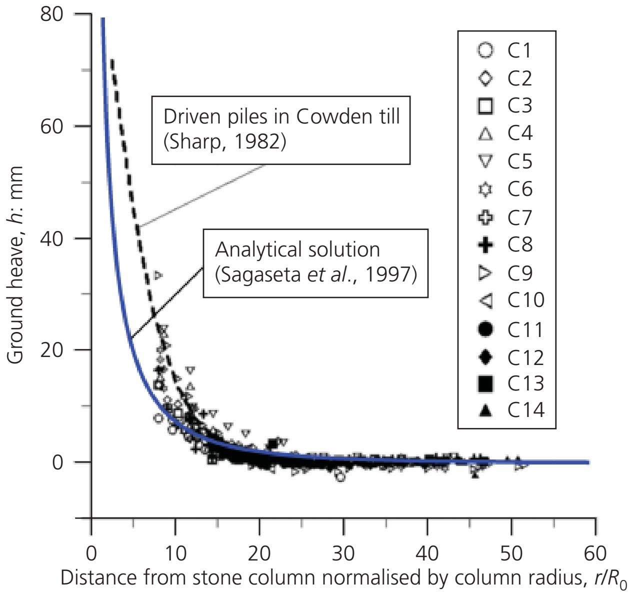
The authors present interesting field measurements of ground heave induced by installing stone columns in soft clay (McCabe *et al.*, 2013). Similar results to pile driving were found and superposition of the heave field caused by each single column seems to be valid to estimate the cumulative heave generated by multiple stone column installations. The authors fit their field measurements by a fourth-order polynomial (Equation 1). The contributors would like to point out that there exists a simple analytical solution to this undrained problem. It is referred to as the shallow strain path method (SSPM) (Sagaseta *et al.*, 1997), and comes from the integration of the point source case (Sagaseta, 1987). Using the authors' notation

$$h = \frac{R_0^2}{2}\left[\frac{1}{r} - \frac{1}{(r^2+L^2)^{0\cdot5}}\right] \qquad (2)$$

This solution has proved its applicability to displacement piles (e.g. Edstam and Kullingsjö, 2010; Sagaseta and Whittle, 2001; Xu *et al.*, 2006), is dimensionally consistent, predicts no heave for high radial distances and includes the influence of a key factor, such as the column length, as the numerical results of the paper also indicate. Furthermore, it also compares well with numerical simulations of stone column installation (Castro and Karstunen, 2010).

The comparison of this solution with the field measurements of the paper is illustrated in Figure 6. The agreement is reasonably good, considering that Equation 2 has no free-fitting parameters (the heave only depends on the column radius and length). There is some scatter in the field measurements, as usual, and the value of many of them is around 0. Another influential factor that may explain some differences is the presence of a rigid base, which increases the heave. That effect may also be considered analytically in an approximate way (Sagaseta and Whittle, 2001).

In this type of undrained situation, the saturated soil does not change its volume; this allows for the development of analytical



Sharp (1982, personal communication)

Figure 6. Comparison between existing analytical solution and field measurements of the original paper (taken from Figure 2(a))

solutions and explains the reduced influence of the soil stiffness, as the authors found numerically in the paper.

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