Numerical modelling of the response of shared anchors to multidirectional loading

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Main objectives

- Developing a 3D finite element numerical model to predict the soil behavior under cyclic and multi-directional loadings
- Performing a sensitivity analysis to investigate the effect of
  - The pile geometry
  - The load characteristics
  - The loading historic
  - The load multi-directionality
- Comparing the behavior of shared and unshared pile anchors to clarify the effect of pile sharing on the pile lateral displacement

Picto credit: Dranan Endar/Noun Project

Numerical model definition

- **Finite element software:** Abaqus/Standard

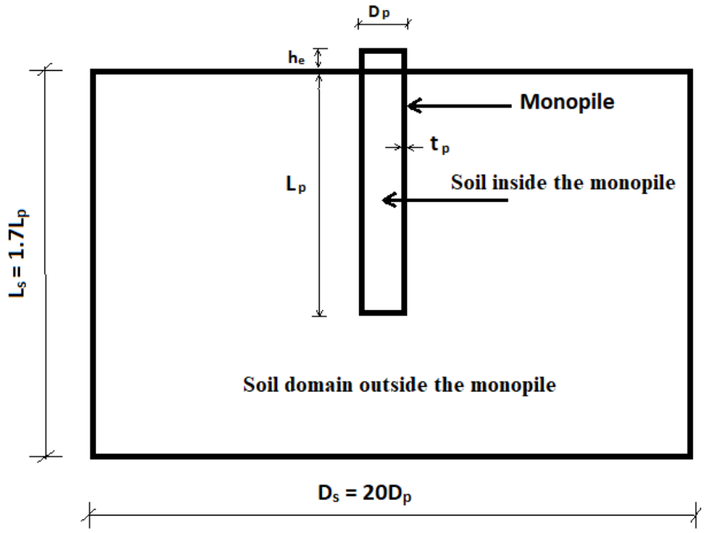
- **Monopile dimensions:**
  D_p=2.50m L_p=20m t_p=0.10m h_e=0.5D_p

- **Soil domain dimensions:**
  D_s=20D_p=50m L_s=1.7L_p=34m

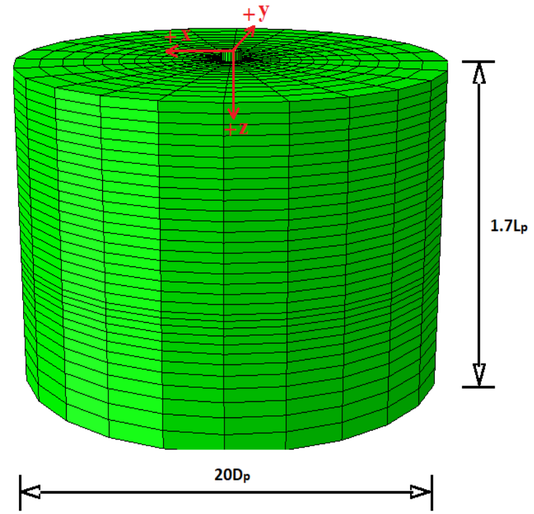
- **Soil-monopile interface follows Mohr-Coulomb friction law**

- **Constitutive models**
  - Linear elastic model was adopted to simulate the pile behaviour
  - **Hypoplastic** constitutive model was adopted to simulate the soil behaviour

- **Adopted mesh**
  A mesh consisting of 15,864 elements and 18,034 nodes was adopted



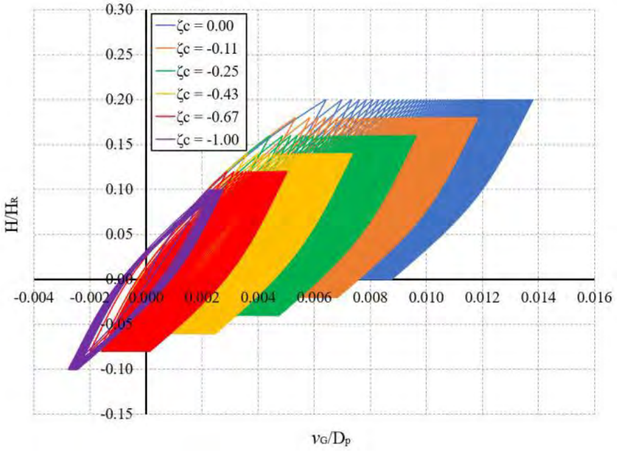
Schematic diagram of the soil-monopile system

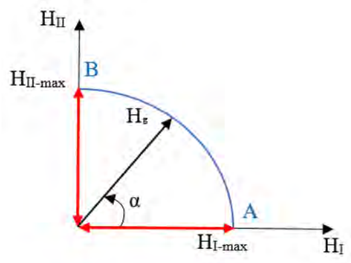


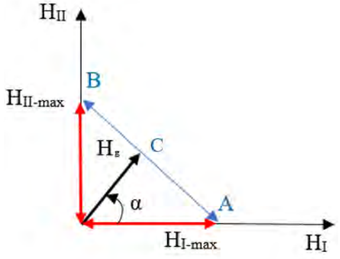
Adopted mesh of the 3D numerical model

Outcomes of the sensitivity analysis

- The **pile diameter** has a high impact on the pile lateral capacity while the pile length has a smaller effect. The effect of the pile wall thickness has shown to be negligible
- The **pile lateral displacement** is sensitive to the cyclic load magnitude ζb. The pile lateral displacement increases with the increase of ζb.
- For a prescribed cyclic load amplitude, the **pile lateral displacement** increases with the increase of ζc. In particular, one-way cyclic load leads to large pile displacement.
- **Pre-cycling** in a given direction affects the soil rigidity in the other directions
- **Multidirectional iso-loads** cause smaller pile lateral displacement than multidirectional non-iso loads







$$\zeta_b = \frac{H_{max}}{H_R} \quad (1)$$

$$\zeta_c = \frac{H_{min}}{H_{max}} = R$$

Comparison of shared and unshared loadings

Focus: Behavior of shared and unshared pile anchors under two stochastic load cases (80m & 600m water depths)

Key Findings (80m Depth, Catenary Mooring)

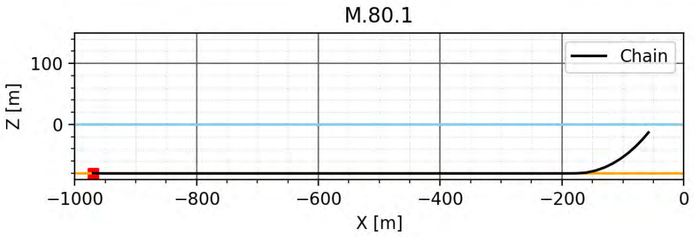
- Unidirectional loading: Unshared anchors show more lateral displacement
- Multidirectional loading: Shared anchors show more lateral displacement
- Overall: Unshared anchors exhibit the largest displacement
- Conclusion: Classical unshared pile design remains valid

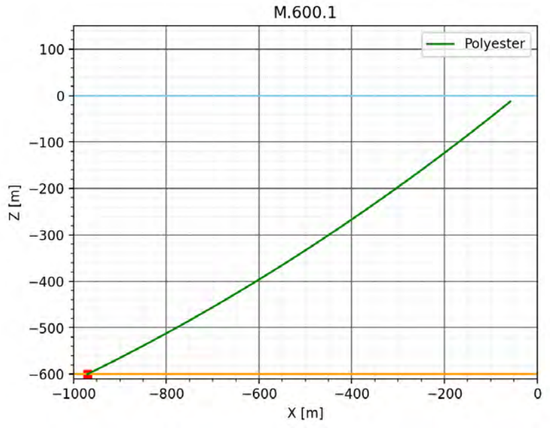
Key Findings (600m Depth, Taut Polyester Mooring)

- Unidirectional loading: Unshared anchors show slightly more lateral displacement
- Multidirectional loading: Shared anchors show significantly more lateral displacement
- Overall: Shared anchors exhibit the largest displacement
- Conclusion: Classical unshared pile design is no longer valid

Design Considerations

- Multidirectional loading can increase displacement, but this is corelated with the configuration and loading types
- In case of high unidirectional loads, extra lateral displacement may be neglectable





Way forward

- **Finalization of the geotechnical numerical study with a comprehensive analysis of anchors loadings**
  - Toward a generalization of previous observation and recommendation for the industry
- **Validation of the numerical models with experimental results:**
  - Including more configurations and metocean cases
  - Including vertically loaded cases
- **Development of simplified industrial tools for pile design under multidirectional and cyclic loading**
- **Extend the study to other types of soil and other types of anchors**
- **Long-term behavior of shared and unshared pile anchors under different extreme events**