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Innovation and Networking for Fatigue and Reliability Analysis of Structures – Training for Assessment of Risk

Lifetime Cyclic Behavior of Offshore Wind Turbine Foundations

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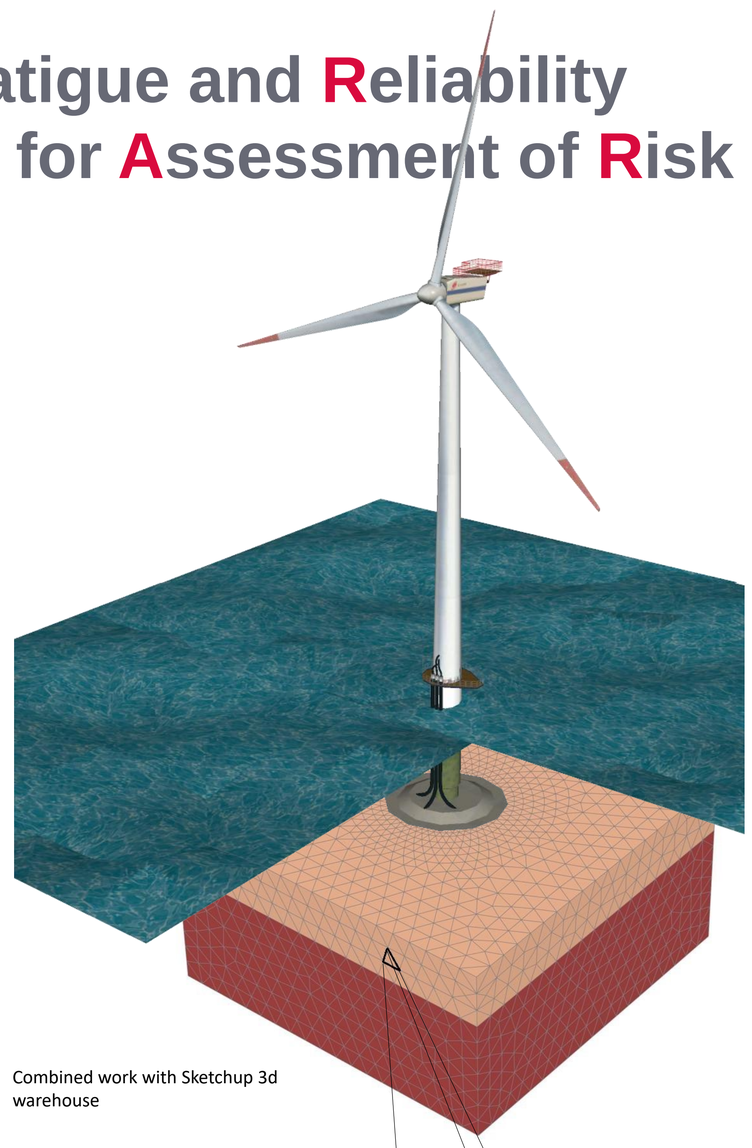


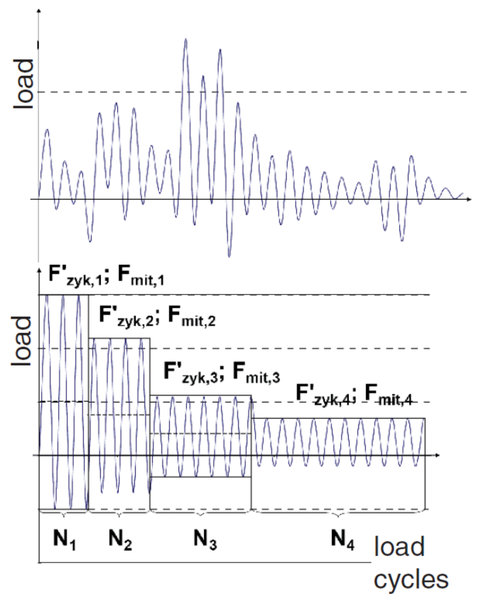
Combined work with Sketchup 3d warehouse

Introduction

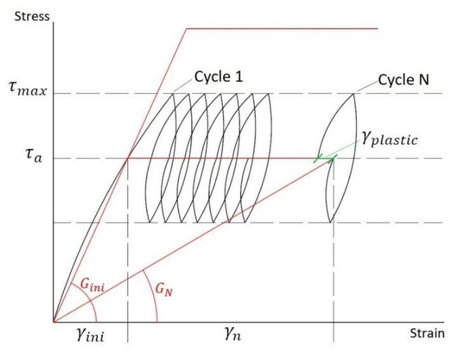
- Predicting the performance of soil under cyclic loading conditions is still a challenge
- One typical application example is the foundation of offshore wind turbines (OWTs), for which the change of the soil condition could lead to irreversible strain accumulation (tilting) and dynamic resonance problems
- The scientific contribution of this research is to diminish the existing lack of an accepted generic method which addresses the foundation design when cyclic loading conditions are considered
- Two different strategies are considered to predict the behavior of cyclic loaded soil:
  1. Implicit strategy (calculation of the soil behavior cycle-by-cycle)
  2. Explicit strategy (prediction of the soil behavior due to N regular cycles).

Explicit method to account for Cyclic Degradation of OWT foundations Using Cyclic Contour Diagrams

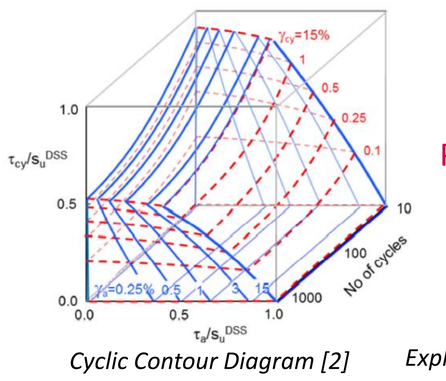
- This methodology evaluates the tilt of a foundation under cyclic loading
- The irregular load history is divided into a number of load packages of constant cyclic load amplitudes, average load and N number of cycles (e.g. Rainflow-Counting)
- The effects of cyclic degradation are taken into account by the modification of a fictional elastic shear modulus of the soil in a cluster-wise division in the finite element domain (PLAXIS 3D [1])
- The modification of the soil modulus is based on the cyclic interaction diagrams framework [2] (laboratory test campaigns)
- A remote scripting interface allows for a fast communication between the finite element model and the cyclic contour diagram
- An application example for a GBF for a storm design condition is presented in Zorzi et al (2018) [3]



Simplification of the irregular loading [6]

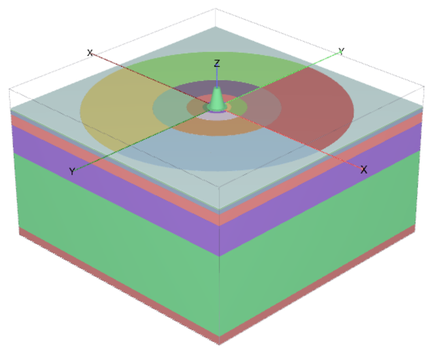


Stiffness Degradation Concept



Cyclic Contour Diagram [2]

Python Interface



Cluster-wise division PLAXIS 3D [1]

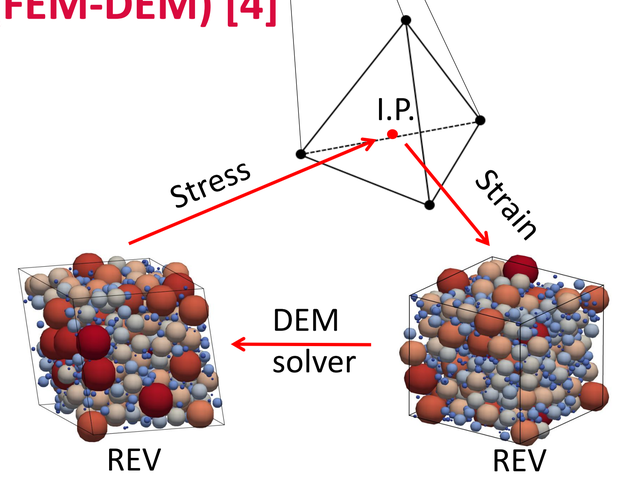
Explicit Method Communication

Future Development

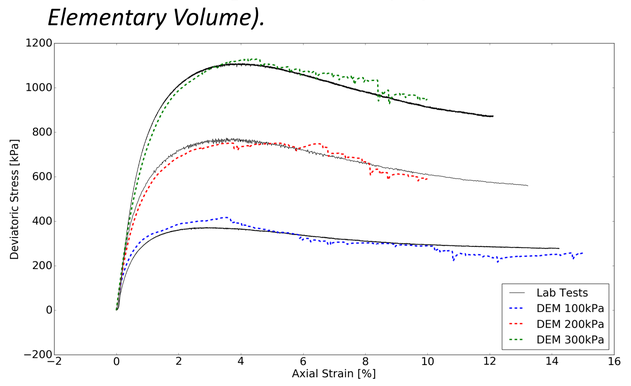
- Different types of foundations, such as monopoles, gravity based or suction bucket foundations, can be modeled.
- Pore water pressure accumulation will be considered in order to account to potential soil liquefaction problems
- Sensitivity analysis of the cluster dimension and the uncertainty related to the cyclic contour diagrams

Hierarchical multiscale coupling Finite Element Method-Discrete Element method (FEM-DEM) [4]

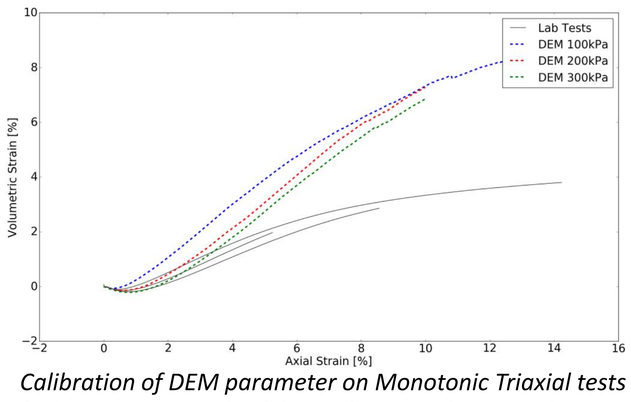
- DEM has the potential to simulate long term cyclic loading as shown in Zorzi et al. [5]
- Hierarchical multiscale coupling FEM-DEM is a promising method
  - FEM solves the boundary value problems
  - DEM provides the mechanical behaviour of the granular material
- The constitutive relations in FEM are given by the stress-strain responses of periodic cells (REV) in which the macromechanical behavior is derived from the micromechanical interaction of a minimum number of discrete elements
- The micromechanical parameters in DEM are calibrated with a single DEM periodic cell on different boundary conditions (confining pressures)
- The DEM micromechanical parameters should be calibrated in monotonic and cyclic tests



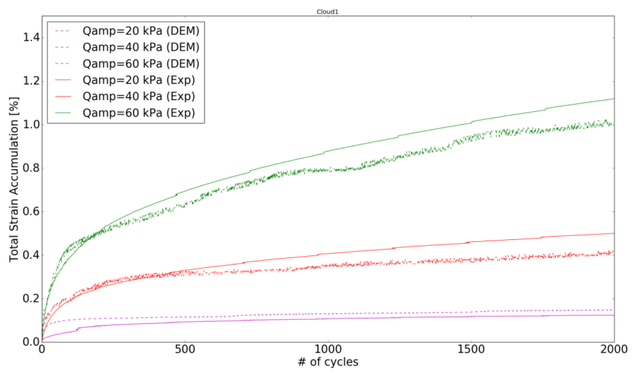
FEM-DEM working scheme. REV (Representative Elementary Volume).



Calibration of DEM parameter on Monotonic Triaxial tests (deviatoric stress plots) for Berliner Sand. 3000 Spheres.



Calibration of DEM parameter on Monotonic Triaxial tests (volumetric strain plots) for Berliner Sand. 3000 Spheres.



Calibration of DEM parameter on Cyclic Triaxial tests (accumulated total strain plots) for Berliner Sand. 3000 Spheres.

Future Development

- Automatic method for the micromechanical parameters calibration
- Reduced integration schemes will be investigated to decrease the computational time in the FEM part
- FEM-DEM method will be validated by simulating cyclic and monotonic triaxial tests

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2. Andersen, K.H. (2015), "Cyclic soil parameters for offshore foundation design". The 3rd McClelland Lecture. *Frontiers in Offshore Geotechnics III*, ISFOG'2015, 1, 5-82.
3. G. Zorzi, T. Richter, F. Kirsch, A.H. Augustesen, M.*U. Østergaard, S.P.H. Sørensen (2018),* Explicit method to account for cyclic degradation of offshore wind turbine foundations using cyclic interaction diagrams. ISOPE2018, The 28th International Ocean and Polar Engineering Conference. Sapporo, Japan.
4. Guo N., Zhao J. *(*2014*),* A coupled FEM/DEM approach for hierarchical multiscale modelling of granular media, Int. J. Numer. Meth. Engng, 99, 789–818
5. G.Zorzi, F. Kirsch, F. Gabrieli, F. Rackwitz (2017), Long-term cyclic triaxial tests with DEM simulations. Particles 2017, V International Conference on Particle-Based Methods (PARTICLES 2017). September 2017 in Hannover, Germany
6. BSH Strandards. Guidance for the use of the BSH standards “Design of Offshore Wind Turbines”

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MARIE CURIE ACTIONS

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