



1 Simple-shear cell, Fraunhofer IWES,

Photo: Fraunhofer IWES

2 Alpha Ventus wind farm,

Photo: Fraunhofer IWES

## GEOTECHNICAL LABORATORY INVESTIGATIONS

**Fraunhofer IWES North-West**  
**Am Fallturm 5**  
**28359 Bremen / Germany**

Taisiya Biryaltseva  
Phone +49 421 218-65848  
taisiya.biryaltseva@iwes.fraunhofer.de

Prof. Dr. Tobias Mörz  
Phone +49 421 218-65840  
tobias.moerz@iwes.fraunhofer.de

[www.windenergie.iwes.fraunhofer.de](http://www.windenergie.iwes.fraunhofer.de)

### Requirements for foundation design of offshore wind turbine structures

According to DNV GL OS-J101 and many other recent guidelines and national requirements, geotechnical soil investigation consists of in-situ testing of soil and of soil sampling with subsequent laboratory testing. All this shall provide the following types of geotechnical data for all important layers:

- Data for soil classification and description
- Shear strength and deformation properties, as required for the type of analysis to be carried out
- in-situ stress conditions

The laboratory test program for determination of soil strength and deformation properties covers a set of different types of tests and a number of tests of each type, which will suffice to carry out a detailed foundation design. For mineral soils, such as sand and clay, *direct simple shear tests* and *triaxial tests* are relevant types of tests for determining strength properties.

Since the offshore wind turbine structures are subjected to waves and wind, the effects of *cyclic loading* on the soil properties shall be considered in foundation design. *Cyclic shear stresses* may lead to a gradual increase in pore pressure. Pore pressure build-up and the accompanying increase in cyclic and permanent shear strains may reduce the shear strength of the soil. These effects have to be taken into account in the assessment of the characteristic shear strength for usage in the design within applicable limit state categories as well as in the assessment of permanent foundation rotations.

Fraunhofer IWES in collaboration with cooperation partners offers advanced geotechnical laboratory testing and provides assistance in planning of cyclic and static test programs for determination of soil properties under a range of load conditions to be covered by the foundation design and installation procedure.



EUROPEAN UNION:

Investing in your future

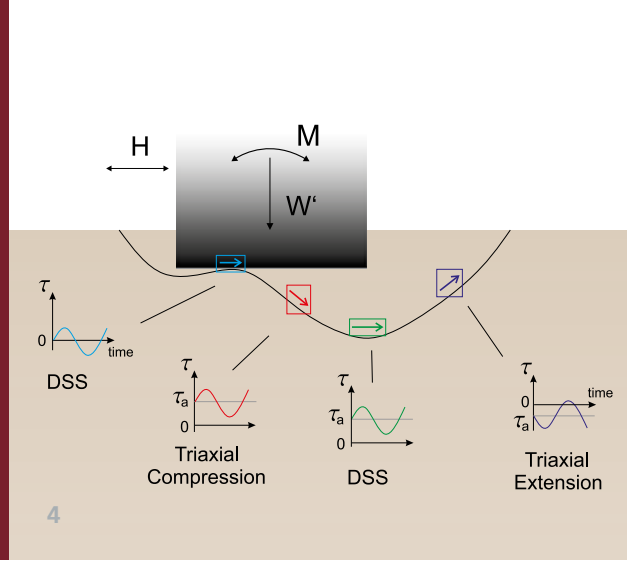
European Regional Development Fund

Supported by:



on the basis of a decision  
by the German Bundestag





### Laboratory tests

#### Basic laboratory tests

- Tests for the classification and state description (DIN 18123, DIN 18125-1, DIN 18126, DIN 18129): grain size distribution, specific gravity, minimum and maximum density, calcite equivalent
- Tests on deformation behaviour in accordance with DIN 18135, DIN 18137-2: oedometer tests, triaxial tests
- Shear strength tests of the ground in accordance with DIN 18137-2, DIN 18137-3: triaxial tests, direct shear box tests

#### Cyclic laboratory tests

- Cyclic triaxial test (undrained and drained)
- Cyclic direct simple shear test DSS (constant volume and drained)
- Cyclic direct shear box test (drained and undrained)
- Cyclic oedometer test

### Cyclic DSS tests at Fraunhofer IWES

- Monotonic and cyclic loading (load/displacement controlled)
- Stress-strain-strength properties (various stress/strain levels and frequencies)
- Drained and undrained (constant volume) conditions
- Estimation of shear modulus
- Creep test
- Cross-sectional area of 20 or 40 cm<sup>2</sup> and a height of 16 up to 25 mm
- Cell consists of stack of Teflon coated rings

Cohesionless specimens are reconstituted to in-situ conditions using specified build-in procedure according to desired density and structure, cohesive soils are tested undisturbed. Preshearing of specimen is possible.

### Cyclic triaxial tests at Fraunhofer IWES / University of Bremen

- Monotonic and cyclic loading
- Stress-strain-strength properties

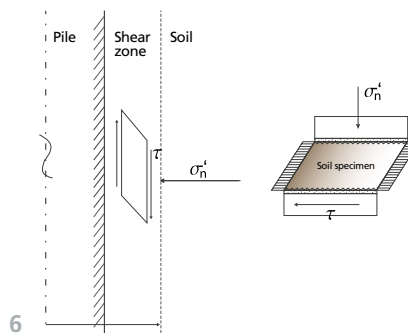
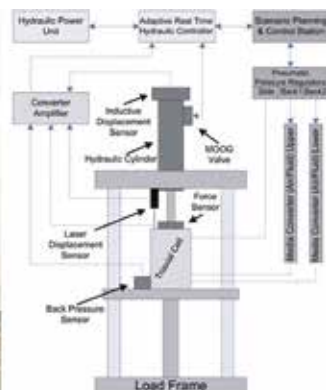
(various stress/strain levels and frequencies)

- Isotropic and anisotropic consolidation
- Drained and undrained conditions
- Creep tests under constant shear stress
- Cylindrical specimen with the cross-sectional area of 10 cm<sup>2</sup> and height up to 100 mm

### Services

Fraunhofer IWES in collaboration with cooperation partners (marum, University of Bremen, Geo-Engineering.org GmbH) offers:

- All the above-listed basic laboratory tests in accordance with DIN
- Cyclic and static triaxial tests
- Cyclic and static direct simple shear tests, cyclic direct shear tests
- Consulting on using the test results in the technical design
- Consulting on planning and development



3 Cyclic DSS, Fraunhofer IWES, photo: Fraunhofer IWES

4 Simplified stress conditions along a potential failure surface beneath a shallow foundation. (Modified after Andersen et al. 1988)

5 Dynamic triaxial testing device (DTTD) at marum, University of Bremen, Photo: marum

6 Application of DSS. Idealization of shear zone adjacent to a pile (modified after Randolph and Wroth, 1981)