Public Report

MIDAS *project summary*

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Content

1 Introduction

The renewable energy sector is experiencing a worldwide boom, with offshore wind playing an increasingly prominent role. Larger and more powerful offshore wind turbines (OWTs) are being installed, which is enabled by the technological progress and cost reduction achieved in the last few years. Installations in deeper waters and harsher environments are significantly challenging engineering design, particularly with regard to OWT foundations such as monopiles. Higher capacity OWTs require larger monopiles, depending on soil conditions and environmental (wind/wave) loading. Presently, about 20% of the investment for the construction of an offshore wind farm relates to the design, production, and installation of substructures. This fact continues to motivate new threads of geotechnical research. Despite the remarkable advances in the analysis of monopile-soil interaction, significant knowledge gaps are still to befilled, for instance regarding the response of monopiles to cyclic loading of different amplitude, duration, and frequency.

This report summarises the background, main results, and final recommendations of the MIDAS project, a research programme led by TU Delft in collaboration with Deltares and offshore industry partners. Over the past four years, the MIDAS project team has been working to enhance the fundamental understanding of monopile-soil interaction under lateral cyclic loading, particularly for sandy soils. The research involved advanced physical and numerical modelling studies, including centrifuge testing and detailed 3D FE modelling. The outcomes of both experimental and numerical activities were used to develop new cyclic 1D soil reaction models for monopiles in sand, which are commonly used in engineering practice. While MIDAS industry partners have gained an early advantage in learning and utilising this new knowledge, substantial efforts will be devoted in the near future to disseminating MIDAS results internationally through journal and conference papers as well as oral presentations.

2 Project overview

The MIDAS project was conducted from May 1, 2020, to April 30, 2024, with funding provided by RVO (Rijksdienst voor Ondernemend Nederland –- Netherlands Enterprise Agency) and industry partners illustrated in **Figure 1**. This project was part of the GROW programme's portfolio for research and development in offshore wind, a collaborative initiative designed to promote research and accelerate innovations in this sector (https://grow-offshorewind.nl/project/midas). Additionally, a podcast aimed at disseminating information about the MIDAS project to the general public is available at https://grow-to-go.nl/202205-midas.

Figure 1: The MIDAS consortium

2.1. Objectives

The project titled MIDAS – Monopile Improved Design through Advanced cyclic Soil modelling, encapsulates its mission. MIDAS aimed to achieve a deeper understanding of cyclic monopile-soil interaction in sand through a combination of physical and numerical modelling. The knowledge gained from these advanced modelling studies was integrated into a 1D monopile-soil interaction model for practical design analysis, focusing on accurately predicting lateral stiffness and deflection/rotation accumulation of offshore monopiles under environmental cyclic loading. Ultimately, the project's results are expected to support optimal use of structural steel, thereby reducing costs in offshore wind developments.

To achieve this mission, experimental and numerical research was conducted using the facilities and expertise at TU Delft and Deltares. An extensive centrifuge testing program was planned to examine the influence of various geometrical, geotechnical, and loading factors on the cyclic response of stiff monopiles. Concurrently, centrifuge data supported the calibration of a detailed 3D FE model, which was used for targeted parametric studies. The high-fidelity experimental and numerical data provided the foundation for developing new cyclic 1D soil reaction models, including distributed soil reactions along the pile shaft (both lateral and rotational) and at the base. The necessity for multiple soil reaction components for short monopiles was highlighted as a significant outcome of the well-known PISA project (Byrne, et al., 2019).

Industry partners had the opportunity to conduct preliminary in-house testing of the new MIDAS 1D model, seeking connections and synergies with other tools currently used in their engineering practices. These activities allowed for a critical assessment of MIDAS' findings, which were then fed back to the core research team to develop recommendations for future work. Additionally, a collaboration with DNV was established to create a plan for the Technology Qualification of the MIDAS design model, which will be further pursued and completed following project completion and additional validation and publication efforts.

2.2. Methodology

The MIDAS project encompassed research tasks ranging from monopile testing and simulation to the development and calibration of new 1D cyclic soil reaction models. These tasks were organized into four interconnected work packages (WPs) (**Figure 2**). In addition to detailing the contents of these four WPs (and their related sub-packages), the interaction between research institutes and industry partners is also depicted in **Figure 2**.

From a methodological standpoint, the research program relied on the interplay between experimental and numerical work (**Figure 3**). Cyclic centrifuge tests were conducted on instrumented monopiles (MPs) with various aspect ratios, yielding novel data on the load-deflection response at the monopile head, the evolving bending moments along the monopile, and the behaviour of the surrounding soil, including total soil pressure and, where applicable, pore water pressure development. In conjunction with small-scale monopile testing, the same sand used in the centrifuge experiments (Geba sand) was characterized through element testing at the Deltares geotechnical laboratory.

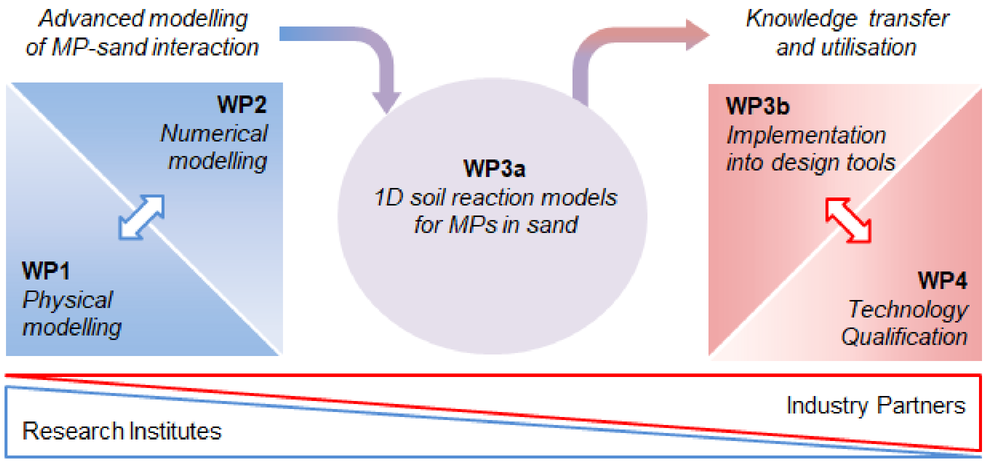

Figure 2: Organisation of project tasks and interaction among WPs.

The experimental data on the cyclic behaviour of the sand and the monopile-sand system supported the parameter calibration for the SANISAND-MS constitutive model by (Liu, Abell, Diambra, & Pisanò, 2019) and facilitated an in-depth validation of 3D FE monopile-soil models (Liu, Kementzetzidis, Abell, & Pisanò, 2022); (Pisanò, Del Brocco, Ho, & Brasile, 2024). Extensive 3D FE parametric studies were conducted to broaden the experimental dataset, covering soil and loading conditions not included in the centrifuge testing program. The insights gained from interpreting soil mechanisms through experimental measurements and 3D FE simulations informed the formulation and calibration of the final 1D cyclic soil reaction model.

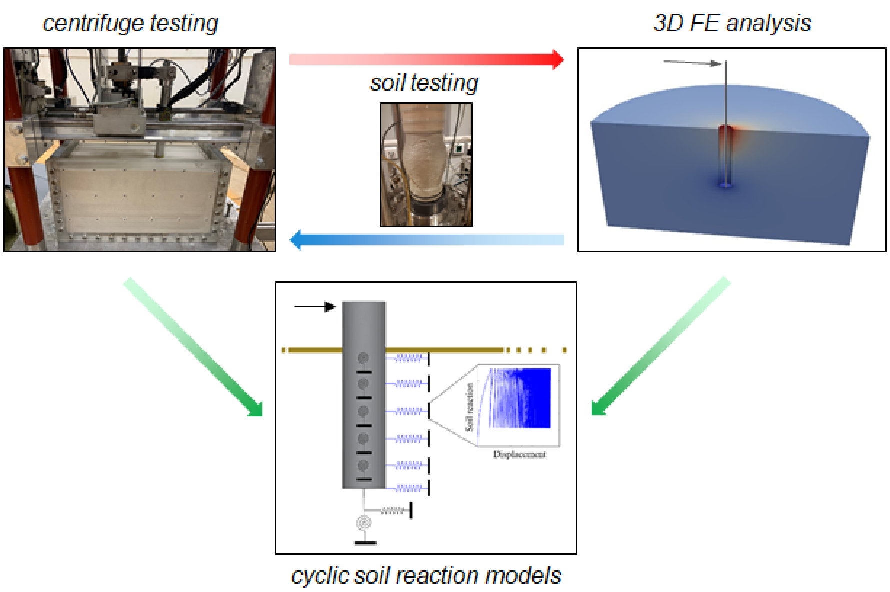

Figure 3: Synopsis of MIDAS' research methodology.

3 Summary of research activities

The results of the research activities conducted over the four-year duration of the MIDAS project are detailed in the following reports – exclusively available to the project partners:

1. Geba sand laboratory tests

2. Cyclic testing of monopiles in sand using Deltares' centrifuge

3. 3D FE simulation of monopile lateral behaviour in Geba sand

4. Cyclic testing of monopiles in sand using TU Delft's centrifuge

5. Formulation and calibration of a new 1D FE cyclic soil reaction model

These reports were prepared by the core research team, reviewed by industry partners, and revised into their final versions. They will remain the confidential property of the MIDAS consortium members, although specific information and data will be extracted for scientific dissemination purposes (see section 5).

3.1. WP1 – Physical modelling of cyclic monopile-sand interaction

The results of MIDAS' experimental activities are comprehensively detailed in Report #1 (element testing program on Geba sand conducted at Deltares) and Reports #2 and #4 (centrifuge testing programs carried out at Deltares and TU Delft, respectively, as illustrated in **Figure 4**).

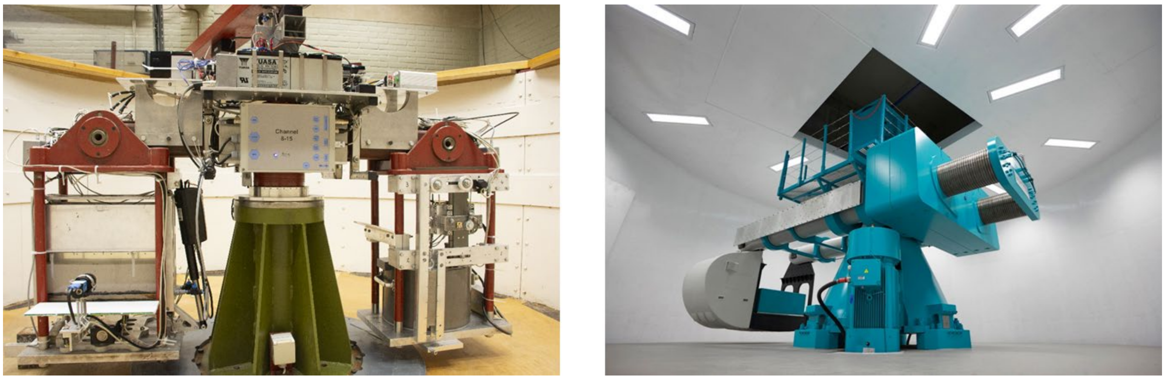

Figure 4: Geotechnical centrifuges at Delft University (left) and Delatares (right).

Several types of soil element tests were conducted to characterize the behaviour of the sand selected for the subsequent centrifuge experiments — Geba sand (**Table 1**). The objective of these experimental tests was to define the properties of the sand and evaluate its behaviour under different loading conditions, stress paths, and density states. The experimental results aligned with trends found in the literature, showing no unusual behaviour, and were deemed repeatable and reproducible. Selected lab test data were used in WP2 for the calibration of the SANISAND-MS model and the execution of 3D FE parametric studies, which were compared to centrifuge test data.

Table 1: List of MIDAS soil element tests on Geba sand.

Test type	Test #	Objective
Particle size distribution	1	To obtain the PSD curve
Grain shape	1	Determine grain angularity/roundness
Maximum and minimum density of sand	1	Obtain the maximum (ρ_{max}) and minimum densities (ρ_{min})
Permeability test	9	Obtain permeability ($\boldsymbol{k}$)
Bender element test	15	Obtain small-strain shear modulus ($\boldsymbol{G_{max}}$)
Monotonic drained triaxial compression test	12	Stress-strain and volumetric response
Cyclic drained triaxial test	7	Stress-strain, deviatoric strain accumulation, volumetric strain accumulation
Undrained cyclic DSS test	5	Infer number of cycles to failure, pore water pressure generation during cycles, liquefaction behaviour
Oedometer test	12	1D compression behaviour

The main goal of the centrifuge testing programme was to assess how different test conditions (e.g., pile aspect ratio, cyclic loading sequence, cyclic loading amplitude, soil saturation) affect monopile rotation accumulation, influenced by soil behaviour and pile structural response. Additionally, the programme aimed to cover a wide range of scenarios to calibrate and verify the MIDAS 1D cyclic soil reaction model.

The MIDAS project's experimental programme included 36 tests in the TU Delft centrifuge and 40 tests in the Deltares centrifuge. The TU Delft tests, conducted at a smaller scale due to equipment dimensions, aimed to verify general features of monopile behaviour in sand and provide qualitative insights into monopile deflection accumulation under cyclic loading. However, these results were less suitable for quantitative model verification due to lower stress levels from small pile dimensions and uncertainties associated with 1g jacking pile installation before centrifuge spinning.

To better replicate large field monopiles and eliminate installation effects, larger diameter wished-in-place monopiles were tested in the Deltares centrifuge. These tests provided the primary data for calibrating and validating the MIDAS 1D model, considering better-defined soil states before testing. In the Deltares centrifuge, 10 monotonic and 24 cyclic tests in dense sand were executed between March and August 2022. Additionally, 2 monotonic and 4 cyclic tests in medium-dense sand were conducted between August and September 2023 to further investigate possible pore pressure effects in the cyclic response of monopiles in sand.

The cyclic loading program, designed based on Siemens Gamesa's estimated loads for 7 MW and 14 MW offshore wind turbines, was structured using the cyclic parameters defined by (LeBlanc, Houlsby, & Byrne, 2010). These parameters, denoted as the dimensionless load factors ζ_b and ζ_c, quantify the maximum load amplitude relative to monotonic lateral capacity and the degree of load asymmetry within a cycle, respectively.

The testing program was designed to investigate several aspects:

- *Cyclic Load Characteristics*: Assessing the effects of cyclic load amplitude and asymmetry on pile rotation accumulation and potential pore pressure accumulation by comparing responses to initial cyclic loading sequences.

- *Load Sequence*: Conducting tests with identical boundary conditions and cyclic load packets but varying loading sequences to evaluate the impact of sequence on the results.

- *Saturation and Pore Fluid*: Investigating the potential accumulation of pore pressure under high-amplitude and two-way cyclic loading using sensors near the pile. Tests were performed with different pore fluids (water and viscous fluid) to study drainage conditions.

- *Sand Density*: Analyzing the effect of sand density on pore pressure accumulation under high-amplitude cyclic loads. Tests were conducted with sand saturated with viscous fluid to simulate realistic drainage responses, maintaining consistency in loading sequences.

These investigations aimed to enhance understanding of how these factors influence monopile behaviour under cyclic loading conditions, crucial for calibrating and validating the MIDAS 1D cyclic soil reaction model. It is also important to highlight aspects that were not part of the MIDAS experimental programme:

— sandy soils different from Geba sand in terms of mineralogy, micro-structure (including grain size distribution and fabric), and presence of fine fractions;
— layered deposits including combinations of sand and clay;
— monopiles with aspect ratio (L/D) lower than 3, bordering the case of caissons;
— differences in cyclic response attributable to differences in pile installation technology;
— more complex lateral loading conditions including random load time histories and/or multi-directional cyclic loading (including variation of load orientation and/or misalignment between dominant load direction and its cyclic perturbation);
— fully dynamic response during soil-monopile motion and possible occurrence of soil liquefaction phenomena (all relevant to seismic loading conditions).

3.2. WP2 – Numerical modelling of cyclic monopile-sand interaction

Numerical modelling results of laterally loaded monopiles in sand are reported in Report #3. The primary objective of WP2 was to provide input to other work packages regarding the lateral behaviour of the monopile, based on the results of advanced 3D simulations.

Two different Finite Element (FE) analysis platforms, Opensees and PLAXIS 3D, were assessed to determine the most suitable simulation tool for the MIDAS project. PLAXIS 3D was selected based on its proven performance and widespread acceptance in the geotechnical community. For further details, refer to (Pisanò, Del Brocco, Ho, & Brasile, 2024) which discusses the application of PLAXIS 3D's implementation of the SANISAND-MS model in simulating PISA field tests in Dunkirk.

The SANISAND-MS model was chosen as the constitutive model for accurately representing sand behaviour under both monotonic and cyclic loading conditions. Calibration and validation of the SANISAND-MS model were conducted using laboratory test results and centrifuge test data obtained from MIDAS experimental research. A parametric study was also undertaken to thoroughly investigate the effects of pile geometry, loading conditions, and sand density on the lateral behaviour of the monopile.

The 3D FE simulation results indicate that the base shear component moderately contributes to the lateral load balance equilibrium, while the contribution of the base moment to the monopile moment balance is less significant and can be ignored for simplicity. The simulation results of both monotonic and cyclic loading cases suggest that the relative stiffness of the monopile (with respect to the surrounding soil) plays a significant role in distinguishing monopile lateral behaviour. It should be noted, however, that the 3D FE simulation programme executed in WP2 exclusively considered the case of one-way cyclic loading, considered herein the most relevant to the development of 1D cyclic soil reaction models capable of reproducing the cyclic accumulation of lateral pile deflection and rotation.

Overall, the study provides valuable insights into the factors influencing the lateral behaviour of monopiles, highlighting the roles of load level, pile geometry, load eccentricity, and sand density. Future work should focus on several key areas to enhance the understanding and performance of monopiles. These include systematically and numerically investigating the effects of installation on monopile capacity and the accumulation of displacement under cyclic loading. Additionally, developing refined calibration methods for constitutive models to account for the effects of soil initial fabric and pile installation on the accumulated tilt of monopiles is essential. Finally, studying the soil drainage conditions around monopiles under irregular cyclic environmental loading will provide deeper insights and improve the predictive capabilities for monopile behaviour under various conditions.

3.3. WP3 – From advanced to engineering modelling of cyclic monopile-sand nteraction

Formulation details, validation, and calibration method of the final MIDAS 1D cyclic soil reaction model are covered in Report #5.

The development of the soil reaction model began with the CPT-based p-y spring model for monotonic loading proposed by (Suryasentana & Lehane, 2016). This model had previously been extended for lateral cyclic loading, including ratcheting behaviour, as part of the Gentle Driving of Piles (GDP) project, which preceded and partially overlapped with MIDAS, by (Kementzetzidis, Pisanò, & Metrikine, A memory-enhanced py model for piles in sand accounting for cyclic ratcheting and gapping effects, 2022) within the framework of memory-enhanced bounding surface plasticity. The resulting cyclic 1D model incorporated a single soil reaction component (p-y) and was validated against the results of GDP test piles, which typically had high slenderness ratios (L/D > 10), somewhat deviating from the characteristics of monopiles (Kementzetzidis, et al., 2023).

In the MIDAS project, monopiles with smaller slenderness ratios (3 < L/D < 7.5, with most piles having L/D between 3 and 5) were tested. Consequently, the influence of additional soil reaction components, namely base shear, base moment, distributed moment, and lateral p-y springs, was investigated.

After confirming through detailed 3D FE modelling work in WP2 that the contribution of base moment reaction can be disregarded for practical purposes under both monotonic and cyclic loading conditions, the MIDAS 1D model was simplified. The simplified model now includes three sets of soil reaction springs: base shear, distributed moment, and lateral p-y springs. These components were selected to accurately capture the behaviour of monopiles subjected to lateral loading in offshore wind environments.

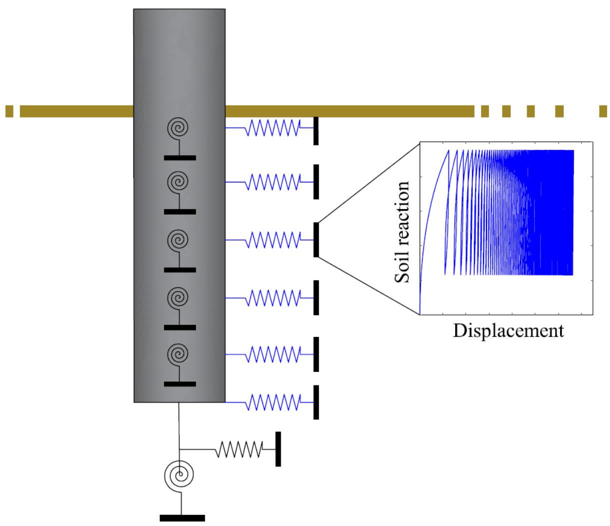

Figure 5: Idealisation of the MIDAS 1D soil reaction model.

The main principles and previous work underlying the MIDAS cyclic soil reaction model can be summarized as follows -- further details provided in Report #5:

- the MIDAS model allows full step-by-step simulation of cyclic response. Model equations are formulated using memory-enhanced bounding surface plasticity, inspired by (Kementzetzidis, Pisanò, & Metrikine, A memory-enhanced py model for piles in sand accounting for cyclic ratcheting and gapping effects, 2022), without considering the pile-soil gapping component deemed irrelevant for underwater piles in sandy soil.

- Previous 1D cyclic modelling work (Kementzetzidis, Pisanò, & Metrikine, A memory-enhanced py model for piles in sand accounting for cyclic ratcheting and gapping effects, 2022), (Kementzetzidis, et al., 2023) focused on traditional *p-y* modelling as a single soil reaction component. MIDAS extends this plasticity framework to include multiple soil reaction components, aligning with the PISA framework.

- Calibration procedures for relevant 1D model parameters used typical site investigation data (e.g., from seismic CPTs). MIDAS's final calibration procedure, integrating centrifuge testing and 3D modelling outcomes, are described in Report #5 and will be a prominent component of upcoming MIDAS dissemination work.

In parallel with the development and calibration/validation of the MIDAS model by the core research team, some industry partners conducted in-house activities to assess the model's merits and shortcomings based on their experience and monopile analysis practices. These preliminary lessons learned and insights were shared with the research team in a timely manner, albeit exclusively on a confidential basis (and therefore not further reported herein). It is worth noting, however, that all partners saw substantial potential in the future adoption of the MIDAS framework as a way to enhance engineering practices and optimize/reduce costs.

Future users of the MIDAS 1D model should consider the following limitations, which will be overcome through further work along the same thread of research:

1) *Monopile Diameter and Aspect Ratio (L/D)*:
    a) The model was developed and calibrated using centrifuge tests with L/D ratios between 3 and 7.5 and diameters from approximately 2 m to 10 m (full prototype scale).
    b) Application outside of these ranges, especially for smaller L/D ratios, would require additional validation to ensure accuracy and reliability.
2) *Soil Type*:
    a) Calibration and validation of the model were performed for centrifuge tests conducted in silica sand under dense and medium-dense conditions (relative densities between 40% and over 90%).
    b) Application to sands with different mineralogical compositions (e.g., carbonate-rich or glauconitic soils) will necessitate site-specific studies and further validation.
    c) The model primarily considers relatively homogeneous soil profiles; significant variation in soil strength and stiffness between layers may require additional analysis and engineering judgement.
3) *Installation Method*:
    a) The model was validated using piles installed in place during centrifuge tests, without explicit consideration of installation effects.

   b) Evidence suggests that the calibration of monotonic 1D model parameters depends significantly on the installation method, whereas the cyclic ratcheting component seems less sensitive.
   c) Further investigation into the impact of installation on monotonic model parameters is ongoing as part of the SIMOX project (https://grow-offshorewind.nl/project/simox).
4) *Load Type*:
   a) The MIDAS 1D model is designed for cyclic loading with relatively low frequencies (<0.3 Hz).
   b) Its applicability to seismic loading conditions is currently under investigation in the DONISIS project, supported by the Offshore Wind Accelerator (OWA) programme of the Carbon Trust and offshore industry partners (https://www.carbontrust.com/our-work-and-impact/impact-stories/large-scale-rd-projects-offshore-wind/design-of-offshore-monopiles-including-seismic-interaction-with-soil-donisis).
   c) The model's accuracy is highest for cyclic loading with regular episodes not exceeding 5000 cycles; validation against field measurements may be required for extrapolations beyond 5000 cycles or under random cyclic loading conditions.
5) *Scale Effects*:
   a) Centrifuge tests, while effective at reproducing soil behaviour at realistic stress levels, remain a small-scale physical modelling approach.
   b) Future efforts should focus on further validating the model against data from large-scale onshore and/or offshore load tests to ensure its robustness across different scales.

These considerations outline the current capabilities and limitations of the MIDAS 1D model, emphasizing the need for context-specific validation when applying the model outside its calibrated parameters.

Following a thorough assessment of the model's performance against individual centrifuge tests, significant effort was dedicated to developing a robust and user-friendly method for calibrating the model, essential for its practical application in industry projects. This calibration process involved several key steps:

1) *Identifying Empirical Correlations*: Establishing empirical correlations between model parameters and fundamental soil properties, with a focus on parameters influencing monotonic behaviour.

2) *Mathematical Optimization*: Quantitatively refining these empirical correlations through mathematical optimization, aiming to minimize discrepancies to within practical acceptability thresholds (e.g., less than 10-15% error).

3) *Validation Against Test Cases*: Evaluating the calibrated model's performance against additional test cases to ensure its predictive accuracy across a range of scenarios.

The outcome of this process included empirically-derived relationships that facilitate straightforward parameter calibration based on depth, load eccentricity, and soil characteristics such as cone resistance and relative density. This approach expanded upon the foundational work of (Suryasentana & Lehane, 2016), adapting it to cyclic loading conditions using data from centrifuge tests and the 1D cyclic soil reaction model developed within the MIDAS project. These advancements aim to enhance the model's utility and reliability in practical engineering applications.

3.4. WP4 – Alignment for future qualification

DNV supported the MIDAS project in qualifying a new cyclic soil reaction model. The objective was to ensure its functionality within defined limits with an acceptable level of confidence and compliance with relevant regulations. This execution followed a structured approach aligned with DNV's Recommended Practice DNV-RP-A203 "Technology Qualification".

The executed Technology Qualification (TQ) process aimed to establish a qualified methodology for assessing lateral cyclic monopile stiffness. Here is a breakdown of the MIDAS TQ process, as visualized in **Figure 6**:

1. *Identification of Challenges and Uncertainties*: DNV, after receiving the MIDAS Qualification Basis, identified and documented key challenges and uncertainties related to the cyclic monopile method.
2. *Workshop and Risk Register*: A workshop was conducted to facilitate discussions and establish a risk register. This register played a crucial role in shaping the Qualification Plan.
3. *Development of the Qualification Plan*: Based on DNV's findings and input, the MIDAS research team developed a comprehensive Qualification Plan. As of the report preparation, DNV is reviewing this plan and considering issuing the Endorsement of Qualification Plan, anticipated by Summer 2024.
4. *Future Execution of the Qualification Plan*: Upon approval of the Qualification Plan by DNV, the MIDAS project team will proceed with its execution. DNV will oversee this process, leveraging internal subject matter experts to provide thorough support. The final phase will involve the Performance Assessment, where a positive evaluation is necessary for the issuance of the Technology Certificate.

Figure 6 illustrates the current phase of activities outlined in the Qualification Plan within the MIDAS project timeline, alongside ongoing efforts towards international dissemination. These efforts will continue until a sufficient level of confidence is achieved to conduct the final Performance Assessment.

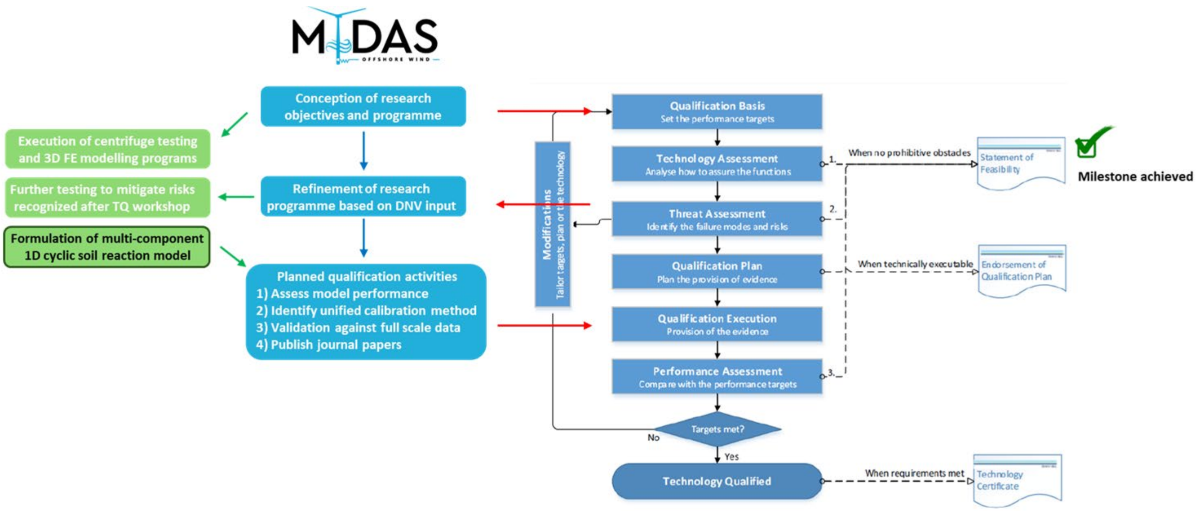

Figure 6: Activities within MIDAS Qualification Plan and path to Technology Qualification.

4 Key conclusions and recommendations

The MIDAS project successfully developed and calibrated a comprehensive 1D cyclic soil reaction model to simulate monopile responses under cyclic loading in sand, validated against extensive centrifuge test data and informed by detailed 3D FE modelling studies. Despite these achievements, several limitations and recommendations for future work should be highlighted:

- *Testing Conditions*: The experimental program encompassed a wide range of geometrical, geotechnical, and loading conditions typical of current monopile designs. However, caution is advised when extrapolating the model beyond these specific conditions, necessitating further validation.

- *Soil Types*: Tests were conducted exclusively in Geba sand. While the model's applicability to general monopile behaviour in sand is expected, its use in soils with significantly different properties (e.g., carbonate or glauconitic sands) requires additional study. Variations in relative density and layered soil properties were not addressed in this research.

- *Loading Conditions*: Cyclic loading scenarios involved uni-directional, regular load packages of varying amplitudes and constant frequency. Future studies should explore multi-directional and irregular cyclic loading conditions, comparing model predictions with data from literature and offshore monitoring campaigns for validation.

- *Installation Methods*: The MIDAS tests assumed wished-in-place conditions, excluding the effects of different installation methods like dynamic driving. Future studies, such as those in the SIMOX project, will be crucial for assessing how installation methods impact cyclic stiffness.

- *Pore Pressure Effects*: Minimal pore pressure effects were observed under the study's conditions due to high sand stiffness and strength. Understanding pore pressure buildup under varying conditions (e.g., different load amplitudes, soil types, and foundation dimensions) requires further investigation, especially in medium-dense sands with higher cyclic loading.

- *Model Calibration*: The calibration of the MIDAS model prioritized capturing the cyclic accumulation of monopile rotation. At the same time, the model returns simulated load-deflection/rotation responses in the time domain, which could be used to quantify the hysteretic damping of the soil-foundation system. Future work should dive deeper into how the model's predicted hysteretic damping compares to the damping observed in experimental data, specifically focusing on the model's capabilities in predicting cyclic energy dissipation, which is relevant for monopile design.

Future efforts are crucial to enhance confidence in applying the MIDAS model across diverse scenarios. The ongoing MIDASclay project addresses monopiles in clay, while the DONISIS project focuses on dynamic conditions and pore pressure effects. Validation against datasets from projects like PISA, PICASO, Vibro, SOLCYP, GDP, and SIMOX, as well as collaborations with offshore wind developers for full-scale test data, are anticipated. These initiatives will further validate and refine the MIDAS model's capabilities for broader application in offshore wind engineering.

5 Dissemination

Throughout its 4-year duration, the MIDAS project maintained a deliberate approach of withholding preliminary results that required further analysis and consideration. The project made exceptions with three conference papers authored by (Pisanò, et al., 2021), (Wang, et al., 2022), and (Kementzetzidis, et al., 2023), which provided insights into the project's setup, objectives, and initial steps towards developing and validating a new 1D cyclic soil reaction model. Recently, an abstract has been accepted for publication in the proceedings of the ISFOG2025 conference, scheduled for June 2025 in Nantes, France. This upcoming paper aims to disseminate the main achievements of the MIDAS project to the international community while preserving detailed findings for future journal publications.

While the dissemination of research findings is among the main objectives of the MIDAS project, publishing high-quality journal papers will provide proof of quality that will support the completion of the Technology Qualification process. The questions and comments from selected expert reviewers will help confirm the validity of the physical and numerical modelling activities, and ultimately, the resulting 1D cyclic soil reaction model.

In addition to journal papers, conference publications and oral presentations will also contribute to the dissemination of MIDAS findings. However, it is believed that only the rigor of a journal peer review can be meaningful to the TQ process and the potential inclusion of the MIDAS approach in relevant industry standards. It is also acknowledged that publishing a few journal papers is an endeavour that could take up to 2-3 years to complete.

6 Acknowledgements

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DNV, as well as NGI's contribution through the unaltered involvement of Federico Pisanò, who continued to lead the MIDAS project after transitioning from Delft University to NGI in January 2023.

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