seanergy
19›20 May, 2026
Nantes • France

Poster n°3

SLOOP: Optimising Offshore Monopiles Design

Stochastic Load Analysis & Advanced Soil-Pile Interaction

ZhongSen LI (NU) | Seung-Yoon HAN (ECN) | Christelle ABADIE (UGE)

Nantes Université | CENTRALE NANTES | Université Gustave Eiffel

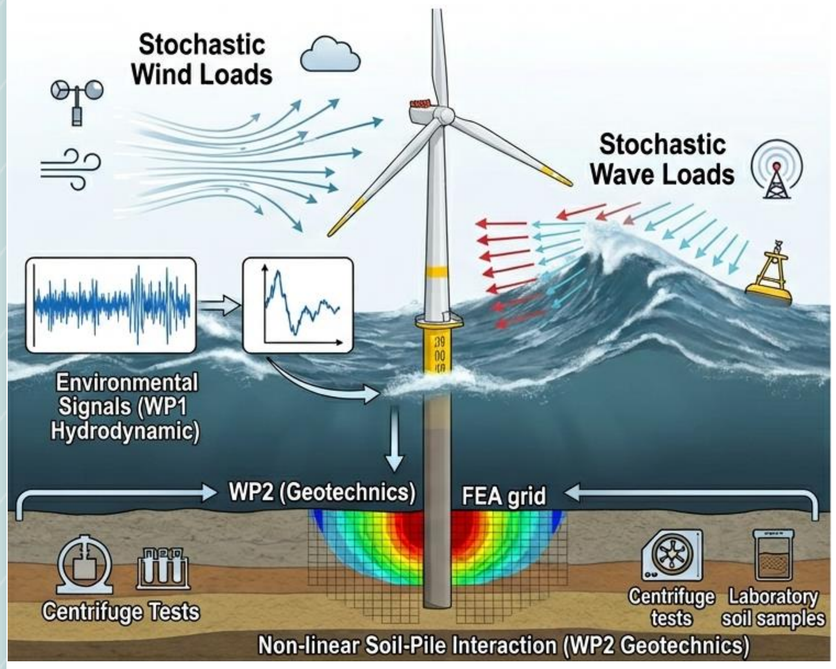
Supported by ORACLE LabEx, the SLOOP project (Stochastic Loads On Offshore Piles) tackles a key industrial challenge in offshore wind: reducing uncertainty in monopile foundation design under stochastic environmental loads. By coupling advanced aero-hydrodynamic simulations with soil–pile interaction models, SLOOP provides a robust numerical framework to optimise monopile sizing and reduce CAPEX and LCOE.

1. Project motivation

St-Nazaire offshore wind farm installation © Valéry Joncheray

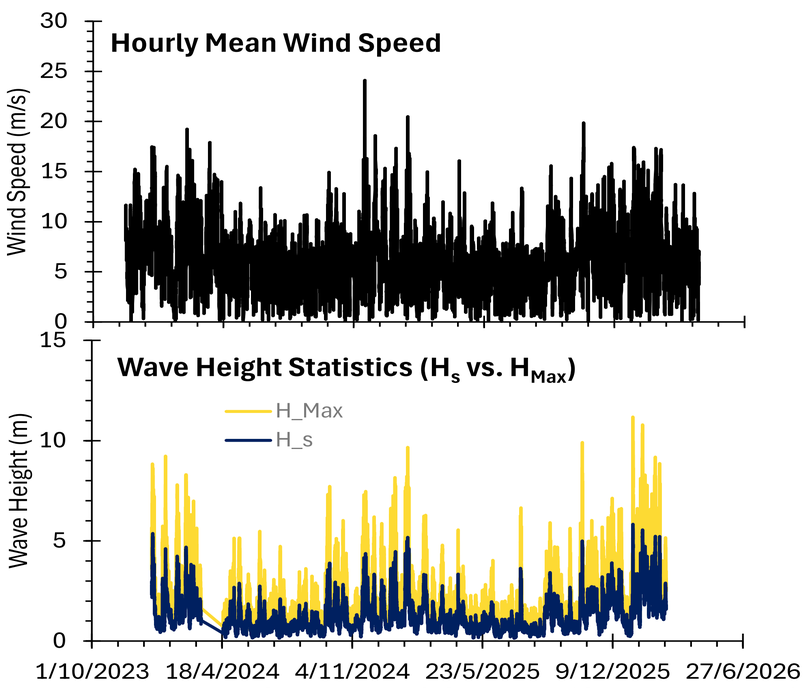
- ❑ Tackling Design Uncertainty: Traditional methods over-engineer monopile foundation to compensate for the stochastic (random) unpredictability of offshore environments.
- ❑ Bridging the High-Fidelity Gap: Current design lacks an integrated framework that connects complex aero-hydrodynamics with advanced non-linear soil mechanics.
- ❑ Driving LCOE Reduction: There is an urgent need for robust, fast-running predictive tools that allow developers to optimise monopile dimensions, ensuring structural integrity over the lifespan while reducing the Levelised Cost of Energy (LCOE).

2. Integrated methodology



- ❑ **Step 1 | WP1 Stochastic Load Calculation**
  - Inputs: Site-specific wind and wave measurements at SEM-REV of Le Croisic.
  - Simulation: OpenFAST/Qblade aero-hydro-servo-elastic modelling.
  - Outputs: Lateral loads and bending moments for geotechnical investigation.
- ❑ **Step 2 | WP2 Advanced Geotechnical Analysis**
  - Geotechnical centrifuge tests to analyse soil-pile interaction under cyclic lateral loadings.
  - 3D Abaqus FEA to capture stiffness degradation, cyclic *P-y* curve, etc.
- ❑ **Step 3: Fast Prediction & Calibration**
  - Macro-element calibration with combined WP1/WP2 results.
  - Life-Cycle Forecasting: Computationally efficient predictions of foundation rotation and fatigue over the lifespan.

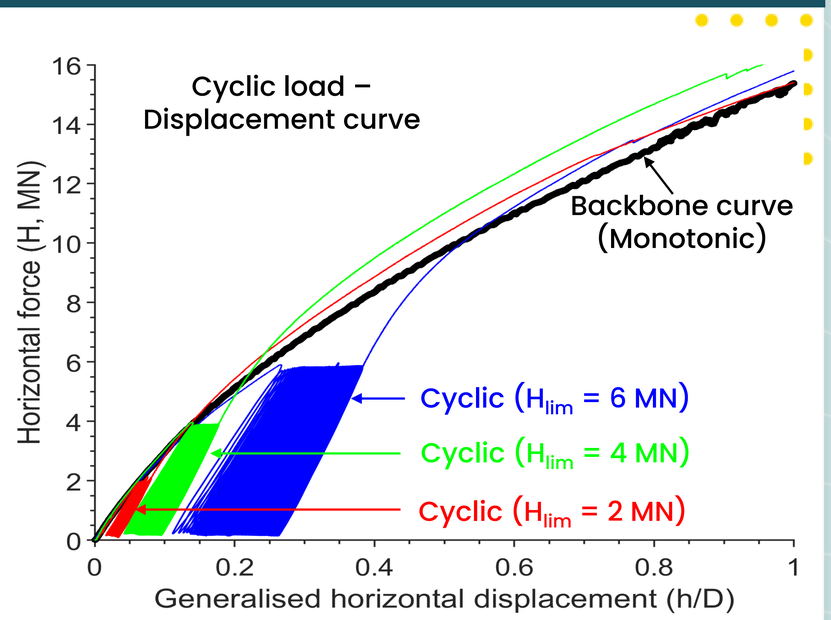
3. Key results



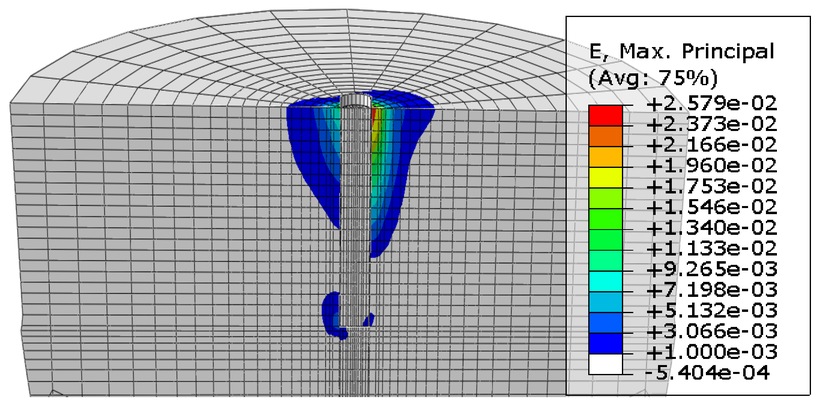
Data obtained from Copernicus & SEM-REV (Centrale Nantes)

Site-specific boundary conditions for the **SEM-REV site** (Le Croisic) were established. Analysis reveals peak hourly mean wind speeds (U_{10}) of **25 m/s**, coinciding with significant wave heights (H_s) of **6.0 m**. These synchronised time-series provide the input for OpenFAST simulations to calculate the stochastic loads and moments.

Cutting-edge sensor technology: Two model piles instrumented with fibre Gragg grating sensor were laterally loaded in a large-beam centrifuge at 100×*g*, allowing to estimate the lateral response of monopiles of D = 5 m.



Centrifuge tests consisted of **a monotonic** test to define the backbone curve and **three cyclic** tests (N = 10,000 cycles) at load amplitudes of **2, 4, and 6 MN**. Results quantify cumulative displacement and **stiffness degradation**, providing a robust physical benchmark for calibrating long-term performance models.



Abaqus 3D FEA was used to simulate monopile behaviour under various lateral loading scenarios. The model captures complex non-linear soil-pile interaction, providing the essential **technical benchmark** required to validate simplified structural models for long-term life-cycle forecasts.

4. Next steps

- ❑ **Model Integration:** Coupling OpenFAST wind & wave time series with Abaqus 3D FEA non-linear foundation responses.
- ❑ **Long-Term Fatigue Analysis:** Assessing the impact of soil-pile interaction on the structural integrity of the monopile.
- ❑ **Design Optimising:** Developing refined safety factors to reduce steel weight and lower the Levelised Cost of Energy (LCOE) for future offshore wind farms.

Scan to follow SLOOP updates

Cette action est soutenue par NExT et par l'Etat au titre du Plan d'investissement France 2030.

ORACLE NExT | anr | FRANCE 2030