cfms
COMITÉ FRANÇAIS DE MÉCANIQUE DES SOLS ET DE GÉOTECHNIQUE

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anteagroup

# Ancrages mutualisés : projets MUTANC et SHAREWIND


## Matthieu Blanc et Cristian Soriano (UGE)

# Ancrages mutualisés pour éoliennes flottantes

## Sommaire de l'intervention

- **Projet MUTANC : MUTualized ANChors for offshore wind farms – Matthieu BLANC (Université Gustave Eiffel)**

- **Projet SHAREWIND – Cristian Soriano (Université Gustave Eiffel)**

Funded by the European Union

# MUTANC : MUTualized ANChors for offshore wind farms

## MUTANC PROJECT

- WP1 : Project Management
- WP2 : Mooring system design and anchor load analysis
- WP3 : Geotechnical numerical analysis (in sand)
- WP4 : Geotechnical experimental analysis (in sand)
- WP5 : Results and further work

**Lead : FEM**
**Scientific lead : Technip Energies**

**Project duration: 3 years** (end November 2024)
**Total budget: 1332 k€** (FEM: 516k€)

# MUTANC : MUTualized ANChors for offshore wind farms

## MUTANC TOPIC

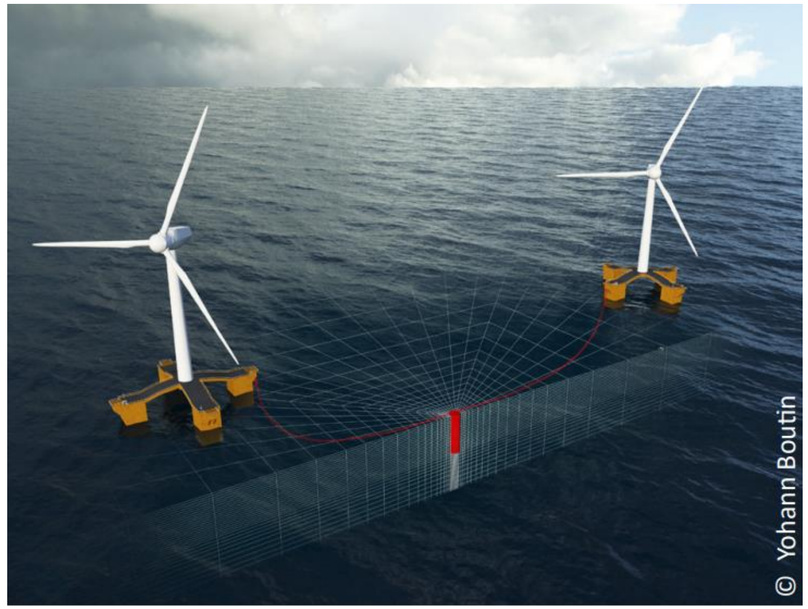
**ORE sector need:  Identification of shared anchor as a way to reduce mooring system cost**

**S&T: challenges :**

- **Farm layout design and optimisation with shared anchors**
- **Soil/structure interaction of shared anchors**
- **Design methodology for shared anchors**
- **Consequences on CAPEX, OPEX and reliability**

**Expected results:**

- **Better understanding about shared anchor potential to reduce costs**
- **Better understanding of anchor/soil interaction**



# MUTANC WP2 : Mooring system design and anchor load analysis
# Lead : France Energies Marines

## WP2 Objectives

- Assess the feasibility and cost of mooring systems with mutualized anchors for different cases
- Calculation of realistic loads at shared anchors in order to evaluate the anchors behavior under a multidirectional-cyclic load in WP3&4.

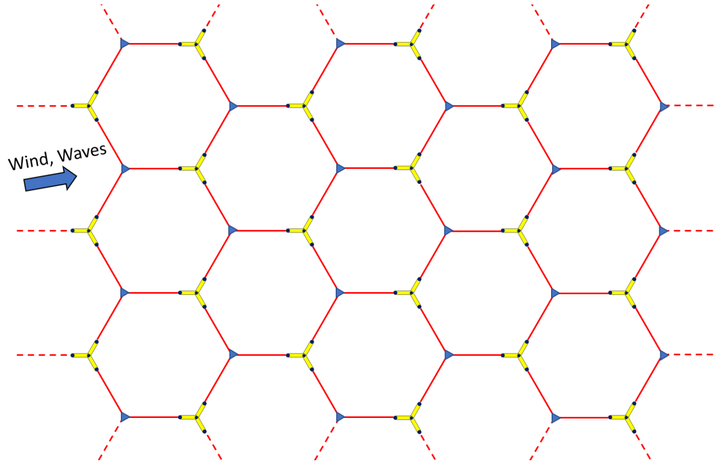
## WP2 Activities

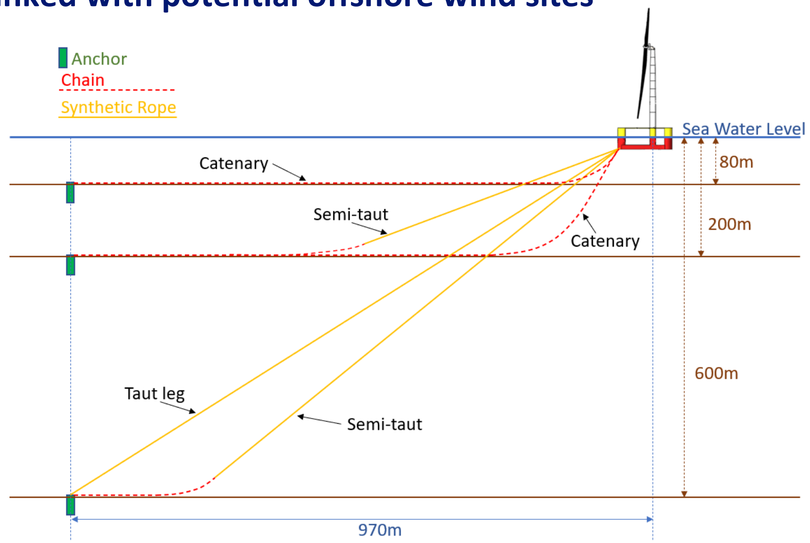
- WP2.1 : Case study definition
- WP2.2 : Mooring system design
- WP2.3 : Results analysis and reliability

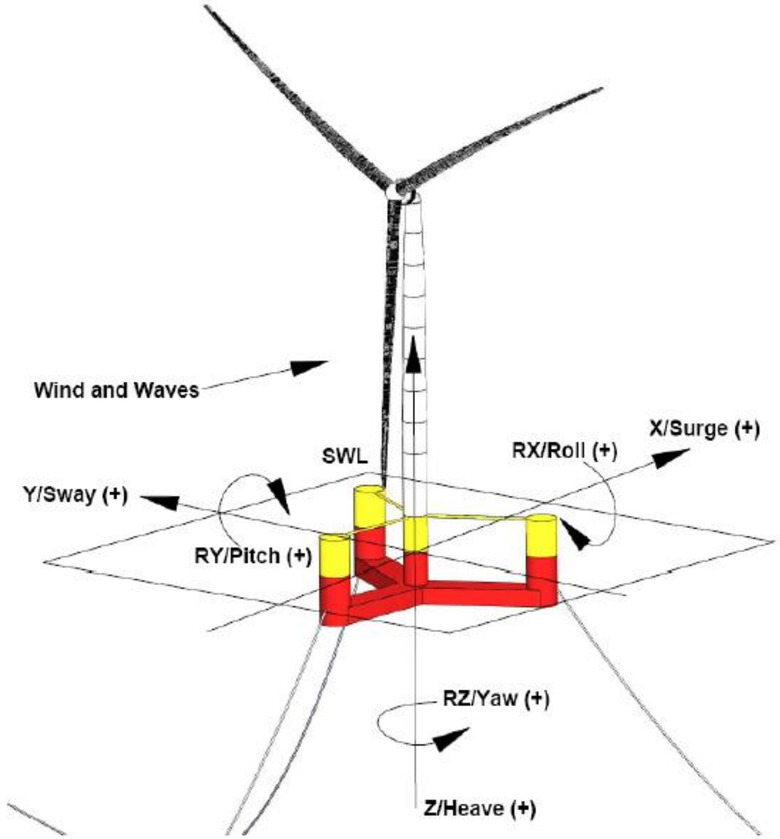
# MUTANC WP2 : Mooring system design and anchor load analysis

## WP2.1 Case study definition

- Turbine and Floater: VolturnUS-S + 15MW NREL
- Anchor Layout: Regular triangle
- Water depth: 3 studied water depth (80m,200m,600m)
- Realistic Environment input linked with potential offshore wind sites



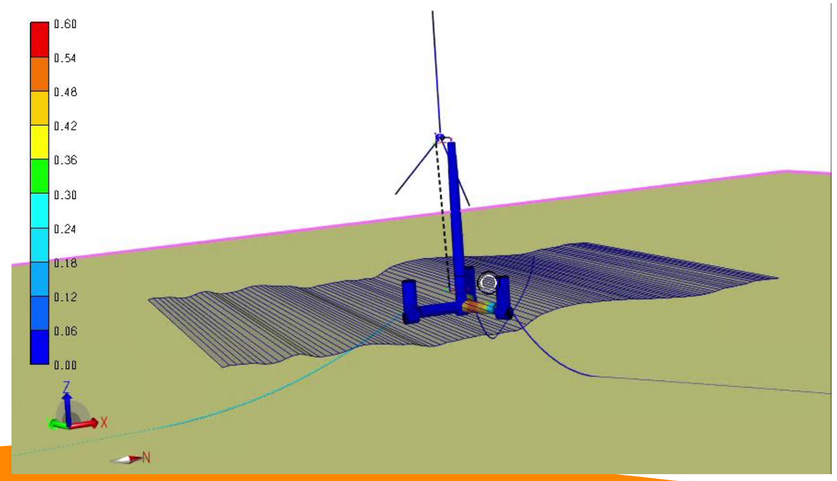



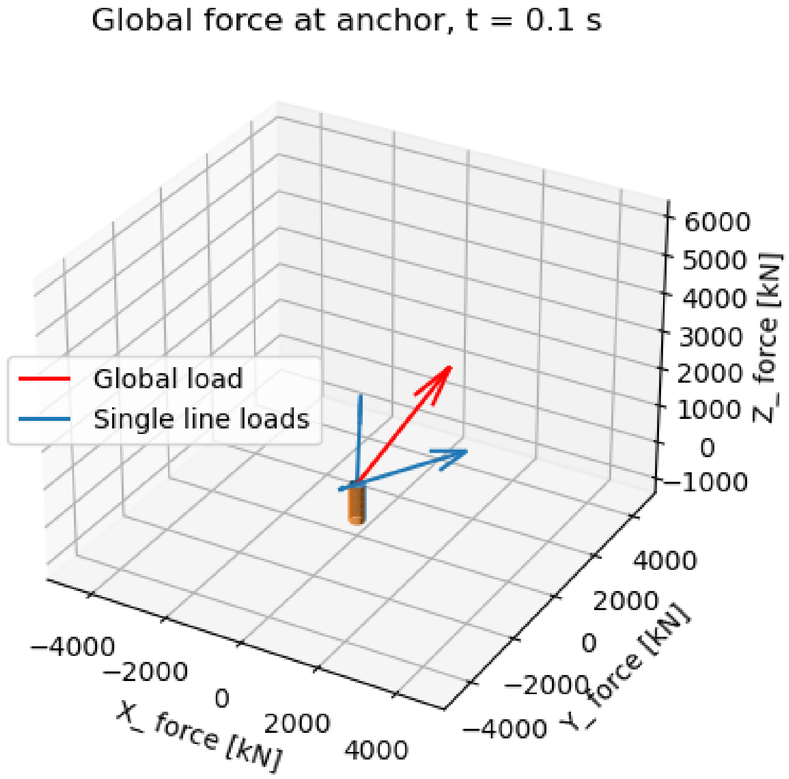



# MUTANC WP2 : Mooring system design and anchor load analysis

## WP2.2 Mooring System Design

- Various material configuration: Chain, Polyester, Nylon, HMPE
- Realistic Environment input linked with potential offshore wind sites
- Mooring optimisation based on ULS and FLS analysis
- Hydro-Servo-Aero-Elastic Analysis Numerical model, with FEA for mooring
- Both mutalized and non-mutualized configurations were optimized



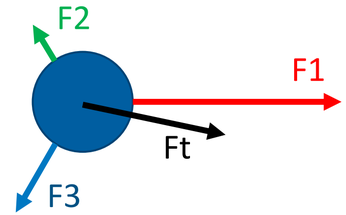
# MUTANC WP2 : Mooring system design and anchor load analysis

## WP2.3 Result Analysis and Reliability

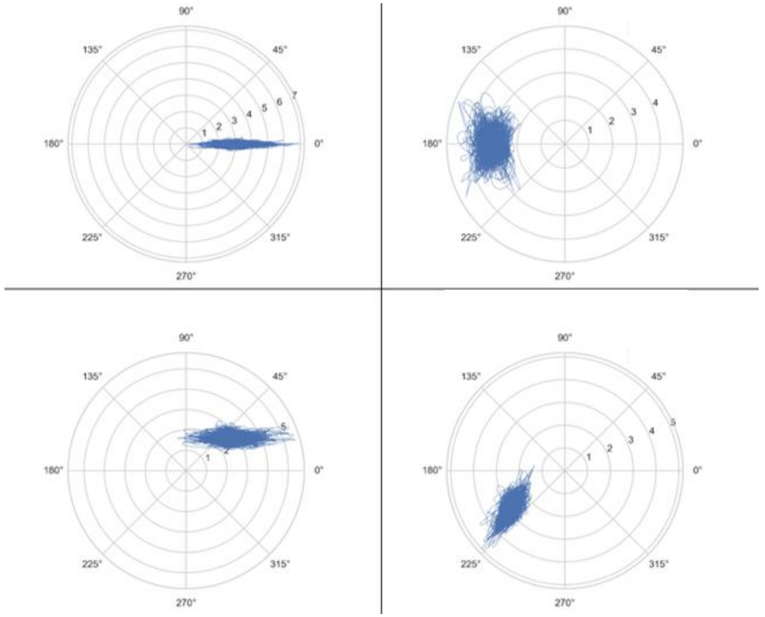
- **Cost Analysis for each optimized configuration**
- **Combined loads calculation at anchors**

Simplified cost analysis output for 2 water depth:

| | Configuration index | Anchor radius | MBL | Mooring length | Design tension | Utilization Ratio | Offset max | Single line Cost |
|---|---|---|---|---|---|---|---|---|
| Water Depth 1 | C1 | | | | | | | |
| | C2 | | | | | | | |
| | C3 | | | | | | | |
| | C4 | | | | | | | |
| Water Depth 2 | C5 | | | | | | | |
| | C6 | | | | | | | |
| | C7 | | | | | | | |
| | C7 | | | | | | | |
| | C9 | | | | | | | |




Time load roses for a mutualized anchor:



# MUTANC WP3 : Geotechnical numerical analysis
# Lead : Université de Nantes

## WP3 Activities

**WP3.1 : Literature review**

**WP3.2 : Calibration of the soil constitutive model**

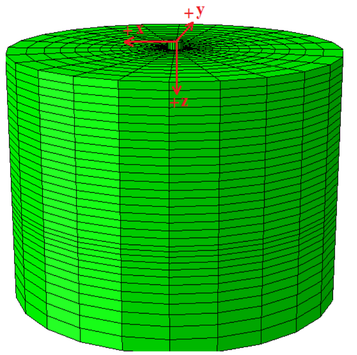
- Determination of parameters of the soil constitutive model (complex law)
- Objective : Numerical and experimental benchmarking of the pile performance under cyclic multidirectional loadings

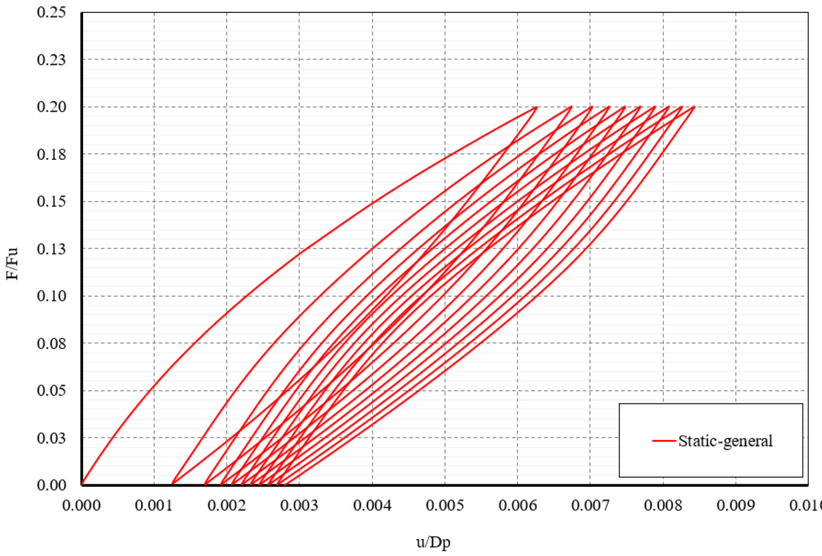
**WP3.3: Geotechnical numerical modelling and analysis of the soil-anchor system**

- Develop a 3D finite element model of the soil-anchor system in ABAQUS
- Nonlinear dynamic analysis of soil-anchor system using complex soil constitutive model
- Cyclic sinusoidal multidirectional loadings used in WP4
- Realistic time-varying environmental loadings from WP2

**WP3.4: Sensitivity and cost analyses of the soil-anchor system**

- Sizing, feasibility and cost of mutualized anchor
- Sensitivity analysis: soil parameters, geometrical parameters
- Possibly : study of an anchor in clay, effect of soil/anchor loading variability on pile performance



# MUTANC WP4 : Geotechnical Experimental Analysis
# Lead : Université Gustave Eiffel

## WP2 Objectives

- Increase the knowledge on shared pile anchors by performing centrifuge tests on small-scale models : Multidirectional loading & Cyclic loading
- Develop Multi-Directional Loading Set-up
- Carry out an experimental campaign in geotechnical centrifuge :
- Validationof the numerical model

## WP5 Activities

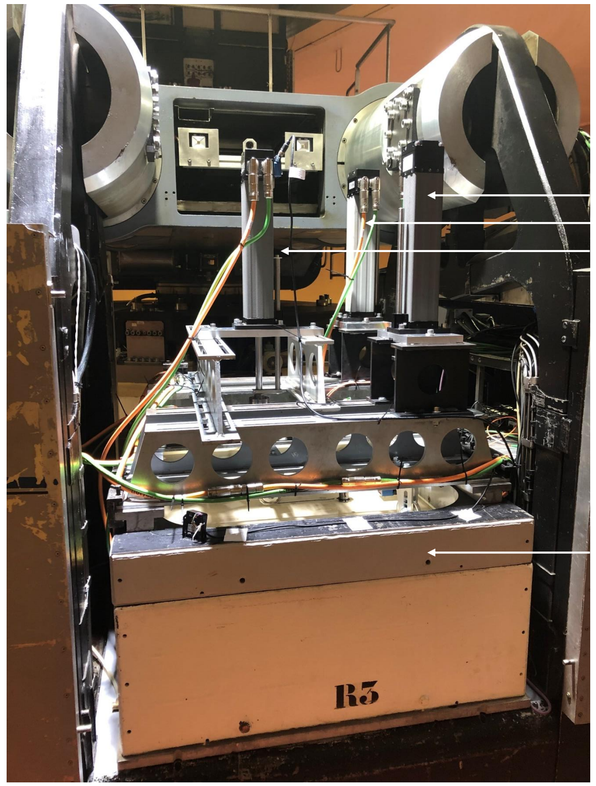
- WP4.1 : Design of the Multi-Directional Loading
- WP4.2 : Choice of the model dimensions and instrumentation
- WP4.3 : Monotonic failure envelope & Multidirectional loading
- WP4.4 : Impact of cyclic loading
- WP4.5: Validation of the physical and numerical modelling

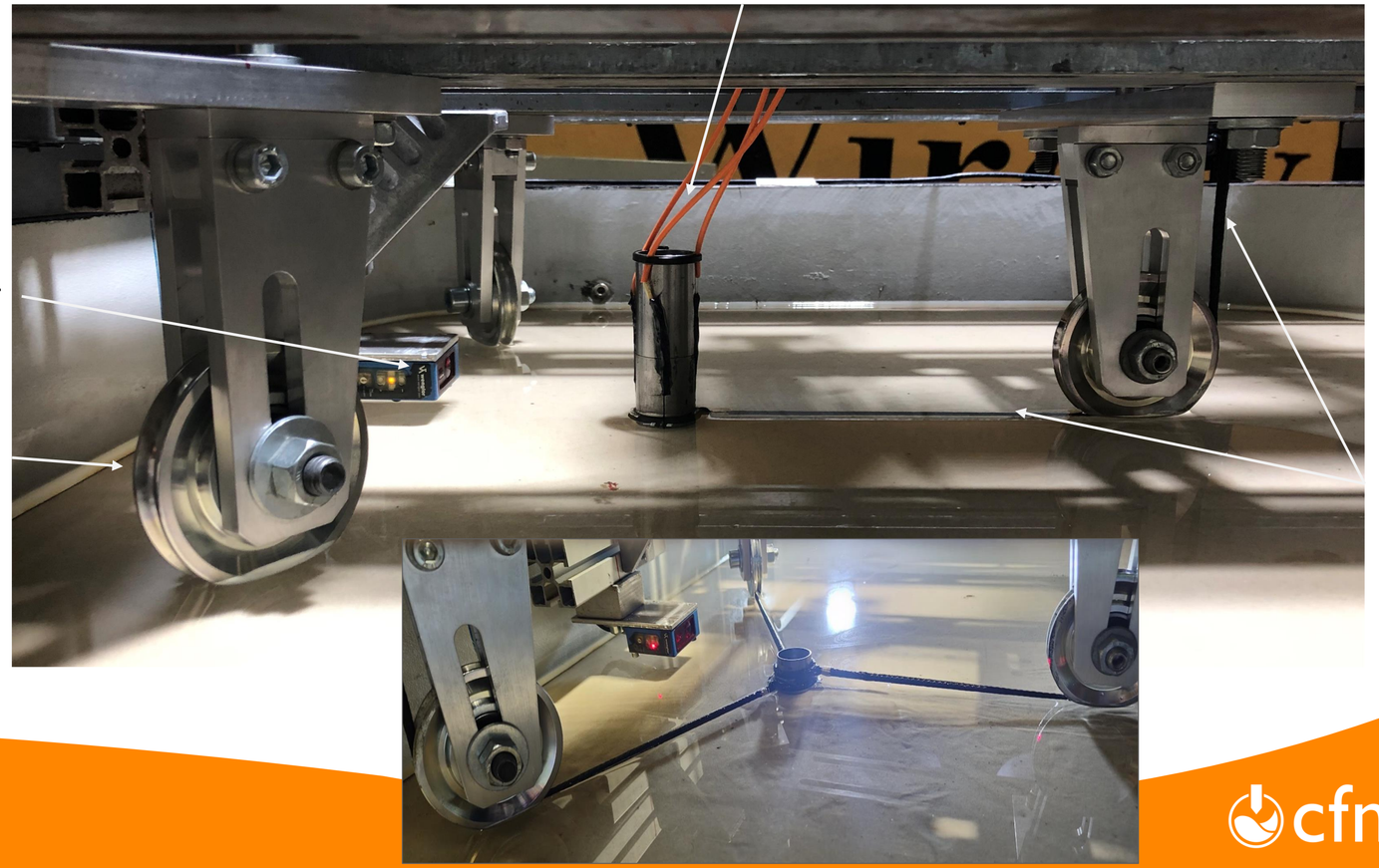

## Physical modelling in centrifuge

- Soil behaviour : highly non linear / stress state dependent
- Univ Eiffel beam centrifuge : Ø 11m - 2t up to 100g

# MUTANC WP4 : Geotechnical Experimental Analysis

## WP4.1 : Design of the Multi-Directional Loading : horizontal loading at anchor head



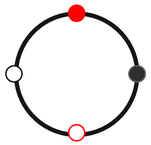



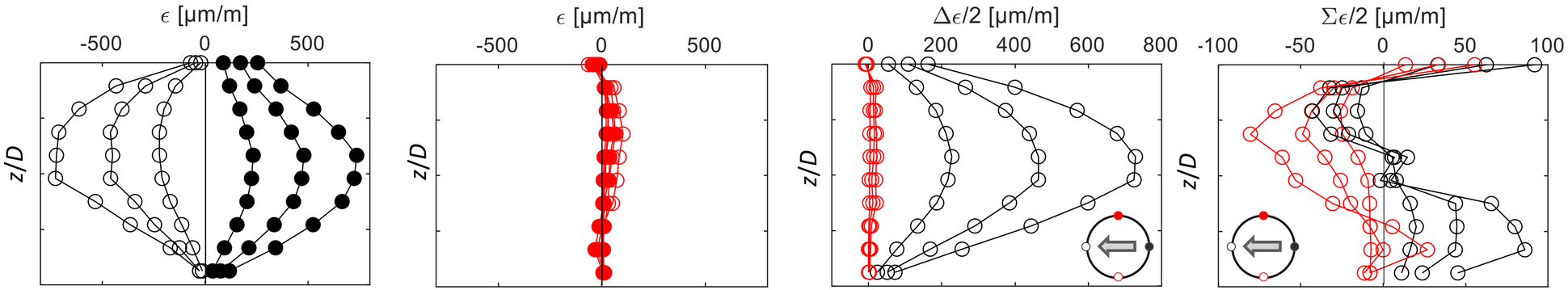
# MUTANC WP4 : Geotechnical Experimental Analysis

## WP4.2 : Choice of the model dimensions and instrumentation : Pile anchor with optical fibers

loading direction

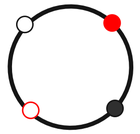
pile @ 0°

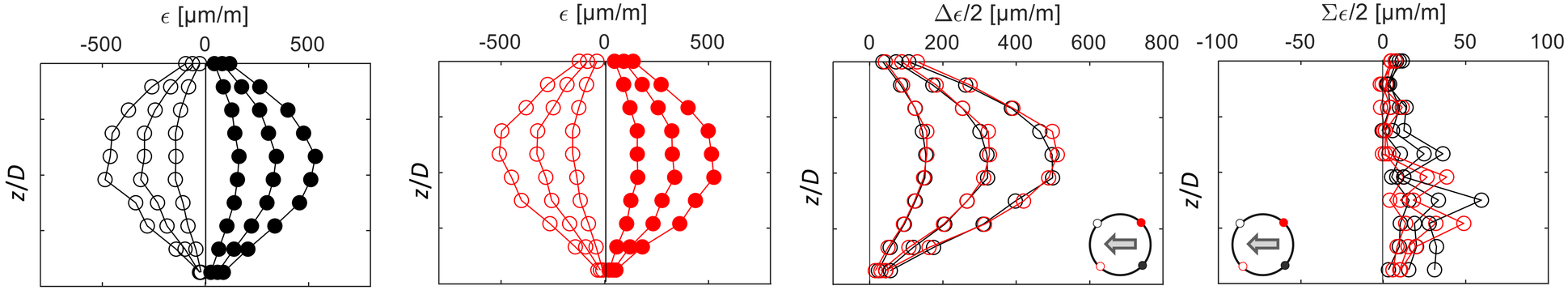





loading direction

pile @ 45°





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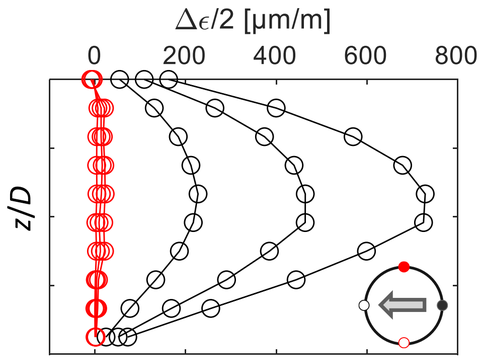
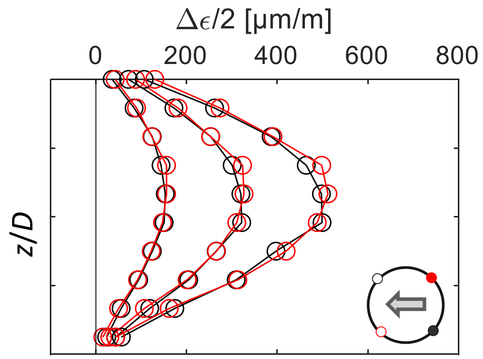
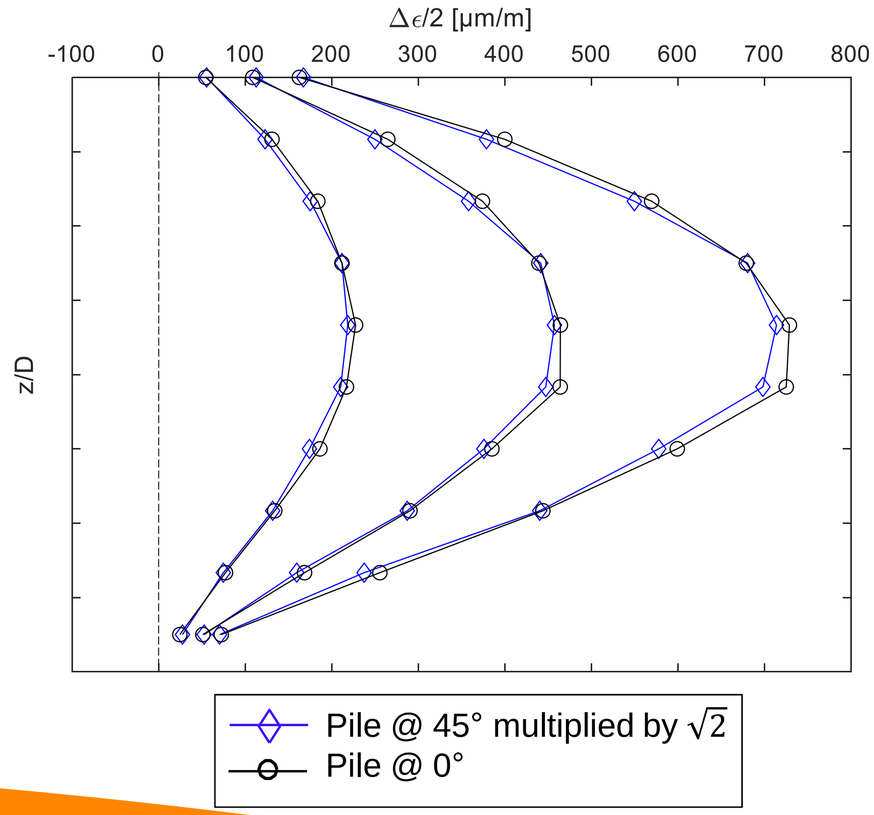
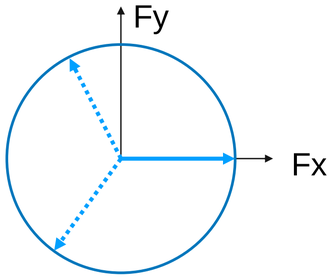


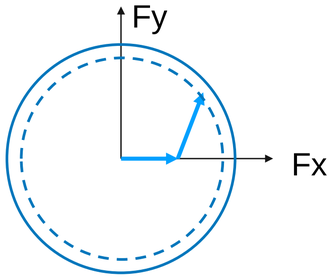



# MUTANC WP4 : Geotechnical Experimental Analysis

## WP4.3 : Monotonic failure envelope & Multidirectional loading

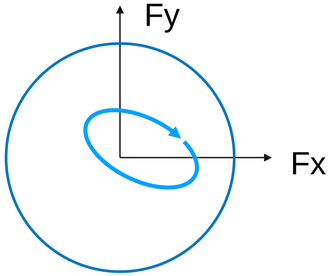



failure envelope (monotonic loading)

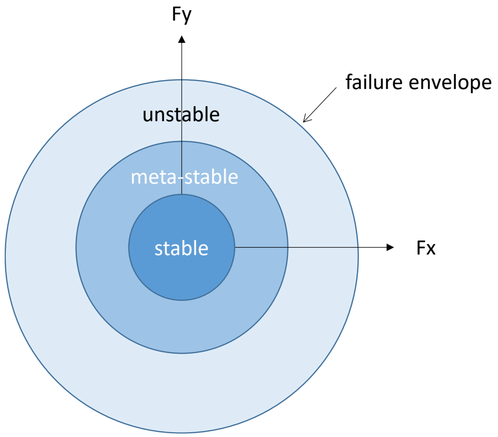



multidirectional loading - impact on failure envelope

## WP4.4 : Impact of cyclic loading




cyclic multidirectional loading
accumulation of displacement
stability zones



# MUTANC WP5 : Results and further work
# Lead : France Energies Marines

## WP5 Objectives

- **Draw conclusions about the overall techno-economic performances of the mutualized anchor solutions for a FOWT farm.**

## WP5 Activities

- **WP5.1 : Methods, challenges and cost estimations of installation, maintenance and decommissioning of mutualized anchors**
  - Evaluation of the cost of various items such as:
    - Line and anchors manufacturing costs
    - Mooring and anchoring installation costs
    - Operation and maintenance costs
    - Dismantling costs
  - Cost study on specific cases with the help of WP 2, 3 &4

- **WP5.2 : Results summary and further work**

# ShareWind
# Shared anchors for floating wind turbines


Cristian SORIANO

Luc THOREL

Matthieu BLANC

# Acknowledgements

Funded by
the European Union

Université
Gustave Eiffel

NGI

University of
Southampton

Marie Sklodowska-Curie Actions (MSCA)
Grant ID: 101106921

# The project

Explore the concept of shared anchors: suction caissons installed in soft clay

- **WP1: to determine load conditions, geometry of the anchors and seabed characteristics involved in sharing anchors – NGI (Norway)**
- **WP2: to physically model multidirectional loading of anchors installed in clay**
- **WP3: to numerically model the behaviour of shared anchors.**
- **WP4: to examine different geometry characteristics of shared anchors and soil conditions**

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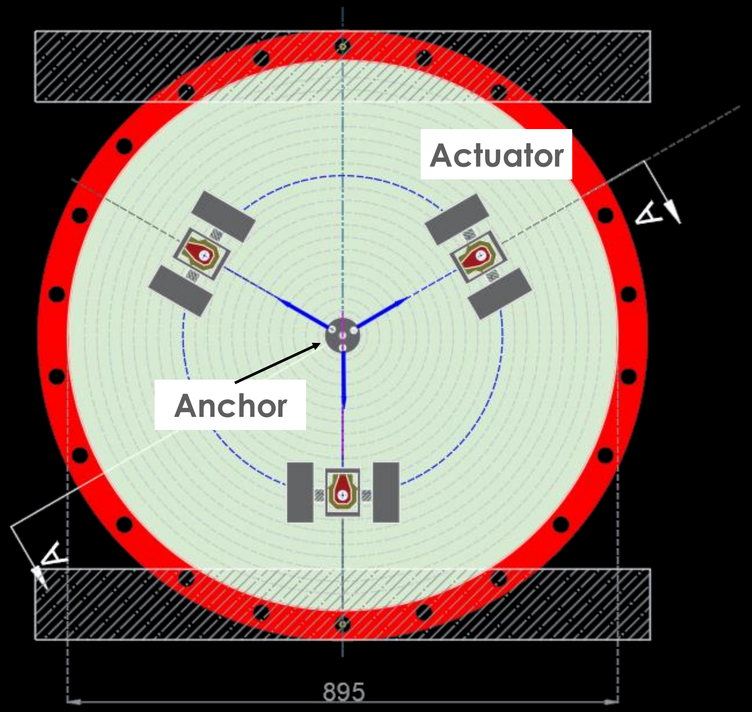
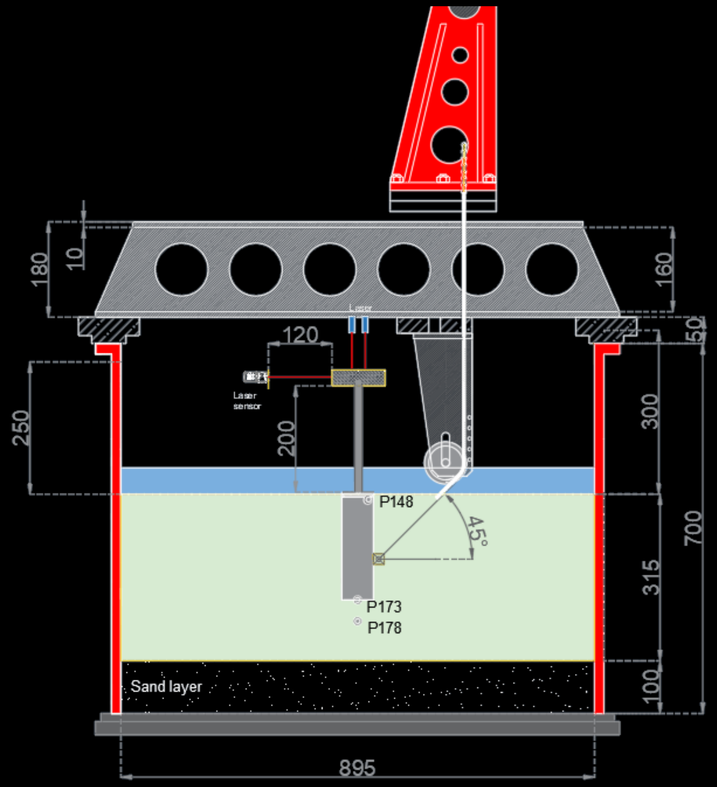
# WP2: Physical modelling



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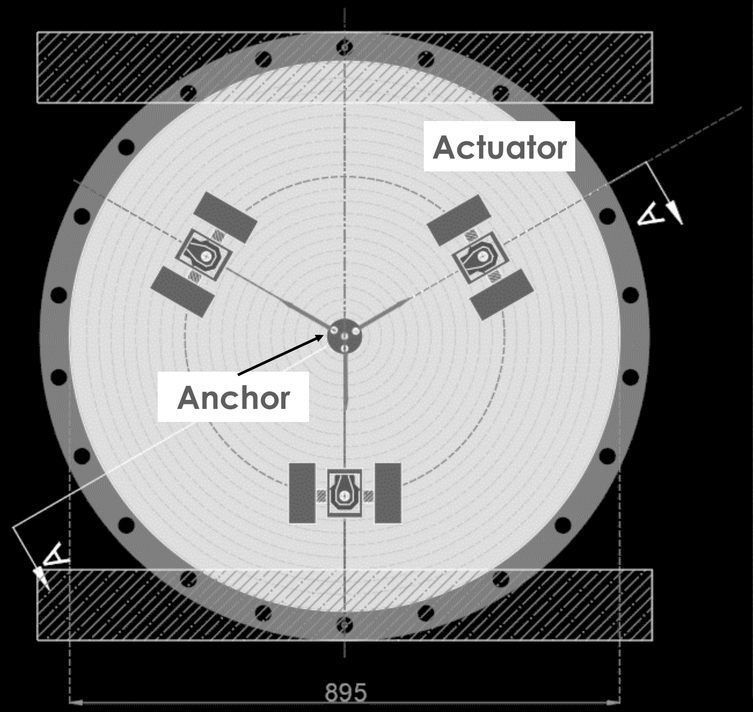
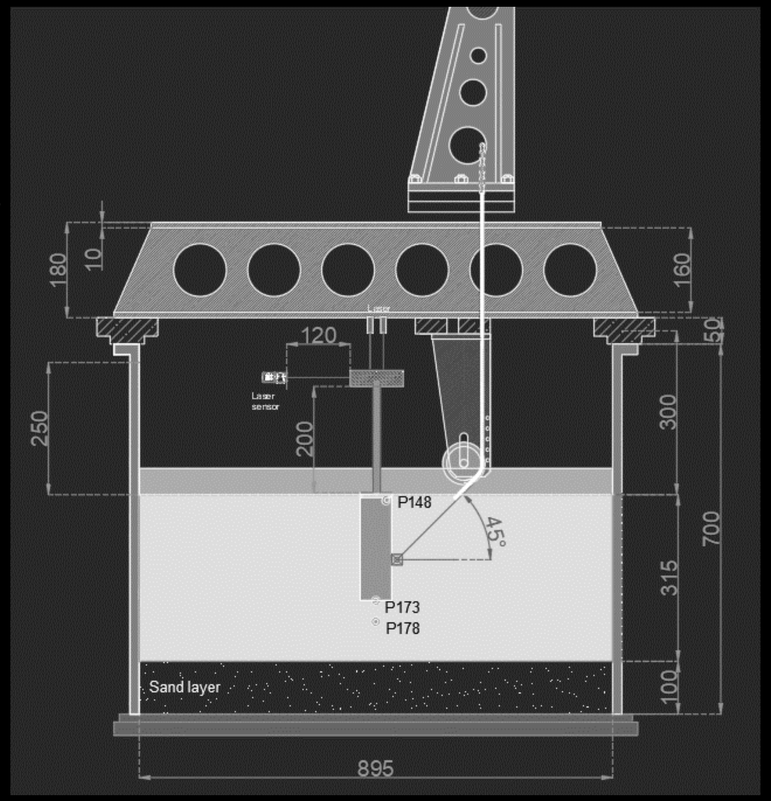
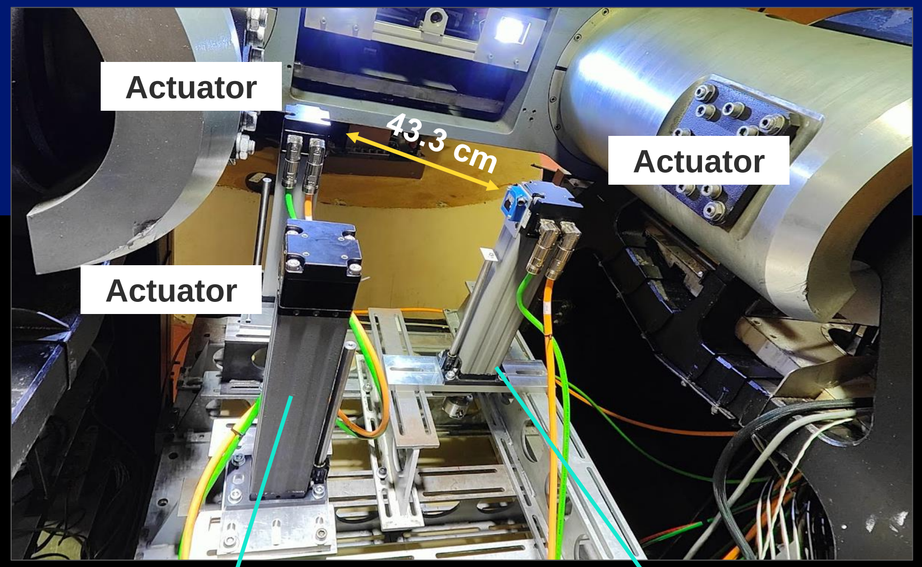
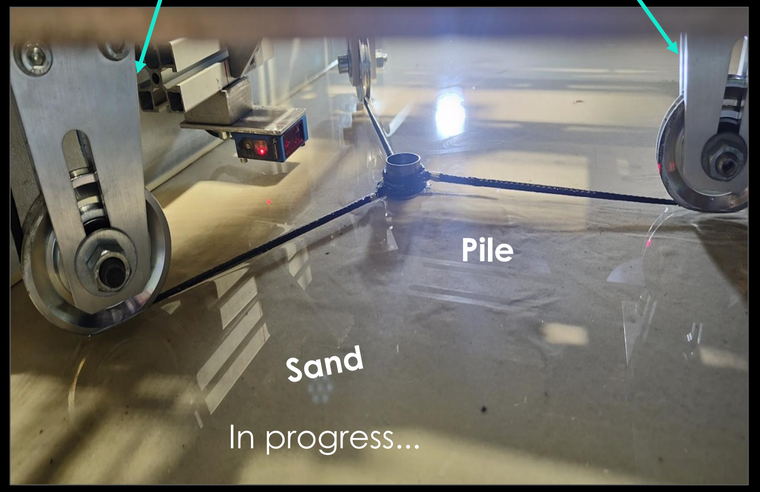


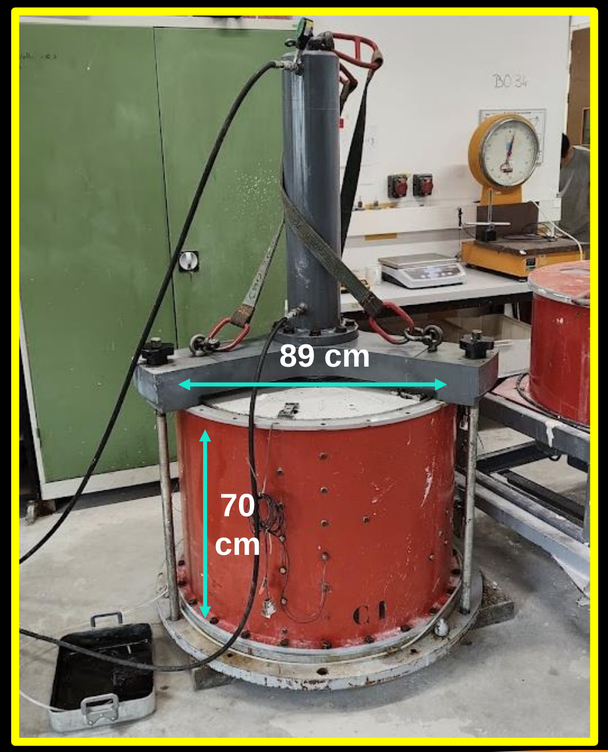




**Based on MUTANC project**
**Shared anchors in sand**

# WP2: Physical modelling
# Test SW_01

Model preparation techniques: For models in clay
Reconstituted Speswhite kaolin + experience from previous tests using anchors – LCPC/IFSTTAR

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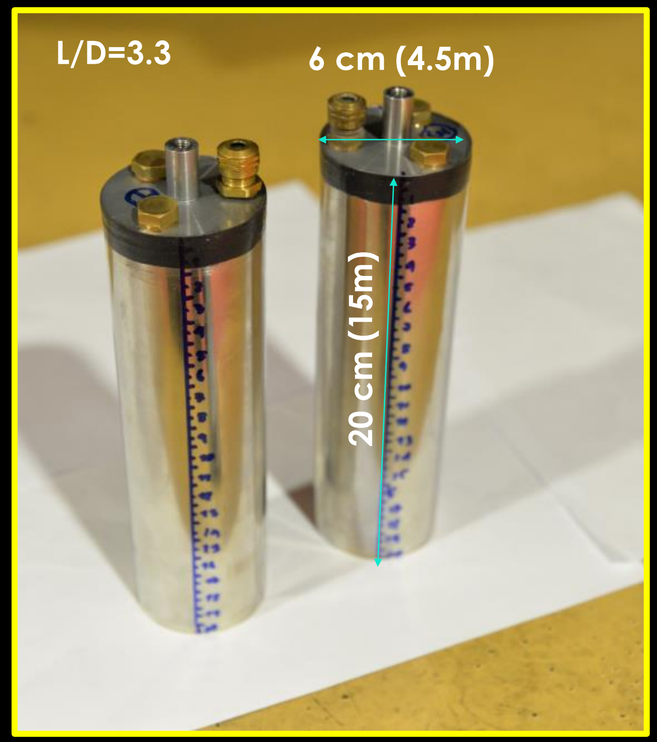


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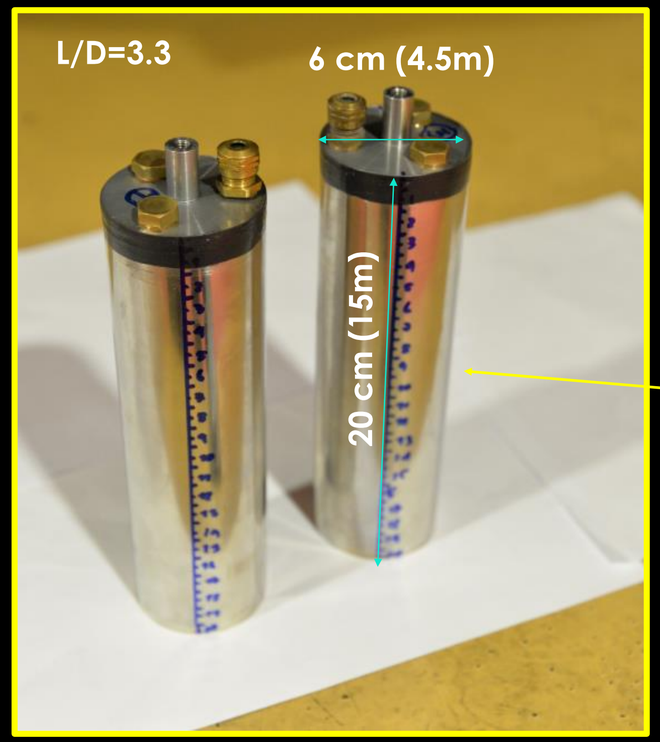


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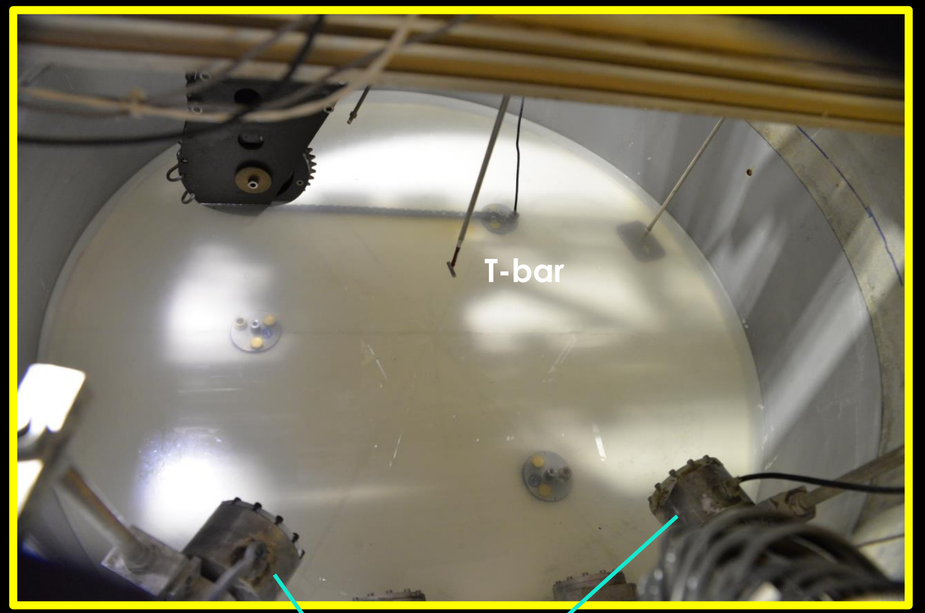
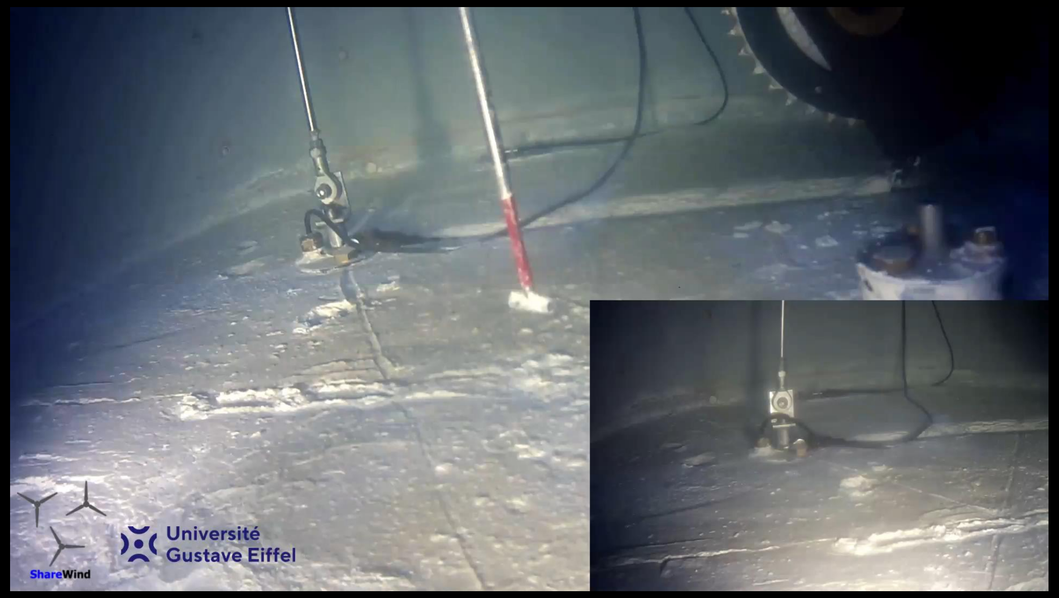
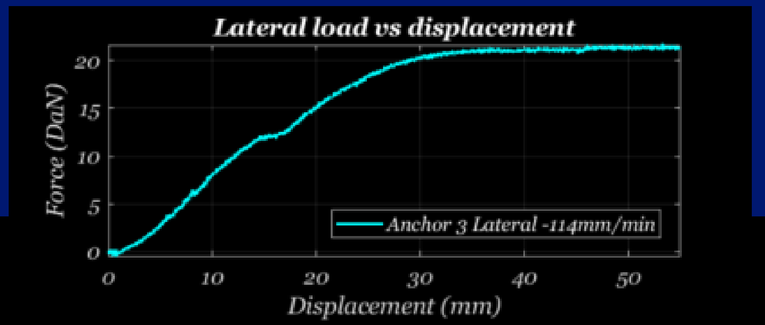
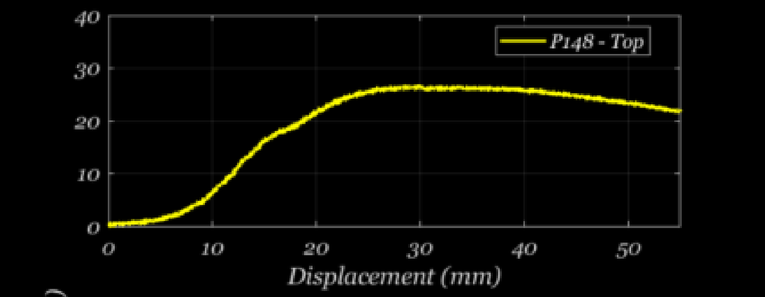


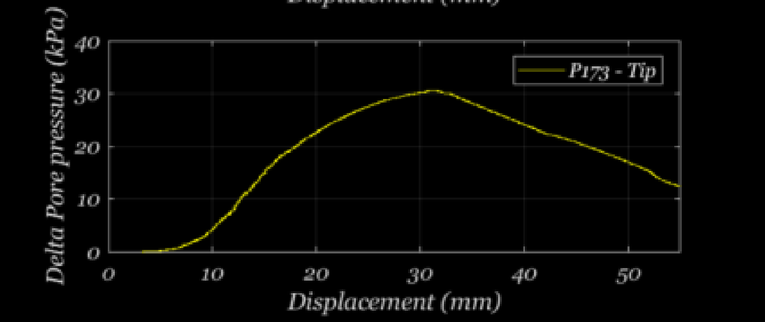
# WP2: Physical modelling
# Test SW_01

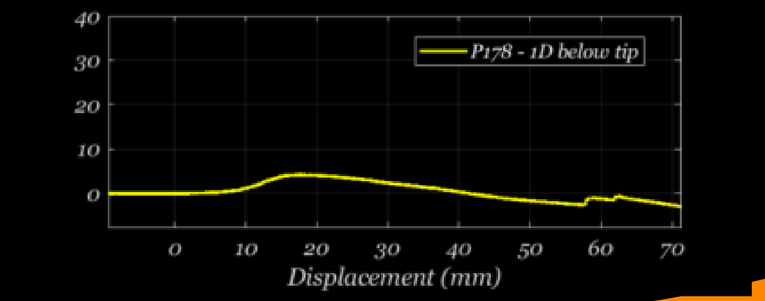
Lateral load and pullout tests



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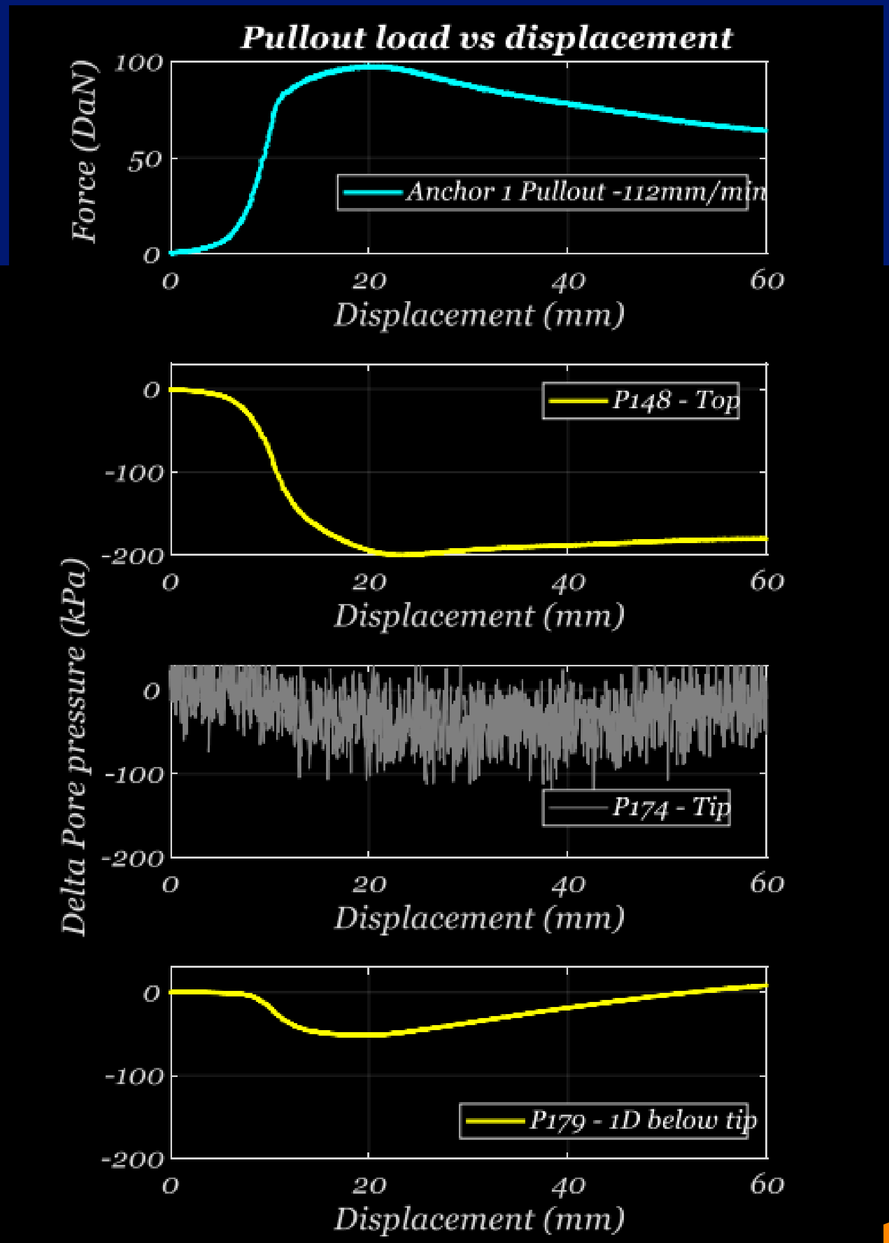
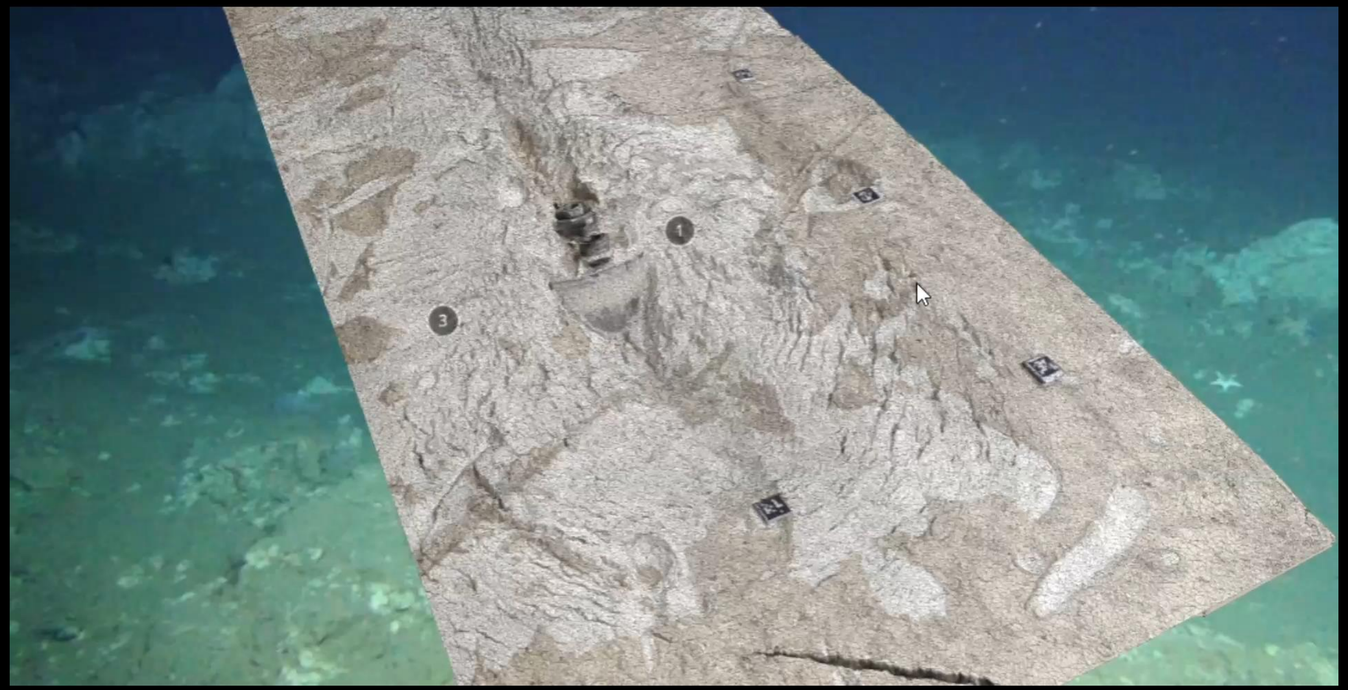
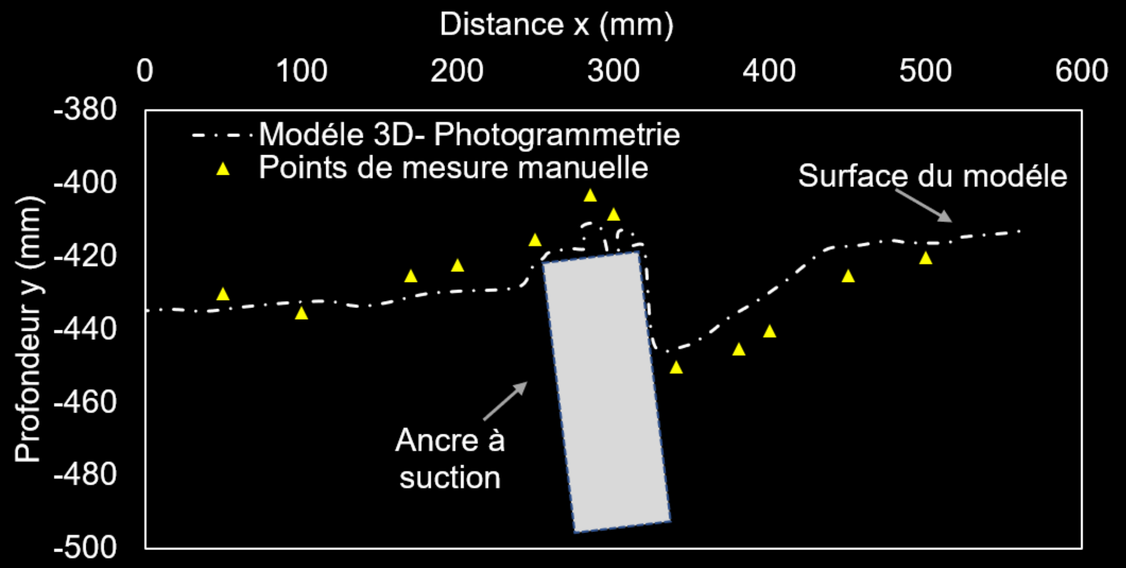


# WP2: Physical modelling
# Test SW_01

## Implementation of photogrammetry

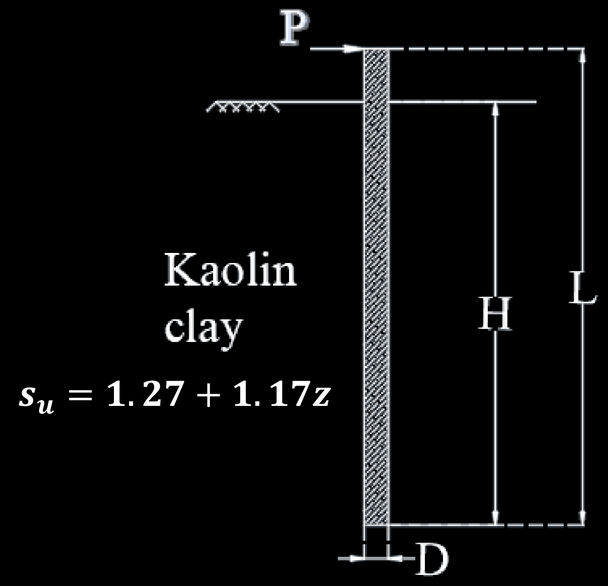


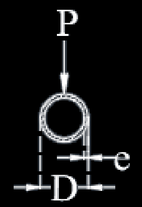
RealityCapture Sketchfab



# WP1 and WP3: Numerical modelling

Methodology for cyclic loading: pile installed in clay
SOLCYP project Khemakhen (2011)

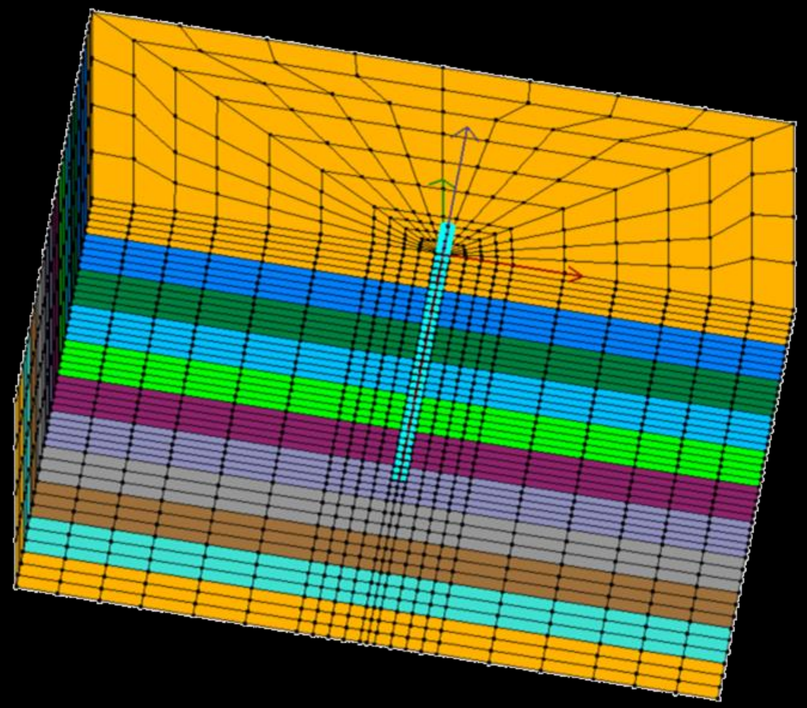


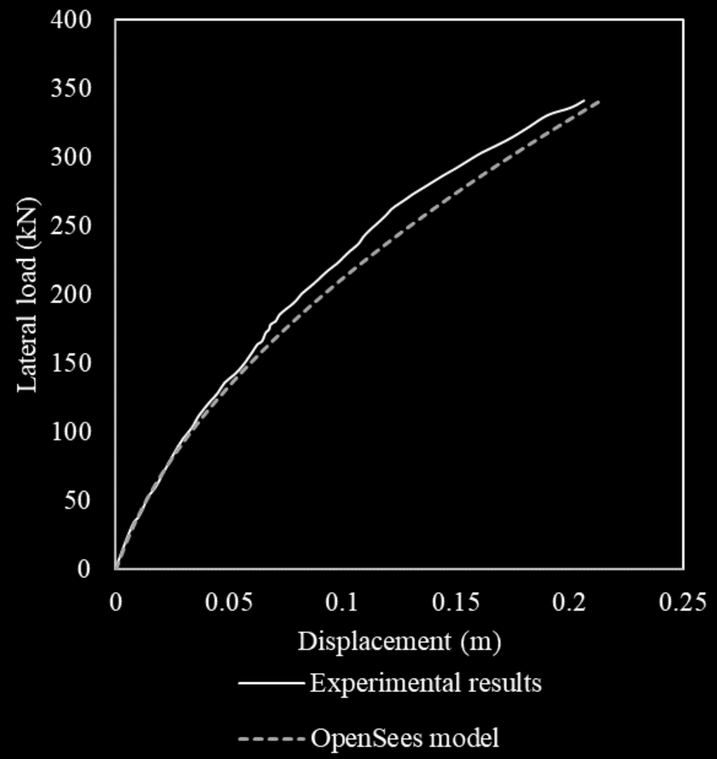



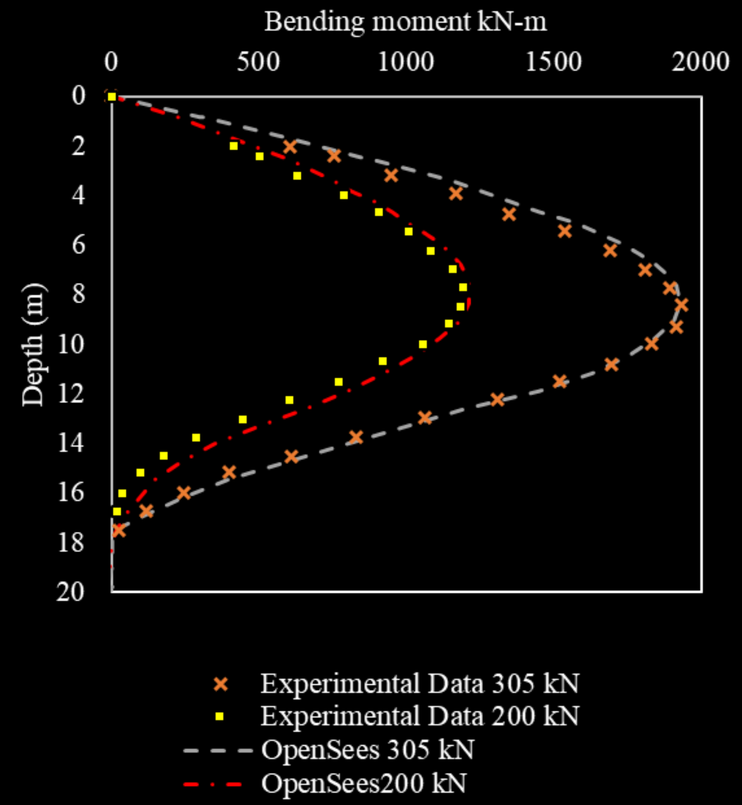

| Parameter | Model dimensions (1/50) | Prototype dimensions |
|---|---|---|
| **Length, L** | **360 mm** | **18 m** |
| **Embedded length, H** | **320 mm** | **16 m** |
| **Diameter, D** | **18 mm** | **0.954 m*** |
| Wall thickness, e | 1 mm | 40 mm* |
| Modulus of elasticity, E | 74 Gpa (aluminum) | 74 Gpa (aluminum) |
| Flexural rigidity, EI | - | 895MNm2 |

# WP1 and WP3: Numerical modelling

## Monotonic load – Model calibration in OpenSees

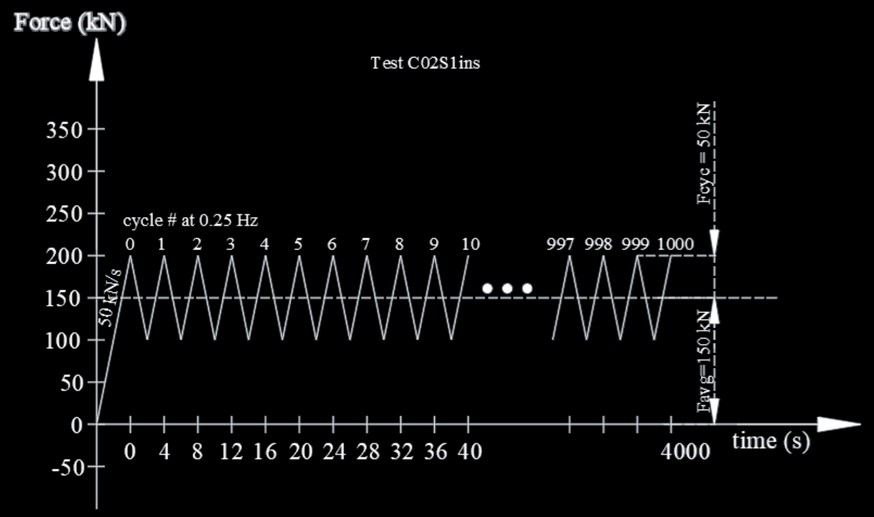


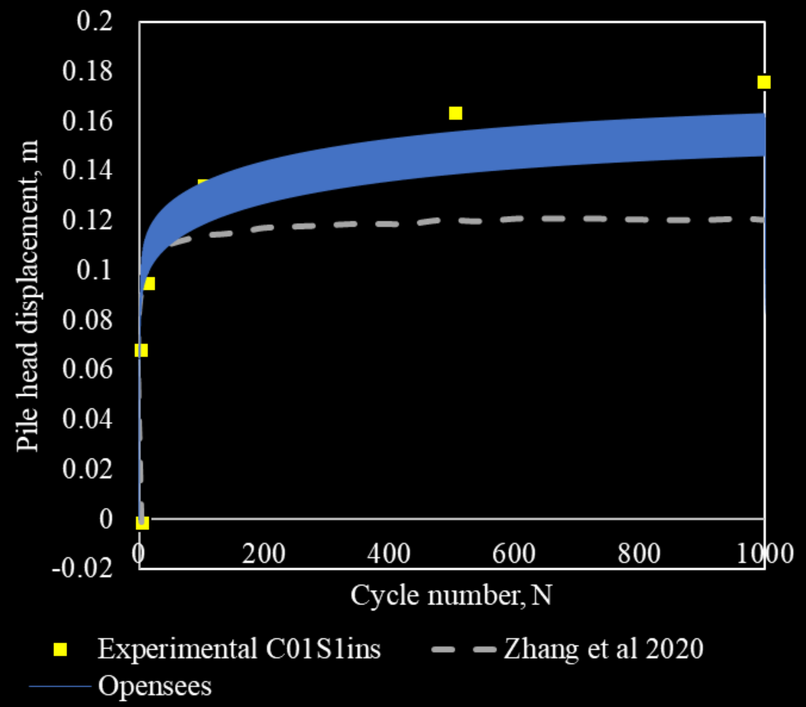


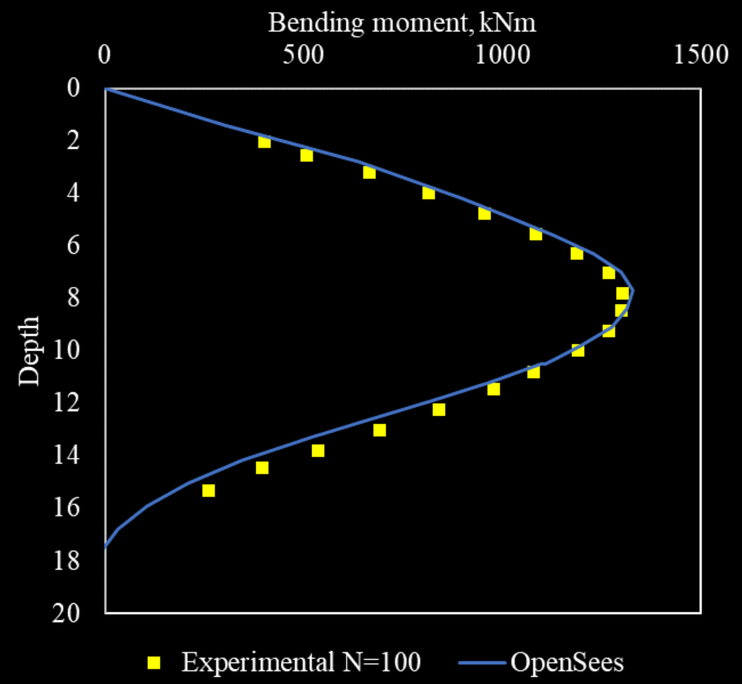



# WP1 and WP3: Numerical modelling

## Cyclic load – Calibration in OpenSees

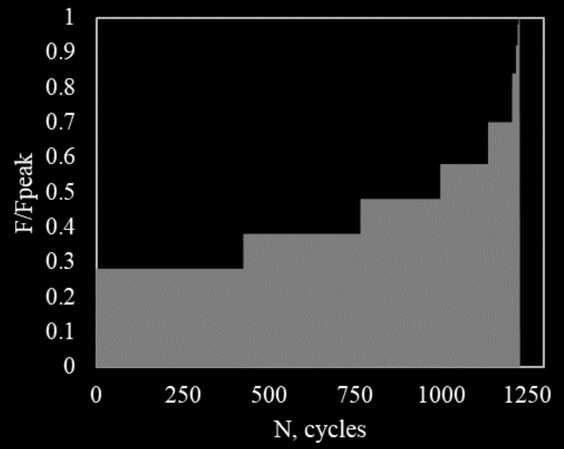


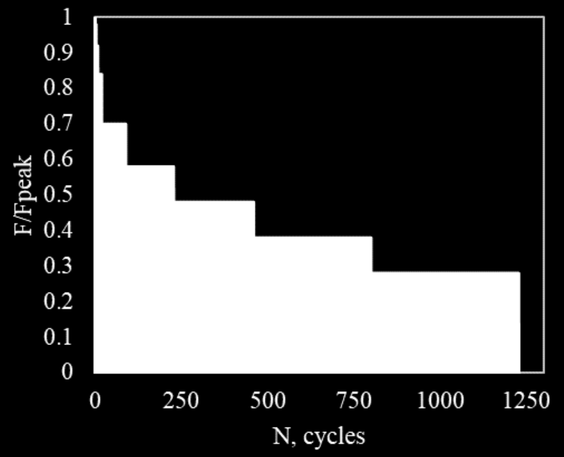



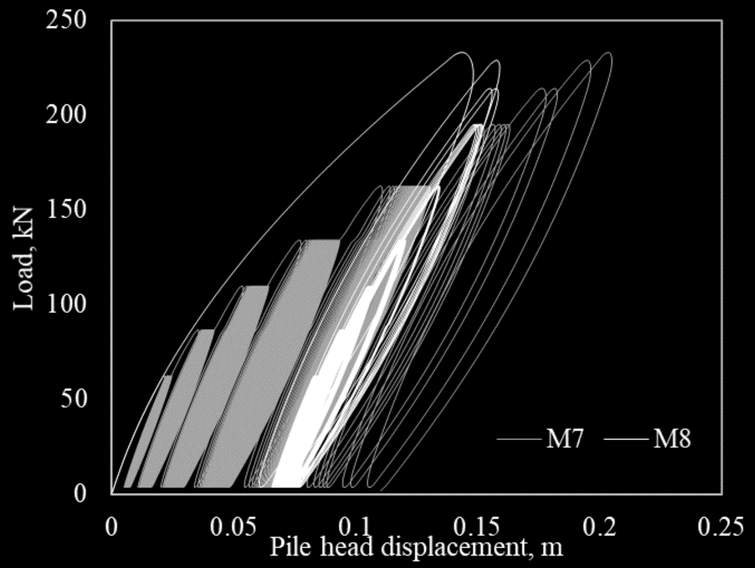



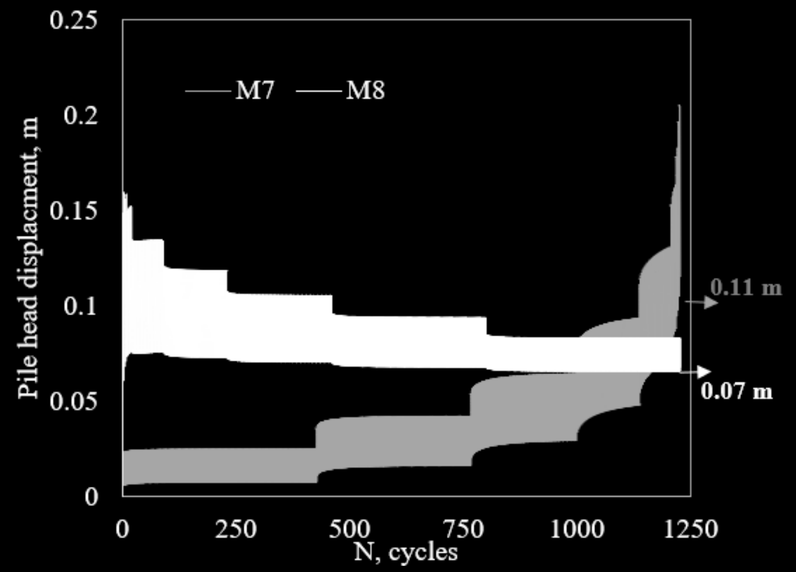
# WP1 and WP3: Numerical modelling

## Cyclic load – Application of variable amplitude loads (Andersen, 2015)



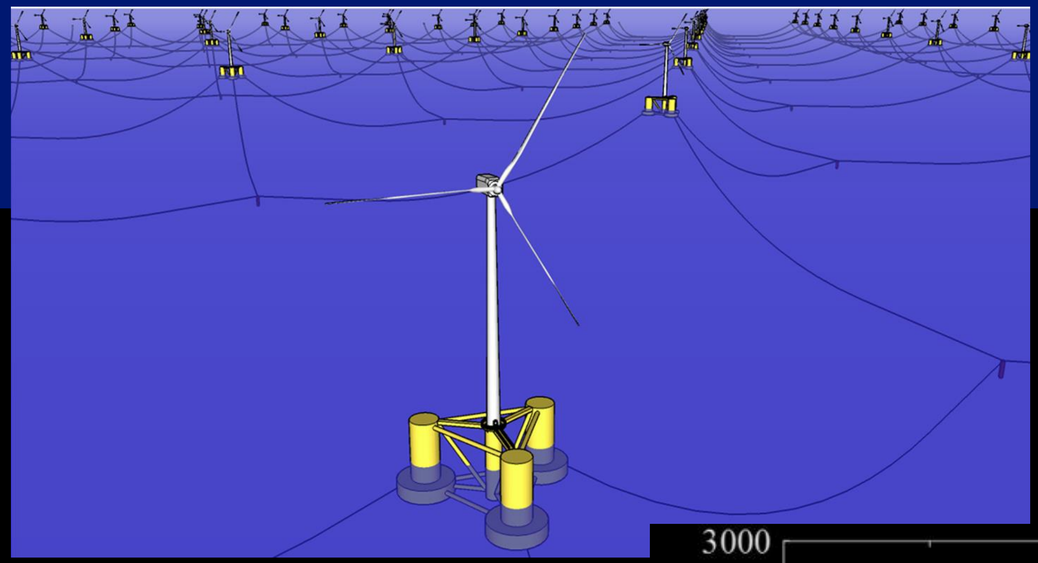



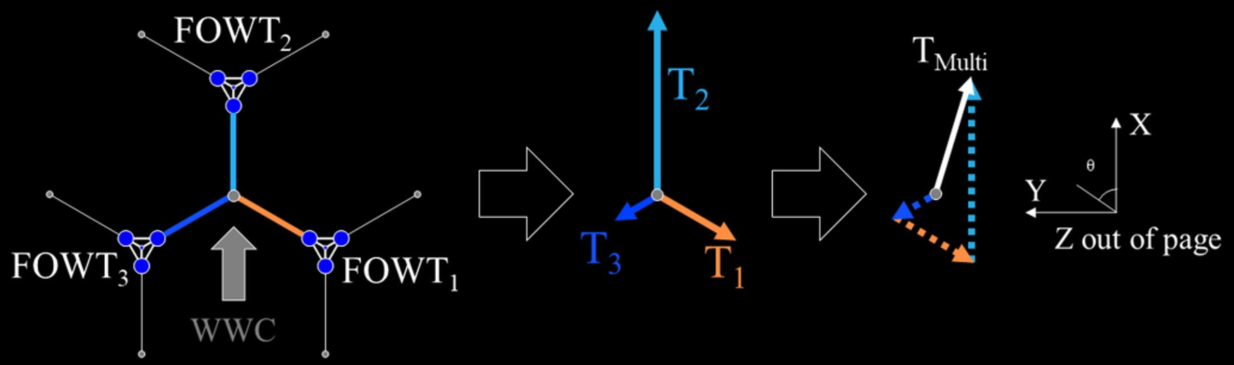



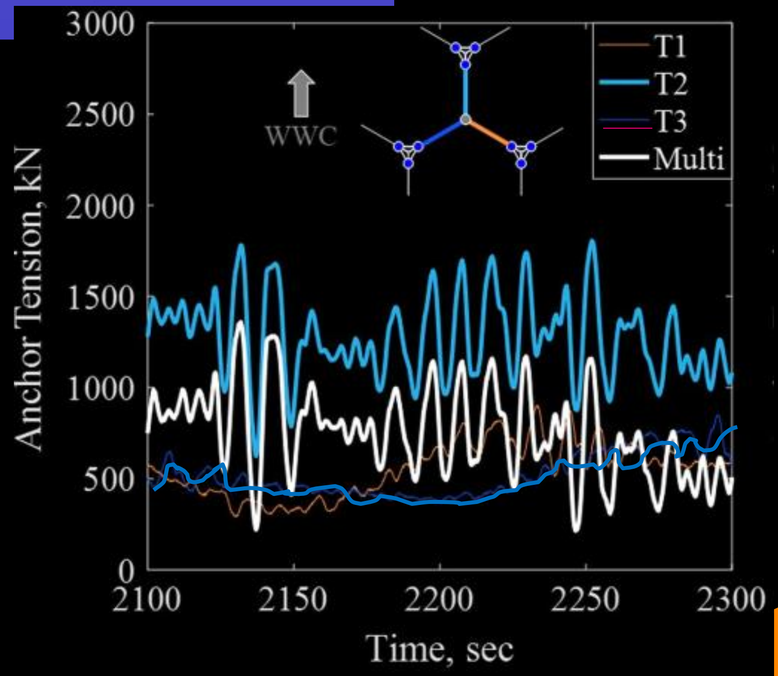
# WP1 and WP3: Numerical modelling

## Cyclic load – Multidirectional



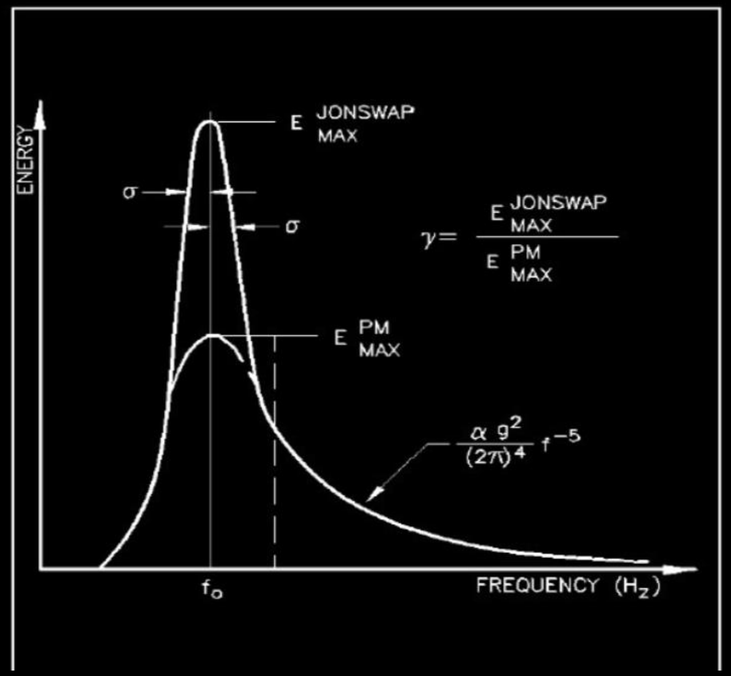



Fontana et al. (2018)

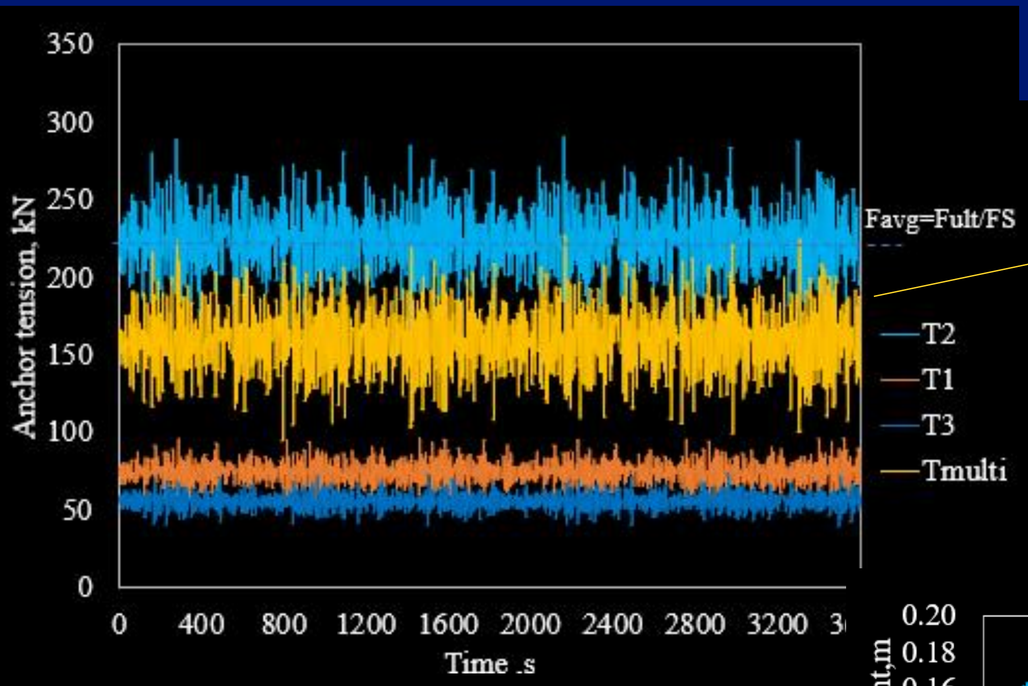


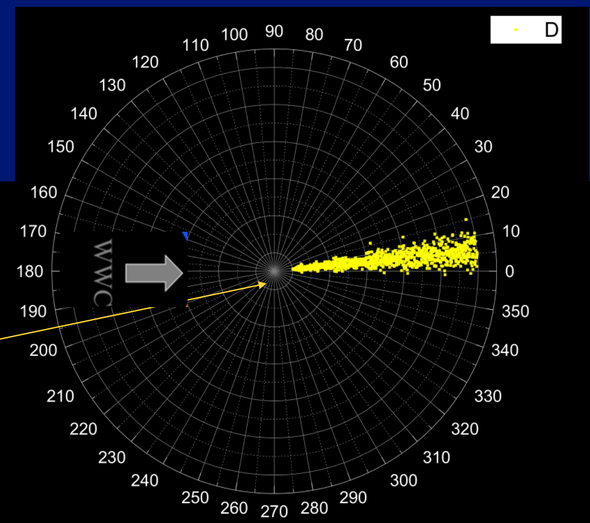
# WP1 and WP3: Numerical modelling

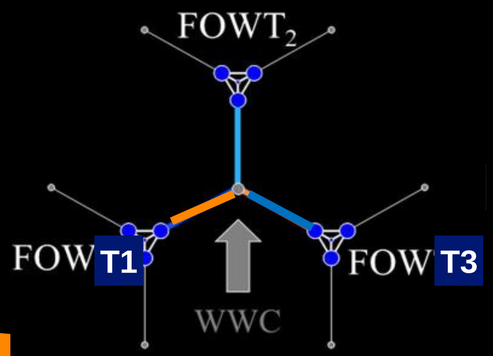
## Cyclic load – Multidirectional

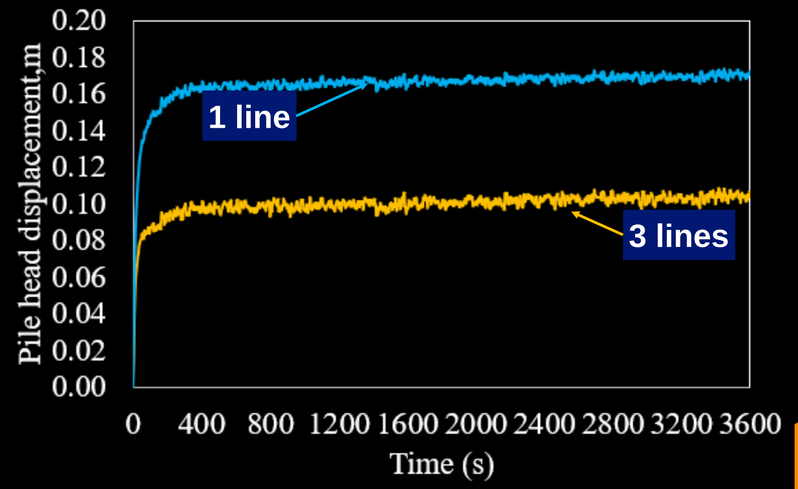



| | |
|---|---|
| Significant wave height | 8.0 m |
| Peak spectral wave period | 12.7 s |
| JONSWAP gamma factor | 2 |



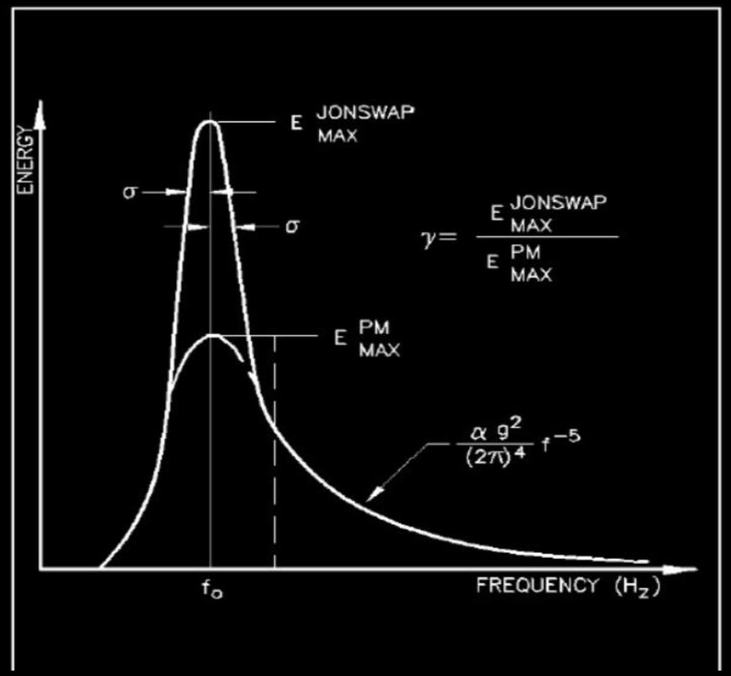



# WP1 and WP3: Numerical modelling

## Cyclic load – Multidirectional




| | |
|---|---|
| Significant wave height | 8.0 m |
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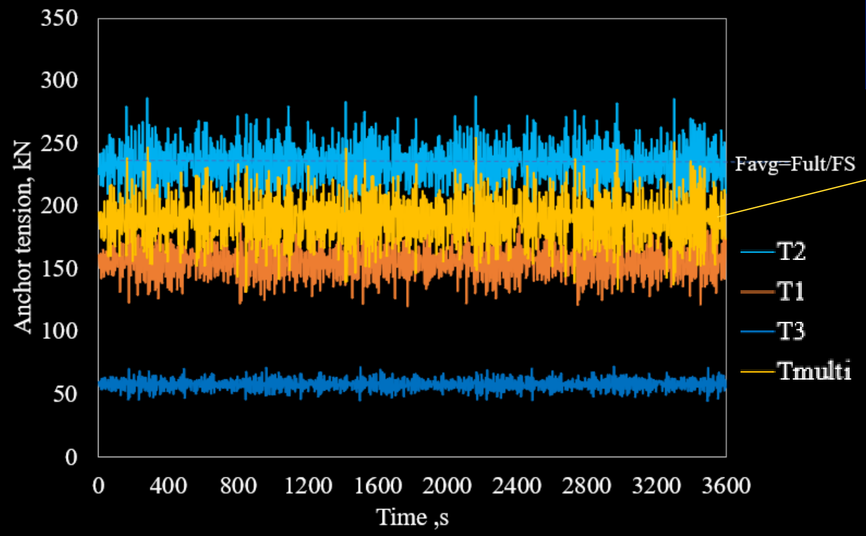


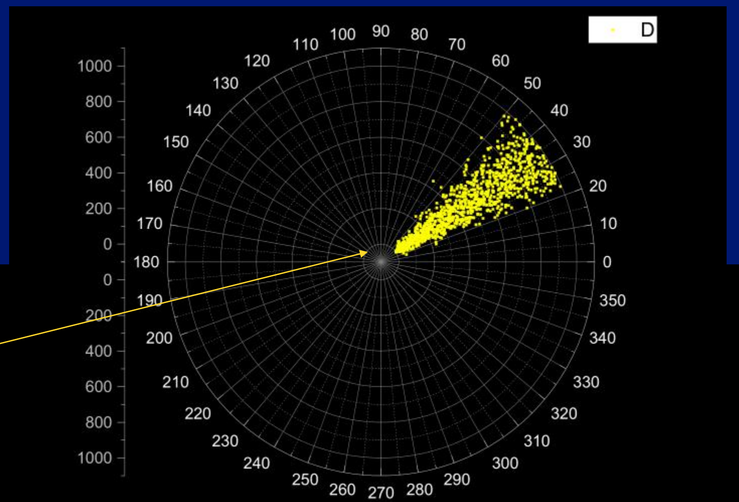


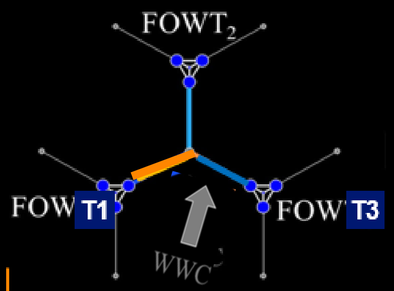


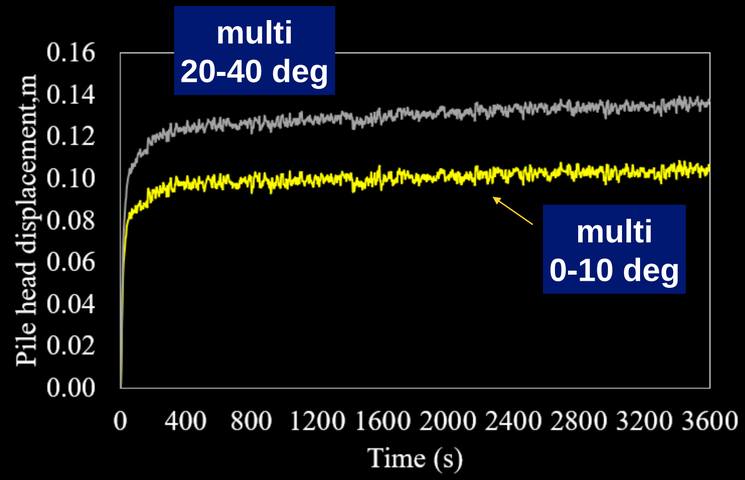

# Final Remarks

- Development of experimental setup for monotonic load
- In progress the setup for multidirectional load
- Application of measuring techniques and preservation of digital copies of the models
- Some insights about the numerical modelling approach, initial application to piles+OpenSees

Project Website