Settlement Prediction in Cape Flats Sands Using Shear Wave Velocity – Penetration Resistance Correlations

Authors : Nanine Fouche

Abstract : The Cape Flats is a low-lying sand-covered expanse of approximately 460 square kilometres, situated to the southeast of the central business district of Cape Town in the Western Cape of South Africa. The aeolian sands masking this area are often loose and compressible in the upper 1m to 1.5m of the surface, and there is a general exceedance of the maximum allowable settlement in these sands. The settlement of shallow foundations on Cape Flats sands is commonly predicted using the results of in-situ tests such as the SPT or DPSH due to the difficulty of retrieving undisturbed samples for laboratory testing. Varying degrees of accuracy and reliability are associated with these methods. More recently, shear wave velocity (Vs) profiles obtained from seismic testing, such as continuous surface wave tests (CSW), are being used for settlement prediction. Such predictions have the advantage of considering non-linear stress-strain behaviour of soil and the degradation of stiffness with increasing strain. CSW tests are rarely executed in the Cape Flats, whereas SPT’s are commonly performed. For this reason, and to facilitate better settlement predictions in Cape Flats sand, equations representing shear wave velocity (Vs) as a function of SPT blow count (N60) and vertical effective stress (□v’) were generated by statistical regression of site investigation data. To reveal the most appropriate method of overburden correction, analyses were performed with a separate overburden term (Pa/σ’v) as well as using stress corrected shear wave velocity and SPT blow counts (correcting Vs. and N60 to Vs1and (N1)60respectively). Shear wave velocity profiles and SPT blow count data from three sites masked by Cape Flats sands were utilised to generate 80 Vs-SPT N data pairs for analysis. Investigated terrains included sites in the suburbs of Athlone, Muizenburg, and Atlantis, all underlain by windblown deposits comprising fine and medium sand with varying fines contents. Elastic settlement analysis was also undertaken for the Cape Flats sands, using a non-linear stepwise method based on small-strain stiffness estimates, which was obtained from the best Vs-N60 model and compared to settlement estimates using the general elastic solution with stiffness profiles determined using Stroud’s (1989) and Webb’s (1969) SPT N60-E transformation models. Stroud’s method considers strain level indirectly whereasWebb’smethod does not take account of the variation in elastic modulus with strain. The expression of Vs. in terms of N60 and Pa/σv’ derived from the Atlantis data set revealed the best fit with $R^2 = 0.83$ and a standard error of 83.5m/s. Less accurate Vs-SPT N relations associated with the combined data set is presumably the result of inversion routines used in the analysis of the CSW results showcasing significant variation in relative density and stiffness with depth. The regression analyses revealed that the inclusion of a separate overburden term in the regression of Vs and N60, produces improved fits, as opposed to the stress corrected equations in which the R^2 of the regression is notably lower. It is the correction of Vs and N60 to Vs1 and (N1)60 with empirical constants ‘n’ and ‘m’ prior to regression, that introduces bias with respect to overburden pressure. When comparing settlement prediction methods, both Stroud’s method (considering strain level indirectly) and the small strain stiffness method predict higher stiffnesses for medium dense and dense profiles than Webb’s method, which takes no account of strain level in the determination of soil stiffness. Webb’s method appears to be suitable for loose sands only. The Versak software appears to underestimate differences in settlement between square and strip footings of similar width. In conclusion, settlement analysis using small-strain stiffness data from the proposed Vs-N60 model for Cape Flats sands provides a way to take account of the non-linear stress-strain behaviour of the sands when calculating settlement.

Keywords : sands, settlement prediction, continuous surface wave test, small-strain stiffness, shear wave velocity, penetration resistance

Conference Title : ICGITM 2022 : International Conference on Ground Investigation, Testing and Monitoring

Conference Location : London, United Kingdom

Conference Dates : December 09-10, 2022