Abstract

Investment into offshore wind farms has been growing to address the growing threat of climate change. The majority of offshore wind turbines (both current and planned) are founded on monopiles, large circular steel pipe piles ranging from 4.0 m – 7.5 m in diameter. Based on available borehole records, most planned wind turbines in the UK will be founded in overconsolidated clay deposits. Monopile design is done via usage of the well established *p-y* curves. However, there are issues with the usage of the *p-y* curves. Firstly, the curves may be unsuitable to model the monopile's behaviour as it is expected to behave similarly to a rigid pile rather than flexibly. Secondly, the curves may not accurately estimate the initial pile-soil stiffness. Thirdly, the curves are not comprehensive enough to account for the accumulated strain and stiffness changes resulting from cyclic loading. Considering these issues, research was carried out to improve the current design of monopiles in clay by carrying out displacement controlled monotonic and load controlled cyclic load tests in a centrifuge.

Results from monotonic tests suggest that the DNV (2014) design methodology to construct *p*-y curves in clay based on Matlock's (1970) soft clay criterion significantly underestimate stiffness. Findings suggested that the experimental *p-y* curves could be characterised through modification of the criterion. Modification of the criterion produced estimates that matched the 3.83 m monopile experimental curves. Pile toe shear force was observed to contribute little to ultimate lateral resistance and stiffness. Despite the marginal contribution, an effort was made to characterise the pile toe shear force. Estimates of the modified criterion on the 7.62 m monopile did not match the observations, indicating that further research should be carried out to improve the modified criterion.

The cyclic tests displayed two distinct regimes; the stiffening regime and the softening regime. Results suggests that cyclic loads of different characteristics influence the locked in stress conditions of the soil which in turn influence the excess pore pressure behaviour, hence dictating whether the stiffening or softening regime takes place. Suggestions were made regarding the conditions that dictated whether the stiffening or softening regime would take place. In the stiffening regime, the stiffening rate decreased with increasing strain while as the accumulated rotation rate increased with vertical load for the same cyclic load magnitude. The softening regime was determined to be extremely detrimental as the high rates of softening and accumulated rotations could cause failure of the system in the short-term. Recommendations were made to estimate the cyclic stiffness and accumulated rotations resulting from both stiffening and softening regime.