Proceedings of the 21st ICSMGE, Vienna, Austria, 14 – 19 June 2026. Pistrol, Adam & Schweiger (eds.)
Published by: ÖGG, Austrian Society for Geomechanics, Salzburg, Austria, ISBN 978-3-9503898-4-5
https://doi.org/10.53243/ICSMGE2026-563

Development of a lifetime cyclic design method for offshore foundations

Pishun Tantivangphaisal, David Taborda
Department of Civil and Environmental Engineering, Imperial College London, United Kingdom, pt620@imperial.ac.uk

Stavroula Kontoe
Department of Civil Engineering, University of Patras, Greece; Department of Civil and Environmental Engineering, Imperial College London, United Kingdom

ABSTRACT: The cost of foundations supporting offshore wind turbines (OWT) continue to influence the feasibility of new developments and the speed at which new sources of renewable energy are brought online. A technical challenge remains to design OWT foundations efficiently, accounting for the impact of long-term cyclic environmental actions. The combined effects of accumulated deformation and soil stiffness evolution with long-term cyclic loading have consequences for both serviceability and fatigue limit state design. Recent work on the implementation of the high-cycle accumulation framework to model the lifetime behaviour of offshore monopile foundations subject to lateral cyclic loading and validation against field tests is first summarised. This includes site-specific calibration procedures for a dense marine sand at Dunkirk and a glacial till at Cowden, demonstrating the field scale response can be reproduced well by calibrating the models using only in-situ CPT data and cyclic triaxial laboratory tests with initial conditions close to those encountered in-situ. Normalisation of results from sets of parametric numerical analyses of reference monopiles founded in uniform sands and layered sand-and-clay stratigraphy are finally presented. These can inform rapid prototyping of foundation solutions at optioneering stage and can be interrogated for use in reliability-based design methods.

KEYWORDS: Offshore, monopile, cyclic design method, finite element analysis, high cycle accumulation

1 INTRODUCTION

The use of site-specific 3D finite element (FE) models of monopile foundations is now commonplace to assess their monotonic ultimate capacities (CFMS, 2020; DNV, 2021). To address issues related to serviceability (pile rotation) and stiffness evolution with number of cycles for fatigue assessments, full 3D FE models with complex cyclic load histories (Charlton & Rouainia, 2021; Liu et al., 2022) are usually too computationally intensive for routine use. This has led to the development of a range of simplified methods, including representing the entire pile-soil system as a single set of springs at mudline or "macro-element" (Page et al., 2019; Abadie et al., 2023), as a distributed set of springs along the length of the pile (Zhang et al., 2020; Kementzetzidis et al., 2022), or 3D FE analyses employing an "accumulation" procedure without explicit modelling of the load time history (Jostad et al., 2015; Staubach & Wichtmann, 2020; Cao et al., 2023; Tantivangphaisal et al., 2025c).

This paper illustrates how a variant of the latter, highest fidelity type of model can reproduce the field scale response when calibrated using only in situ and laboratory test data. This seeks to establish a unified treatment of site-specific design, illustrated with parametric studies employing modified HCA-sand and HCA-clay models for both uniform and layered sites.

2 HIGH-CYCLE ACCUMULATION FRAMEWORK

2.1 *Synopsis*

The high-cycle accumulation (HCA) framework (Niemunis et al., 2005) is a multi-stage FE calculation strategy to analyse the effect of a large number of regular loading cycles on geotechnical structures. Figure 1 shows a schematic of a FE model of a monopile subject to lateral cyclic loads using the HCA framework. Analysis of a package of N load cycles involve the use of a conventional "low-cycle" constitutive model for (i) irregular loads prior to regular cyclic loads and (ii) one recorded regular cycle, followed by (iii) a "high-cycle" accumulation phase using these recorded strains.

The framework was modified and coupled with the Taborda et al. (2022) practice-oriented constitutive model for sands, then implemented in the commercial FE software PLAXIS (Tantivangphaisal et al., 2025b). It was validated against over tens of thousands of lateral load cycles in full-scale field testing carried out at Dunkirk (Tantivangphaisal et al., 2025c) and large-scale laboratory testing at Darmstadt (Tantivangphaisal et al., 2025a). This version of a sand model coupled with HCA is denoted as "HCA-sand" herein.

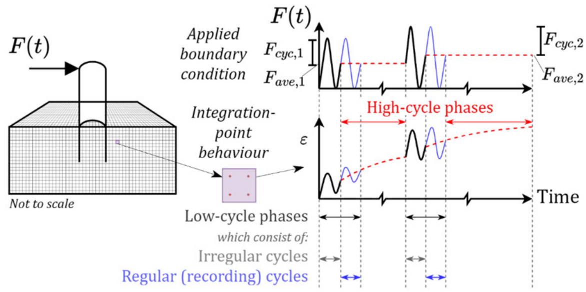

Figure 1. Illustration of a HCA laterally loaded monopile boundary value problem (Tantivangphaisal et al., 2025c)

Further extension of the basic framework for use with clays was developed by Staubach et al. (2022) for reconstituted kaolin. In-situ and cyclic laboratory tests on Cowden till were incorporated into recent work coupling further modifications of HCA with a modified Cam Clay model with non-linear elastic stiffness (Taborda et al., 2016) and a Hvorslev surface (Tsiampousi et al., 2013). This was recently validated (Tantivangphaisal, 2025) against field tests carried out in a highly overconsolidated glacial till at Cowden. This HCA-enhanced clay constitutive model is denoted as "HCA-clay".

2.2 *Calibration against in-situ and laboratory tests*

Each model is calibrated following four broadly sequential steps:

- Elastic moduli at very small strains from shear wave velocity (SCPT and/or intact sample bender elements)
- Shear modulus reduction (monotonic lab tests: small strains measured using local strain instrumentation)
- Response at large strains (triaxial and oedometer)
- Shear strain and/or pore pressure accumulation with number of cycles

In-situ (Zdravkovic et al., 2020) and laboratory test data (Liu, 2018; Ushev, 2018) were used to calibrate material specific parameters for the marine sand at Dunkirk, weathered and unweathered glacial till at Cowden using. Figure 2 shows the model's initial maximum shear modulus profiles calibrated from measurements of shear wave velocities (and densities).

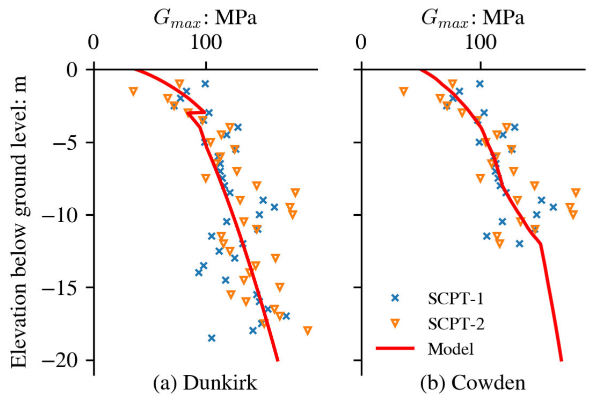

Figure 2. In-situ G_{max} profiles at (a) Dunkirk and (b) Cowden

The resultant monotonic and cyclic single element responses of HCA-sand are compared to laboratory data in Figure 3, with the corresponding monotonic and cyclic single element responses for intact Cowden till in Figure 4.

Drained monotonic, drained and undrained cyclic triaxial tests were carried out on 38mm and 100mm sand samples (water-pluviated, given the marine depositional history at Dunkirk). High quality intact samples (both rotary cored and blocks) were taken at Cowden, with mainly 100mm samples used in undrained monotonic and cyclic triaxial tests. All tests utilised high-resolution local strain instrumentation.

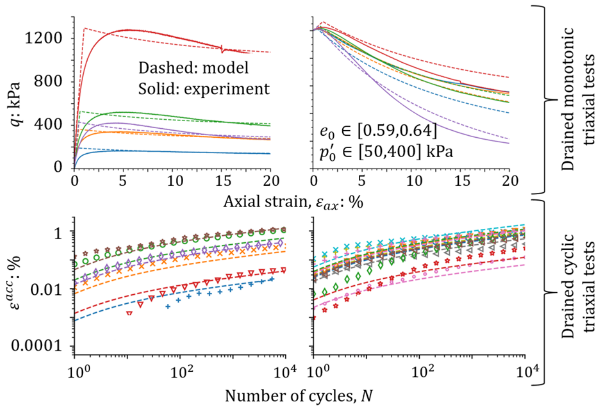

Figure 3. Calibrated monotonic and cyclic single element – Dunkirk

3 PISA FIELD TEST VALIDATION

Sets of monotonic and cyclic field tests at Dunkirk and Cowden (Byrne et al., 2017; McAdam et al., 2020; Byrne et al., 2020) were used to validate HCA-sand and HCA-clay, calibrated using in-situ site investigation and laboratory data only. Representative FE meshes for each of the long-term cyclic load test analyses (piles DM2 and CM5) are shown in Figure 5. The monopile structure was modelled using isotropic linear elastic shell elements with Young's modulus $E = 200$ GPa, Poisson's ratio $\nu = 0.3$ and varying thicknesses (DM4, DM2: 14mm; DL2: 38mm; CM9, CM5: 11mm; CL2: 25mm). The pile-soil interface is modelled using zero-thickness interface elements with linear elastoplastic Mohr-coulomb (adjacent soil critical state angle) and Tresca failure criteria (adjacent soil undrained shear strength) for sand and clay, respectively. Each soil domain was discretised using over 30,000 10-noded quadratic tetrahedral finite elements with heavy refinement near the pile.

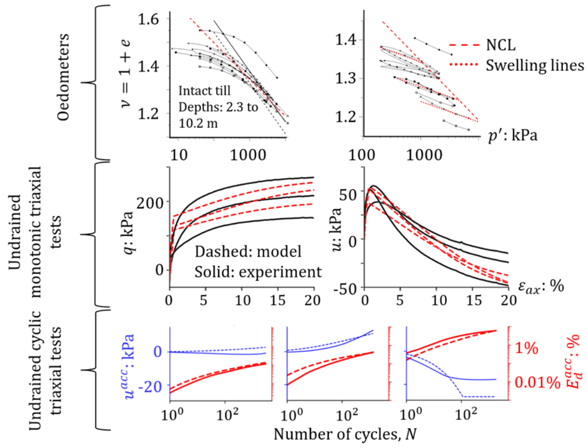

Figure 4. Calibrated monotonic and cyclic single element – Cowden

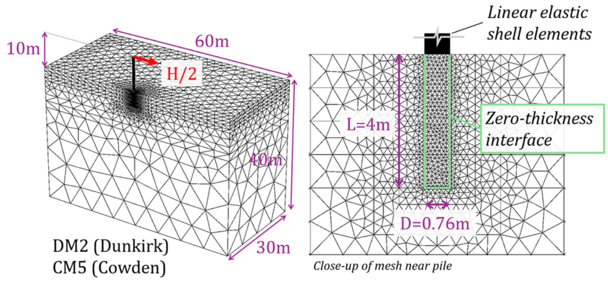

Figure 5. Finite element mesh employed in PISA validation studies

Figure 6 summarises the initial stress conditions used to model each site, as obtained from PISA site characterisation studies (Zdravkovic et al., 2020) with minor model-specific re-interpretation (Tantivangphaisal, 2025).

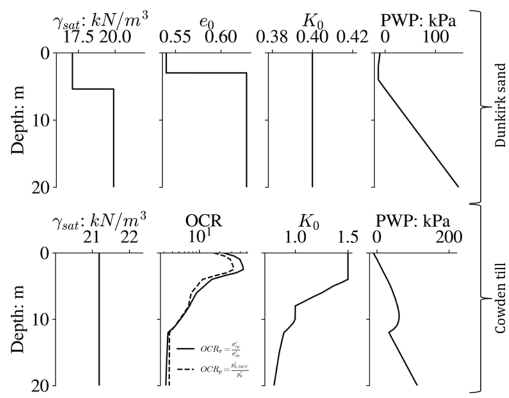

Figure 6. Initial stress conditions at Dunkirk and Cowden

The computed response at Dunkirk compares well with the field scale monotonic (two pile geometries) and cyclic tests. Figure 7 presents the field and modelled cyclic accumulation for one-way load cycles of three different magnitudes, with the maximum load level reaching 40% ULS for over 10,000 cycles.

Similarly at Cowden, the material and site-specific calibration resulted in good agreement between the model predictions and the monotonic field tests. By correcting for the untested cyclic accumulation trends of the upper weathered till layer, see Tantivangphaisal (2025), the long-term cyclic response, at three different one-way loading levels corresponding to approximately 10, 20 and 60% ULS load, also shows a reasonable match with field measurements at pile head (see Figure 8).

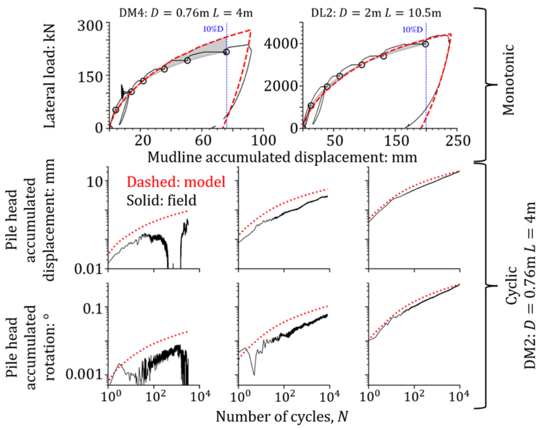

Figure 7. Model and field data at Dunkirk (pile head / mudline)

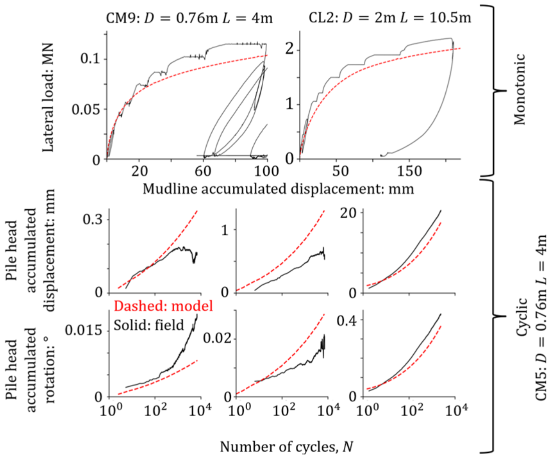

Figure 8. Model and field data at Cowden (pile head / mudline)

4 PARAMETRIC INVESTIGATION IN SAND AND SAND/CLAY LAYERED STRATIGRAPHY

Parametric FE analyses to 1 million loading cycles are used to inspect the response of HCA-sand and HCA-clay, individually and in layered strata. 10 m diameter D monopiles with length-to-diameter (L/D) ratios of 2 and 4, and moment arms h of 50 and 100m, as used in Burd et al. (2020) were selected. The same diameter was used for the monopile supporting a 15MW reference turbine in Gaertner et al. (2020). A single D/t ratio of 110 has been modelled. A consistent FE mesh, scaled to the size of each analysed monopile is employed (Figure 9).

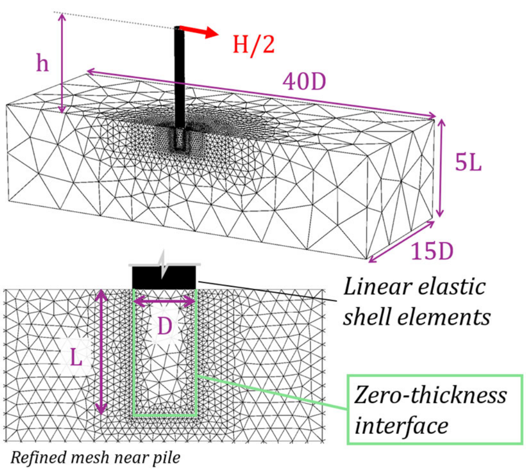

Figure 9. Finite element mesh for parametric studies

4.1 *Finite element model set-ups*

Four representative sites with idealised stratigraphies (see Figure 10) were analysed using calibrations for Dunkirk sand and the unweathered Cowden till, assuming hydrostatic conditions, full drainage in the sand and undrained clay. Initial K_0, sand state parameter ψ_0 and the undrained shear strength in triaxial compression $S_{u,TXC}$ profiles are shown in Figure 11.

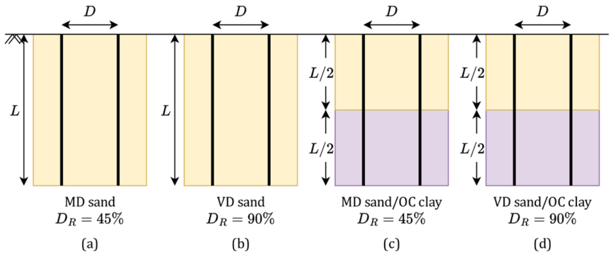

Figure 10. Representative single-layer and multi-layer site conditions (MD=medium dense; VD=very dense)

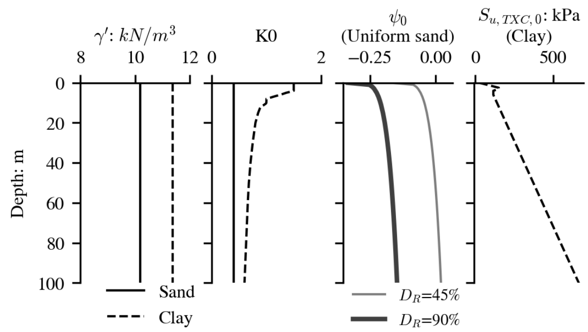

Figure 11. Initial conditions used for the sand and clay layers

Monotonic pushover analyses are shown in Figure 12 for each pile geometry, moment arm and site to obtain reference capacities (M_{ref}) corresponding to 4° tilt at pile head.

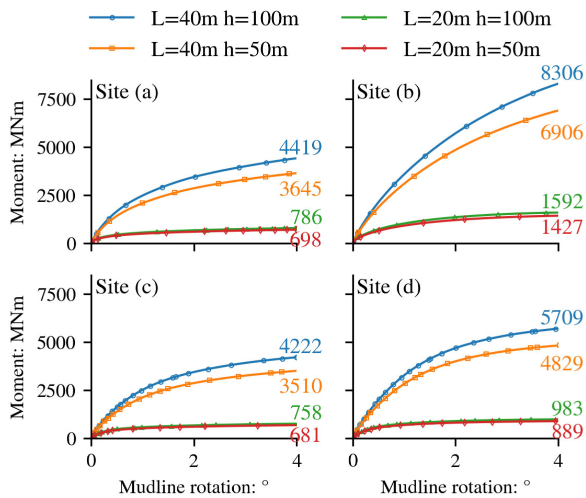

Figure 12. Reference monotonic pushover analyses

Applied lateral cyclic loads were defined following the dimensionless cyclic loading parameters from Leblanc et al. (2010). For each pile at each site, loads applied varied between $\zeta_b \in \{0.1, 0.3, 0.5\}$ and $\zeta_c \in \{-1, -0.5, 0, 0.33, 0.5\}$, where:

$$\zeta_b = M_{max}/M_{ref} \tag{1}$$

$$\zeta_c = M_{min}/M_{max} \tag{2}$$

with M_{max} and M_{min} denoting maximum and minimum moments $M = H \cdot h$ (see Figure 9) applied at pile head. Figure 13 shows the direction and magnitude of the loading cycles considered with reference to the backbone curve for one representative pile, with pre-accumulation load paths in broken lines and the start of accumulation in symbols.

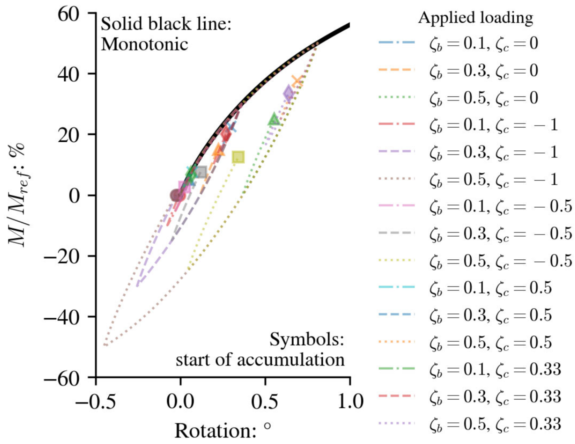

Figure 13. Illustration of average load at start of accumulation and prior irregular load cycle, for Site (b) and pile D=10m, L=40m, h=50m

4.2 *The need for site- and geometry- specific analyses*

The use of simple normalised accumulation laws for laterally loaded piles in sands, e.g. Lin & Liao (1999), Leblanc et al. (2010) and Frick & Achmus (2022) is first examined. Cyclic accumulated rotation $\Delta\theta$ is defined as the change in average pile head rotation with respect to the start of the HCA calculation phase. This is subsequently normalised by θ_s, i.e. the equivalent rotation at pile head sustained at M_{max} on the monotonic curve, as suggested by Leblanc et al. (2010) and illustrated in Figure 14.

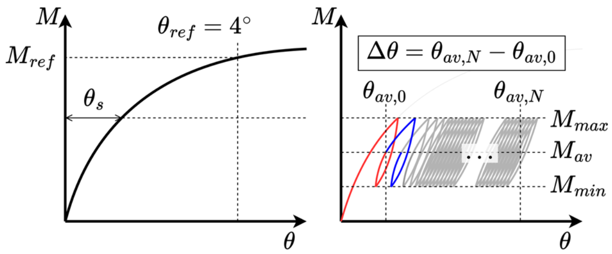

Figure 14. Illustration of start of rotation accumulation quantities

When examining computed pile head rotation with number of cycles from uniform sand sites across all ζ_b, ζ_c, h, L and D_R, under certain combinations of site, geometry and two-way loading ($\zeta_c = -1$), the model produces negative rotation with number of cycles.

At $\zeta_c = -1$, the downwind direction is simply the initial loading direction and is arbitrarily distinguished from the upwind direction. These analyses show that piles subject to symmetric two-way loads may accumulate rotations either in the direction of or opposite to the initial direction. Conventional accumulation laws cannot account for such behaviour, and the two-way analyses were first removed from the FE dataset and each pile head rotation with N is further fitted using a power law function of the form:

$$\frac{\Delta\theta}{\theta_s} = m \cdot (1 + N)^r - m \qquad (3)$$

This follows the single element accumulation law in the HCA-sand formulation, found to describe well the shape of the computed pile head global rotation trends. A conventional power law of the form $a \cdot N^b$ would fit linearly in the same log-log space and thus fail to capture the observed response.

The fitted parameters m (**m**agnitude of accumulation, i.e. parallel upward/downward shift of curve in log-log space) and r (**r**ate of accumulation, gradient of curve in log-log space) are presented for all analysed piles in uniform sands in Figure 15.

Each row represents fitted parameters for the same loading direction ζ_c, with different sizes of cyclic load magnitude ζ_b on the x-axis. It is evident that a linearly increasing trend can be seen for the rate of accumulation parameter r when pile lengths are grouped together (circles: L=20m, squares: L =40m), although deviations from a clear pattern with D_R (blue: 45%, red: 90%) is observed for $\zeta_c = 0.33$. The same patterns do not seem as apparent for the overall magnitude of accumulation, which plots more erratically, as seen on the left column in Figure 15. On further inspection, both increasing and decreasing trends of m can be seen for increasing load magnitude ζ_b, suggesting that effects of site, material, geometry and loading conditions may not be easily generalised using catch-all functions considering only ζ_b, ζ_c and D_R. Although the single set of model parameters employed describes well the mechanical response of Dunkirk sand across a range of different relative densities and pressures, the current study considers only one sand of one geological origin.

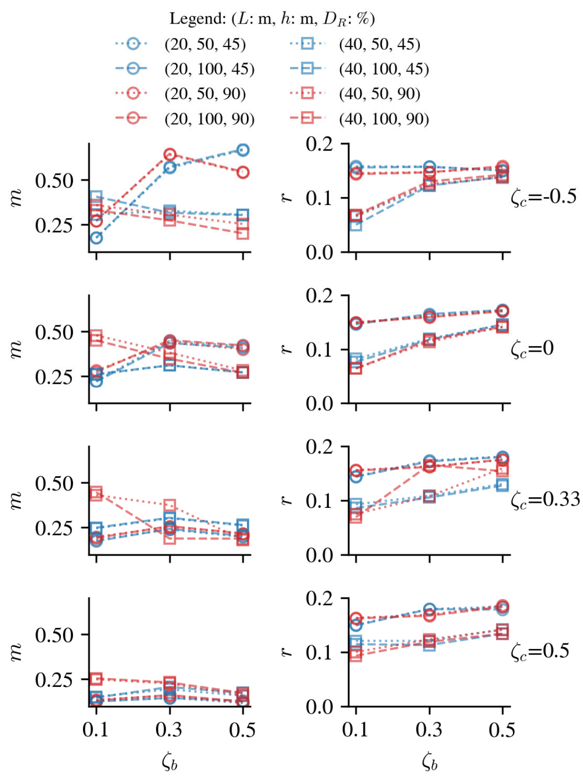

Figure 15. Fitted m and r for uniform sand sites

4.3 *Single site, single pile, multiple loading conditions*

To tie in with the loading inputs derived from integrated load analyses of a turbine-structure-foundation model, a design chart for a single site and a single pile geometry is suggested to be used for quick assessments of the cyclic accumulation due to a range of different loading characteristics. Figure 16 shows an example for a single cycle number N = 10,000 from such a design chart, plotting accumulated pile head rotation on the y-axis against ζ_b and ζ_c along the x-axes.

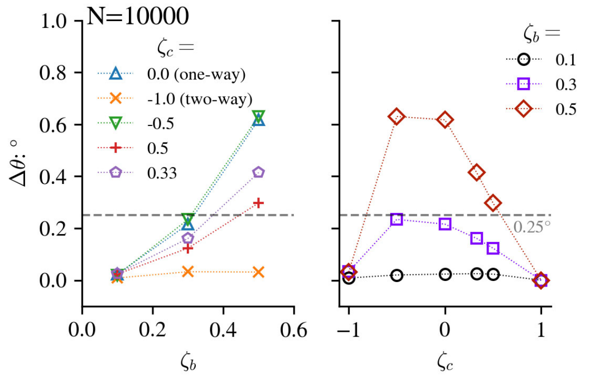

Figure 16. Example of normalised cyclic accumulation chart for Site (a) and pile D=10m, L=40m, h=50m at $N = 10{,}000$

A horizontally stacked view in 3D allows visualisation of the accumulation of pile head rotation with number of cycles. The right-hand plot in Figure 16 (at $N = 10^4$) is shown as the middle group of curves in Figure 17, with $N = 10^2$ and $N = 10^6$ to its left and right. Data points at other cycle numbers are not shown for clarity but are easily read from the FE results.

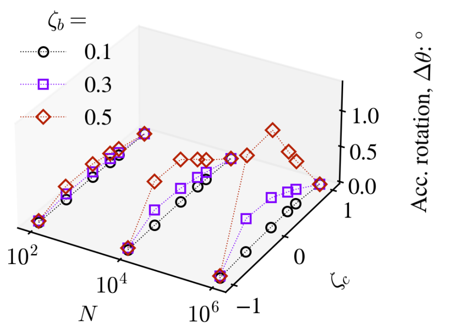

Figure 17. Example of a single pile cyclic accumulation design chart

4.4 *Differences in normalised response: D_R and L*

To establish the effects of D_R and L, the response of monopiles embedded in a medium dense site with (a) $D_R = 45\%$ and a very dense site (b) $D_R = 90\%$ are compared. These results are shown in Figure 18 for two embedment lengths, across different loading directions $\zeta_c \in \{-0.5, 0, 0.33, 0.5\}$ at the maximum applied load magnitude $\zeta_b = 0.5$. When removing the effects of moment arm and load magnitude, the adopted normalisation procedure generalises reasonably well for the two selected embedment lengths and relative densities. It is also noteworthy that, when holding all else constant, longer pile embedment (comparing left and right subplots in each row) provides greater resistance against (normalised) rotations, which is not necessarily an intuitive result, given that load levels are also correspondingly larger (see Figure 12, Equations (1) and (2)).

4.5 *Multiple sites with layered stratigraphy*

Focusing on a single geometry (L=40m, h=50m), the effect of an overconsolidated (OC) clay layer underlying a sand stratum of either $D_R = 45\%$ or $D_R = 90\%$ are examined at pile head in Figure 19, for a single magnitude of $\zeta_b = 0.5$. Using the monotonic curves as reference, the sand/clay site (c) provides very similar resistance to the sand-only at $D_R = 45\%$ (a). However, for $D_R = 90\%$, the layered site (d) is significantly weaker than the sand-only site (b). Cyclic accumulations at three different values of ζ_c are plotted in normalised terms to account for the different loading magnitudes due to M_{ref}. On the left, although applied loads are practically the same, the $D_R = 45\%$/OC-clay site (red) accumulates at a greater rate at all load magnitudes; on the right, a similar phenomenon can be seen. Clearly, normalisation with respect to θ_s provides a unified response across D_R when the same pile length, moment arm, load magnitude ζ_b and material parameters are kept constant, as seen comparing the left and right subplots.

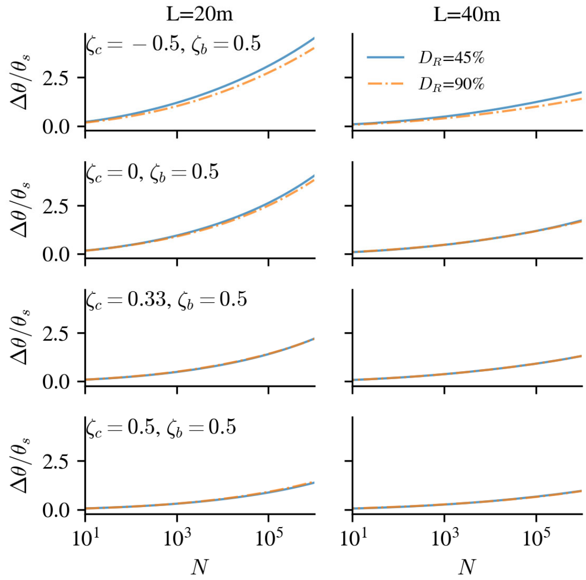

Figure 18. Normalised pile head rotation response with number of cycles, comparing embedment lengths (columns) and loading direction (rows)

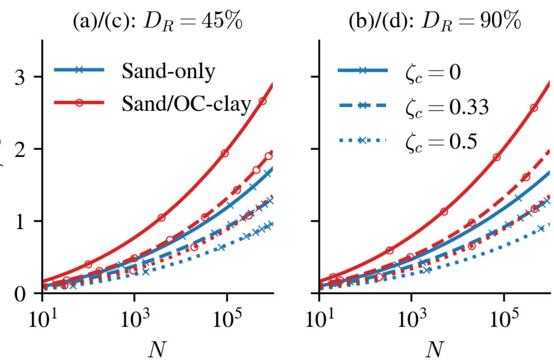

Figure 19. Normalised accumulation comparing single and multi-layered sites

5 CONCLUSIONS

A unified framework to account for the long-term cyclic accumulation of piles founded in sands, clays or multi-layered sites has been developed based on the high-cycle accumulation (HCA) framework. Material parameters for HCA-sand and HCA-clay calibrated using only in-situ and laboratory test data form the basis of a set of parametric FE studies varying moment arm, loading directions, magnitudes, single/layered stratigraphy and pile length.

The study showed that these factors all contribute to global cyclic accumulation trends for laterally loaded monopiles. Further refinement of simplified pile head accumulation functions may be possible. While new functions are likely required for L/D and moment arm effects, an across-site normalisation is demonstrated for uniform and two-layered sites. The HCA framework can also be used to produce cyclic accumulation contours or response surfaces across a wide range of loading conditions. This provides a robust means for rapid validation of serviceability with varying design load cases.

6 ACKNOWLEDGEMENTS

The authors acknowledge the financial support of the Skempton scholarship from the Department of Civil and Environmental Engineering, Imperial College London for the first author's PhD studies.

7 REFERENCES

Abadie, C.N., Beuckelaers, W.J.A.P., Byrne, B.W., Houlsby, G.T., Burd, H.J. & McAdam, R. (2023) Modeling Lifetime Performance of Monopile Foundations for Offshore Wind Applications. Journal of Geotechnical and Geoenvironmental Engineering. 149 (8), 04023051. doi:10.1061/JGGEFK.GTENG-9833.

Burd, H.J., Abadie, C.N., Byrne, B.W., Houlsby, G.T., Martin, C.M., McAdam, R.A., Jardine, R.J., Pedro, A.M.G., Potts, D.M., Taborda, D.M.G., Zdravkovic, L. & Andrade, M.P. (2020) Application of the PISA design model to monopiles embedded in layered soils. Géotechnique. 70 (11), 1067–1082. doi:10.1680/jgeot.20.PISA.009.

Byrne, B., McAdam, R., Burd, H., Houlsby, G., Martin, C., et al. (2017) PISA: New Design Methods for Offshore Wind Turbine Monopiles. In: 2017 p. 20.

Byrne, B.W., McAdam, R.A., Burd, H.J., Beuckelaers, W.J.A.P., Gavin, K.G., Houlsby, G.T., Igoe, D.J.P., Jardine, R.J., Martin, C.M., Muir Wood, A., Potts, D.M., Skov Gretlund, J., Taborda, D.M.G. & Zdravkovic, L. (2020) Monotonic laterally loaded pile testing in a stiff glacial clay till at Cowden. Géotechnique. 70 (11), 970–985. doi:10.1680/jgeot.18.PISA.003.

Cao, S., Abdel-Rahman, K. & Achmus, M. (2023) A new method for the analysis of foundation behavior in sand under drained high-cycle loading. International Journal for Numerical and Analytical Methods in Geomechanics. 47 (10), 1876–1893. doi:10.1002/nag.3542.

CFMS (2020) Recommendations for planning and designing foundations of offshore wind turbines version 2.1. Version 2.1. Comite Francais de Mecanique des Soils et de Geotechnique.

Charlton, T.S. & Rouainia, M. (2021) Cyclic performance of a monopile in spatially variable clay using an advanced constitutive model. Soil Dynamics and Earthquake Engineering. 140, 106437. doi:10.1016/j.soildyn.2020.106437.

DNV (2021) DNV-2021-ST-0126 Support structures for wind turbines.

Frick, D. & Achmus, M. (2022) A model test study on the parameters affecting the cyclic lateral response of monopile foundations for offshore wind turbines embedded in non-cohesive soils. Wind Energy Science. 7 (4), 1399–1419. doi:10.5194/wes-7-1399-2022.

Gaertner, E., Rinker, J., Sethuraman, L., Zahle, F., Anderson, B., Barter, G., Abbas, N., Meng, F., Bortolotti, P., Skrzypinski, W., Scott, G., Feil, R., Bredmose, H., Dykes, K., Shields, M., Allen, C. & Viselli, A. (2020) Definition of the IEA 15MW offshore reference wind turbine. https://www.nrel.gov/docs/fy20osti/75698.pdf.

Jostad, H.P., Grimstad, G., Andersen, K.H. & Sivasithamparam, N. (2015) A FE procedure for calculation of cyclic behaviour of offshore foundations under partly drained conditions. In: Frontiers in Offshore Geotechnics III. 2015 Oslo, Norway, CRC Press. pp. 153–172.

Kementzetzidis, E., Pisanò, F. & Metrikine, A.V. (2022) A memory-enhanced p-y model for piles in sand accounting for cyclic ratcheting and gapping effects. Computers and Geotechnics. 148, 104810. doi:10.1016/j.compgeo.2022.104810.

Leblanc, C., Houlsby, G.T. & Byrne, B.W. (2010) Response of stiff piles in sand to long-term cyclic lateral loading. Géotechnique. 60 (2), 79–90. doi:10.1680/geot.7.00196.

Lin, S.-S. & Liao, J.-C. (1999) Permanent Strains of Piles in Sand due to Cyclic Lateral Loads. Journal of Geotechnical and Geoenvironmental Engineering. 125 (9), 798–802. doi:10.1061/(ASCE)1090-0241(1999)125:9(798).

Liu, H.Y., Kementzetzidis, E., Antontio Abell, J. & Pisanò, F. (2022) From cyclic sand ratcheting to tilt accumulation of offshore monopiles 3D FE modelling using SANISAND-MS. Géotechnique. 72 (9), 753–768.

Liu, T. (2018) Advanced laboratory testing for offshore pile foundations under monotonic and cyclic loading. PhD. Imperial College London.

McAdam, R.A., Byrne, B.W., Houlsby, G.T., Beuckelaers, W.J.A.P., Burd, H.J., Gavin, K.G., Igoe, D.J.P., Jardine, R.J., Martin, C.M., Muir Wood, A., Potts, D.M., Skov Gretlund, J., Taborda, D.M.G. & Zdravkovic, L. (2020) Monotonic laterally loaded pile testing in a dense marine sand at Dunkirk. Géotechnique. 70 (11), 986–998. doi:10.1680/jgeot.18.PISA.004.

Niemunis, A., Wichtmann, T. & Triantafyllidis, Th. (2005) A high-cycle accumulation model for sand. Computers and Geotechnics. 32 (4), 245–263. doi:10.1016/j.compgeo.2005.03.002.

Page, A.M., Grimstad, G., Eiksund, G.R. & Jostad, H.P. (2019) A macro-element model for multidirectional cyclic lateral loading of monopiles in clay. Computers and Geotechnics. 106, 314–326. doi:10.1016/j.compgeo.2018.11.007.

Staubach, P., Machacek, J., Tafili, M. & Wichtmann, T. (2022) A high-cycle accumulation model for clay and its application to monopile foundations. Acta Geotechnica. 17 (3), 677–698. doi:10.1007/s11440-021-01446-9.

Staubach, P. & Wichtmann, T. (2020) Long-term deformations of monopile foundations for offshore wind turbines studied with a high-cycle accumulation model. Computers and Geotechnics. 124, 103553. doi:10.1016/j.compgeo.2020.103553.

Taborda, D.M.G., Pedro, A.M.G. & Pirrone, A.I. (2022) A state parameter-dependent constitutive model for sands based on the Mohr-Coulomb failure criterion. Computers and Geotechnics. 148, 104811. doi:10.1016/j.compgeo.2022.104811.

Taborda, D.M.G., Potts, D.M. & Zdravkovic, L. (2016) On the assessment of energy dissipated through hysteresis in finite element analysis. Computers and Geotechnics. 71, 180–194. doi:10.1016/j.compgeo.2015.09.001.

Tantivangphaisal, P. (2025) Development of a constitutive framework to model the long-term cyclic performance of offshore foundations. PhD. London, U.K., Imperial College London.

Tantivangphaisal, P., Ortiz-Wall, F., Taborda, D.M.G., Machacek, J., Liaudat, J. & Zachert, H. (2025a) GEOLAB Blind Prediction Contest: Winning Methods for Predicting Pile Behaviour under Monotonic and Cyclic Lateral Loading. In: Proceedings of the 5th International Symposium on Frontiers in Offshore Geotechnics. 2025 Nantes, France. pp. 1533–1538. doi:10.53243/ISFOG2025-390.

Tantivangphaisal, P., Taborda, D.M.G. & Kontoe, S. (2025b) Implementation of a practical sand constitutive model coupled with the High Cycle Accumulation framework in PLAXIS. MethodsX. 14, 103183. doi:10.1016/j.mex.2025.103183.

Tantivangphaisal, P., Taborda, D.M.G., Kontoe, S., Jardine, R.J. & Liu, T. (2025c) Numerical modelling of the long-term cyclic response of laterally loaded piles driven in sands using the High-Cycle Accumulation framework. Geotechnique. Ahead of print. doi:10.1680/jgeot.24.01404.

Tsiampousi, A., Zdravković, L. & Potts, D.M. (2013) A new Hvorslev surface for critical state type unsaturated and saturated constitutive models. Computers and Geotechnics. 48, 156–166. doi:10.1016/j.compgeo.2012.09.010.

Ushev, E. (2018) Laboratory Investigation of the Mechanical Properties of Cowden Till under Static and Cyclic Conditions. PhD. Imperial College London.

Zdravkovic, L., Jardine, R.J., Taborda, D.M.G., Abadias, D., Burd, H.J., Byrne, B.W., Gavin, K.G., Houlsby, G.T., Igoe, D.J.P., Liu, T., Martin, C.M., McAdam, R.A., Muir Wood, A., Potts, D.M., Skov Gretlund, J. & Ushev, E. (2020) Ground characterisation for PISA pile testing and analysis. Géotechnique. 70 (11), 945–960. doi:10.1680/jgeot.18.PISA.001.

Zhang, Y., Andersen, K.H., Jeanjean, P., Karlsrud, K. & Haugen, T. (2020) Validation of Monotonic and Cyclic p-y Framework by Lateral Pile Load Tests in Stiff, Overconsolidated Clay at the Haga Site. Journal of Geotechnical and Geoenvironmental Engineering. 146 (9), 04020080. doi:10.1061/(ASCE)GT.1943-5606.0002318.