Third Semester and Master's Thesis Ideas 2020: M.Sc. in Civil and Structural Engineering

Nielsen, Jannie Sønderkær

M.Sc. in Civil and Structural Engineering:

Third Semester and Master's Thesis Ideas 2020

Edited by Jannie Sønderkær Nielsen

DEPARTMENT OF THE BUILT ENVIRONMENT
AALBORG UNIVERSITY

Aalborg University
Department of the Built Environment

M.Sc. in Civil and Structural Engineering: Third Semester and Master's Thesis Ideas 2020

Edited by

Jannie Sønderkær Nielsen

May 2020

Aalborg University

Aalborg University
Department of the Built Environment
Thomas Manns Vej 23,
DK-9220 Aalborg Ø, Denmark

M.Sc. in Civil and Structural Engineering: Third Semester and Master Projects Ideas

The following pages contain a list of project ideas proposed by the scientific staff at the Department of the Built Environment, Aalborg University, and a number of companies. The project ideas in this catalogue may form the basis for long and short master projects as well as regular 3rd semester projects at the M.Sc. programme in Civil and Structural Engineering. On the project proposals it is stated which type of project the proposal is suitable for, and this can should be further discussed with the potential supervisor.

The preferred group size for master projects is two or three students. In the interest of students as well as supervisors, single-student projects are generally not recommended. In a short third semester project the recommended minimum group size is three students, some supervisors may require more.

Each project description provides a brief overview of the purpose as well as the main activities. Further, a weighting between theoretical analysis, experimental work and computer modelling has been proposed. Usually, this weighting can be changed slightly in accordance with the wishes of the students. The contact persons listed will usually act as supervisors. Questions regarding details about each proposed project should be directed at the contact persons. Most projects in this catalogue are proposed by researchers from the following research groups:

- Ocean and Coastal Engineering Research Group
- Geotechnical Engineering Research Group
- Reliability and Risk Analysis Research Group
- Risk, Resilience and Sustainability in the Built Environment
- Advanced Structures Research Group

This catalogue is ordered in parts corresponding to these research groups, and you can use the “Navigation Pane - Bookmarks” to navigate in the document. Each part starts with a one-page description of the research group and with the names of potential supervisors. This should give an overview of the persons that you can contact, if you have an interest in an area, and would like to discuss ideas for projects that are not in the catalogue. The contact details can be found via a person search on the university home page.

Many private engineering companies have a homepage on which they state that they would like to collaborate with students on a master project. Find out more on the individual company home pages.

A final remark about master projects: A signed thesis contract must be handed to your study secretary at latest October 1st for long master projects and March 1st for short master projects. The contract must contain information about the project, in

particular regarding the educational goals. These must be defined in accordance with the Master Curriculum (danish: Studieordningen) for the M.Sc. Programme in Civil and Structural Engineering at https://studieordninger.aau.dk/2019/17/890. The thesis contract template is the online form available at https://www.en.build.aau.dk/education/rules-and-forms/thesis-contract/. The delivery date for project reports will be set by the Study Board. It is usually around June 7 for Master theses. For third semester projects, the thesis contract is not needed.

Aalborg, May 18, 2020 Jannie Sønderkær Nielsen

Ocean and Coastal Engineering Research Group

Research area:
We conduct research within the field of ocean waves and hydrodynamic modelling, with particular focus on marine renewables and coastal structures.

Our research is primarily carried out through externally funded collaborative projects, involving both private and public organizations, and our teaching is primarily aimed at master level courses within civil engineering and PhD courses within its primary field of research.

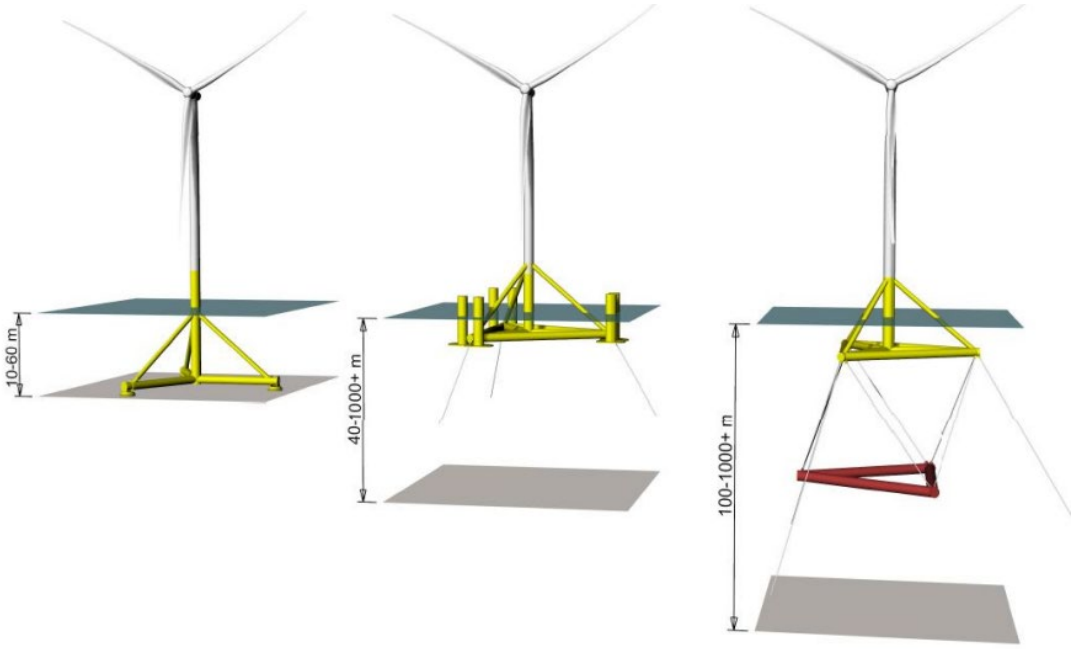
Key topics:

- Numerical and experimental modelling and design of coastal and harbor structures, with specific focus on breakwaters.
- Numerical and experimental hydrodynamic modelling and design of (arrays of) wave energy converters and floating wind turbines.
- Power performance assessment, control optimization and evaluation of levelized cost of energy for wave energy converters
- Real sea testing of wave energy converters and floating wind turbines.
- Measurements, analysis and forecasting of ocean waves.
- Design, analysis and optimization of moorings for floating structures exposed to waves.
- Development and commercialization of software packages for wave laboratory equipment and wave generation systems.

Supervisors:
Thomas Lykke Andersen, Peter Frigaard, Amélie Têtu, Morten Kramer, Claes Eskilsson, Jonas Bjerg Thomsen, Francesco Ferri

Next Generation of Offshore Wind Turbine Foundations

Purpose: The offshore wind industry in Northern Europe has seen rapid growth of the last decade. This growth had been greatly assisted by the relatively shallow waters of the North Sea where monopiles have proven to be a cost-effective foundation solution.
Currently AAU is heavily involved in the research and development of the next generation of offshore wind turbines foundations. For countries with deeper waters floating foundations are the only answer, and multiple concepts are already claiming commercial readiness. For shallower waters self-installing bottom-fixed foundations are on the horizon in order to (like the floating counterparts) negate the costly heavy offshore lifting operations currently taking place.
A thesis project within this area can cover one or more of several disciplines: hydrodynamic calculation of stability/wave loading, design of novel mooring systems, structural design of foundations, innovative installation techniques, and many more. The project scope will be defined via discussion with supervisor.



Main activities: Depending on topics chosen the main activities will vary. Numerical modelling will likely form the basis of the project, while comparisons to experimental investigations or analytical solutions are optional.

Possible external collaborations: Depending on project scope/focus:
Stiesdal Offshore Technologies, Siemens Gamesa Renewable Energy, Welcon, Blue Power Partners, DIS/CREADIS.

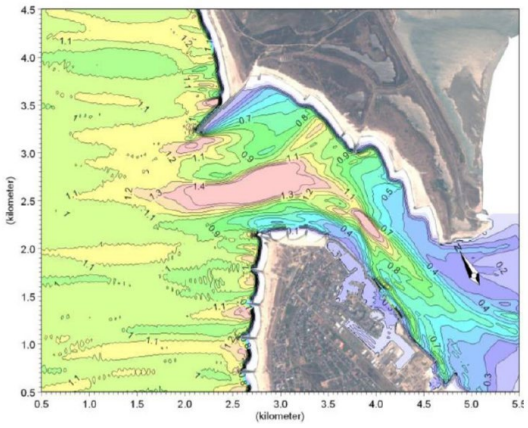
Contact persons: Jonas Bjerg Thomsen

Theory: ☒☒☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☐ **short master:** ☒ **Long master** ☒

Evaluation of closing the Thyborøn Channel to reduce the coastal erosion at down drift beaches along the Danish West Coast

Purpose: Recent research has shown a potential for protecting the Limfjord against storm surges by installing a storm surge barrier in Thyborøn channel. The storm surge barrier can be closed temporarily during storms, which significantly reduce the extreme water levels in the fjord. The high flow velocities into the fjord during storms brings large amount of sediments into the fjord. The present situation is thus that the sediment, which accumulates inside the fjord, is missing in the sediment budget at the west coast, which results in erosion.

The purpose of this project is to use numerical models to analyse whether the storm surge barrier can have a positive effect on the coastal erosion at down drift beaches close to Thyborøn channel, since the flow into the fjord will be much less and thus a much smaller part of the long-shore sediment transport at the west coast is expected to enter into the Limfjord. For the study, there is an opportunity for cooperation with the Danish Coastal Authority.



Main activities: The project will contribute to the on-going research on the subject and thus the following activities can be included:

- Evaluation of the processes leading to coastal erosion near the Thyborøn channel
- Numerical modelling of the influence of closing Thyborøn channel during storm on the coastal erosion at neighbouring beaches

Contact persons: Jørgen Quvang Harck Nørgaard, Thomas Lykke Andersen

Theory: ☒☒☐ Experimental work: ☐☐☐ Computer modelling: ☒☒☒
Suitable project type(s): 3rd sem ☐ short master: ☒ Long master ☒

Wave height distributions and wave attack on coastal protection structures in highly nonlinear deep and depth limited irregular wave conditions

Purpose: Most state of art design formulae for estimation of influence from wave attack on coastal protection structures (stability of superstructures, stability of armour layer, wave overtopping, etc.) are based on relatively linear wave conditions. However, many coastal protections structures are located in relatively shallow water wave conditions with long waves, i.e. non-linear wave conditions.

Recent research has indicated that the existing design tools might provide unsafe predictions in non-linear wave conditions and moreover existing wave height distributions are seen to underestimate the highest wave heights during a storm. The purpose of this study is to evaluate the influence of wave non-linearity and to derive modifications to existing design formulae and wave height distributions based on physical model tests or numerical models.

Main activities: The project will contribute to the on-going research on the subject and thus the following activities can be included:

- Experimental and/or numerical modelling of wave height distribution in deep and depth limited non-linear wave conditions
- Experimental and/or numerical modelling of wave run-up, wave overtopping, and armour stability on rubble mound breakwaters in non-linear wave conditions
- Experimental and/or numerical modelling of dynamic wave loads on rubble mound breakwater crown walls in non-linear wave conditions

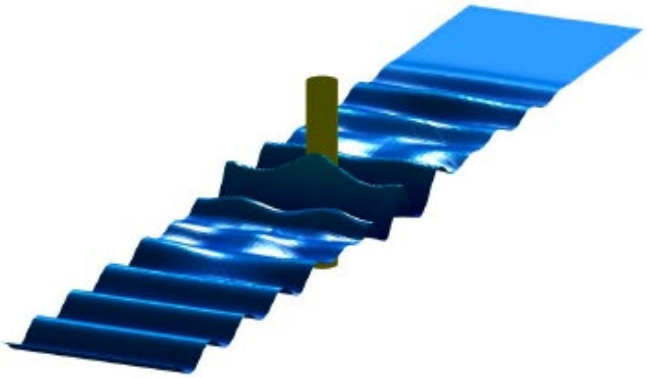
Contact persons: Jørgen Quvang Harck Nørgaard, Thomas Lykke Andersen

Theory: ☒☒☐ Experimental work: ☒☒☐ Computer modelling: ☒☒☐
Suitable project type(s): 3rd sem ☐ short master: ☒ Long master ☒

Wave breaking in a fully nonlinear potential flow spectral element model

Purpose: The purpose is to implement, verify and validate different levels of fidelity in modelling wave breaking in a fully nonlinear potential flow (FNPF) model. The FNPF model is based on the based on the spectral element method (SEM) – an unstructured arbitrarily high order numerical model based on sigma-transformed coordinates. The use of sigma-transformation makes that wave breaking cannot be naturally handled by the model but needs to be approximated in some way.

In the project different approaches to modelling wave breaking will be tested, initially the eddy viscosity concept and the wave roller concept.



Main activities: The project will contribute to the on-going development of the model and the following activities can be included:

- Study of theoretical breaking models
- Implementation into the numerical code (requires skill in matlab or c++)
- Verification and validation against standard test cases

The project will involve co-operation with external parties (DTU, Denmark and INRIA, France).

Contact person: Claes Eskilsson

Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☐ **short master:** ☐ **Long master** ☒

Limiting wave conditions for caissons installation: Developing a design methodology

Purpose: Caisson breakwaters are generally the preferred solution for new marine terminals/ports built in deep water locations. The caisson installation is generally planned to be carried out in the season where sea conditions are relatively calm. The installation of caisson breakwaters is expensive with high daily mobilization cost and with very large specialist equipment. However, due to the locations of these terminals, many are exposed to swell conditions making installation particularly difficult and time consuming. There is no present guidance for designers or contactors with clear methods to determine limiting wave conditions for caisson installing operations. COWI has been involved in several projects where caisson installation challenges were experienced.

The objective of the project is to study the wave-structure hydrodynamic interaction of the caisson in its pre-final stage (during ballasting and immersion), in order to determine the limiting wave conditions for the caisson installation. The project focuses on the hydrodynamic characteristics in the prefinal stage where the caisson is still acting as a large floating structure.

Main activities: The project will contribute to the on-going research on the subject and thus the following activities can be included:

- wave-structure interaction modelling for large floating structures
- data analysis and assessment for different caisson size/weight and wave conditions
- developing a general design methodology for limiting wave conditions for caisson installation using artificial intelligence or other advanced methods.
- Experimental verification of the developed model (in case of long master thesis).

Contact persons: Thomas Lykke Andersen

Theory: ☒☒☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Wave loads on concrete caisson during installation

Purpose: The purpose is to estimate the wave loads on a concrete caisson during installation where it is filled with water and before ballast material is installed. Under such situation there will be wave induced pressure on also the inner walls. COWI has estimated that omission of these pressures may lead to a significant contribution to the overall fatigue loads on the caisson walls. This project aims at studying the wave induced loads on the wall of the caisson (numerically and/or through model tests) and is carried out in close cooperation with COWI and actual projects.

Main activities: The aim is to develop a simplified model for the loads on the caisson walls before the caisson is ballasted. In order to develop and calibrate such model CFD modelling and/or experimental model tests should be carried out.

Contact persons: Thomas Lykke Andersen, Morten M. Kramer

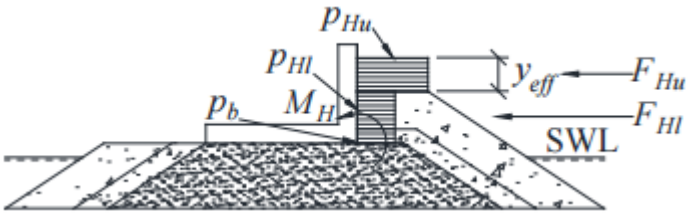
Theory: ☒☒☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

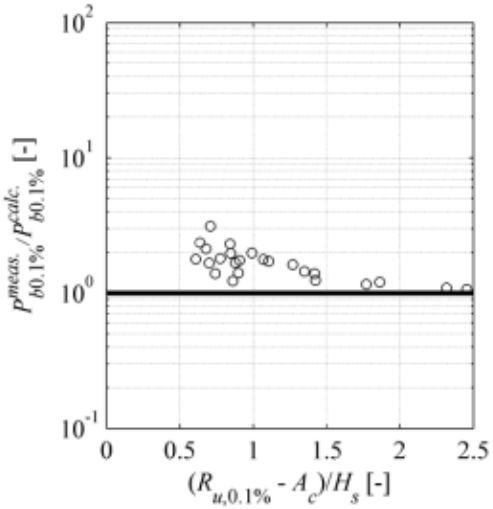
Reanalysis of wave loads on breakwater crown walls

Purpose: The purpose is to extend the formula by Nørgaard et al. (2013) for wave load calculation on breakwater crown walls. The formulae can be extended to include the roughness effect from the armour units. Furthermore, is the prediction of the pressure at the corner (p_b) under-predicted when the wave run-up is equal to or below the crest elevation A_c. Therefore, modifications to the present formula should be performed such that the formula is also valid for low run-up levels.

New tests in the flume at AAU should also be performed if white spots in previous tests are identified.

Contribution: The project can contribute to an on-going PhD study that is working with response of structures exposed to long waves, and the suggested project is a natural extension of this work.





Main activities:

- Extend present formulae to include different armour types and low wave run-up levels

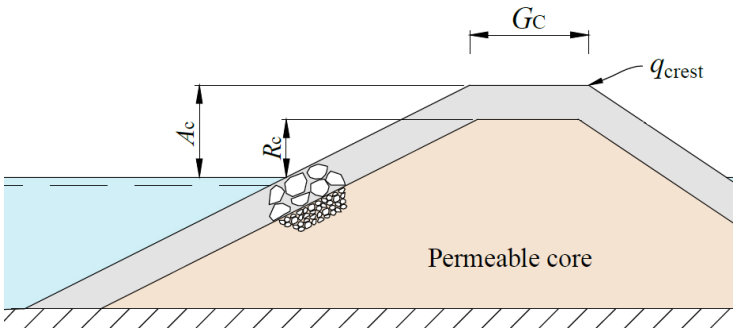
Contact persons: Mads Røge Eldrup, Thomas Lykke Andersen

Theory: ☒☒☒ **Experimental work:** ☒☒☐ **Computer modelling:** ☐☐☐
Suitable project type(s): **3rd sem:** ☐ **short master:** ☒ **Long master:** ☐

Design Tools for Wave Overtopping and Stability Of Rubble Mounds Exposed to Deep and Shallow Water Waves

Purpose: In a recent PhD study, tests with wave overtopping and rock armour stability were performed. In that study, new design formulae were established improving the reliability for estimations for surging waves (long period waves) and highly nonlinear waves (stream function waves). However, there are many white spots not yet investigated. This involves for example the influence of the thickeness and permeability of the different layers. Moreover, the influence of the crest width (Gc) on overtopping of long waves (swells) is a significant white spot in existing design tools.

New physical model tests with wave overtopping and rock armour stability should in the present project be performed in order to investigate the identified white spots. The tests will be carried out in the wave flume at Aalborg University. The present study will lead to new design tools relaveant for coastal engineers worldwide.



Main activities:

- Litterature study to clarify white spots in existing design formulae
- Experimental modelling to study identified white spots
- Update design formulae based on obtained experimental data

Contact persons: Mads Røge Eldrup, Thomas Lykke Andersen

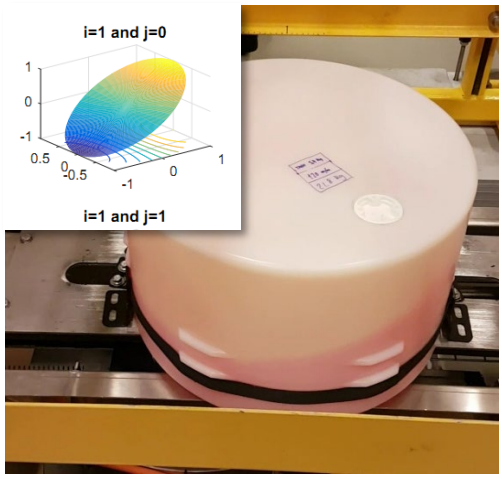
Theory: ☒☐☐ **Experimental work:** ☒☒☒ **Computer modelling:** ☐☐☐
Suitable project type(s): **3rd sem:** ☐ **short master:** ☒ **Long master:** ☒

Damping of liquid damper for wind turbine tower

Purpose: The purpose of the project is to enable accurate prediction of the damping from a so-called tuned liquid damper for use in tall wind turbine towers.

The tower engineering group at Vestas Wind Systems has been developing a tuned liquid damper to supress vibrations of towers exposed to vortex induced vibrations. The design has largely been based upon physical tests to document sufficient damping. However, this render design optimization and design changes difficult as changes are difficult to predict and consequences of changes requires extensive laboratory test campaigns.

The damper mounted inside a tower section is shown below (left), and the fundamental of the damping is the liquid sloshing out of phase with the tower. See below (right) a picture of an actual damper sloshing test and the theoretical 1st wave mode. The liquid motion is damped used flow restrictor plates.



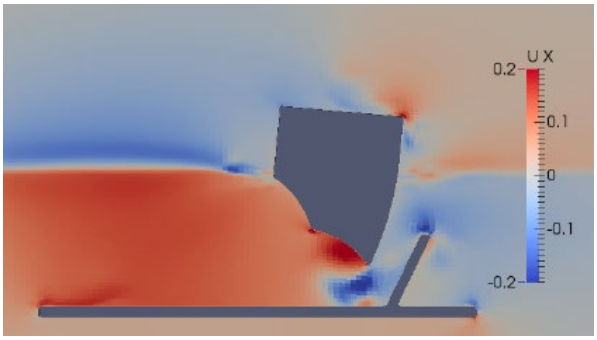
Main activities: The project will contribute to the on-going development and optimization of tuned liquid dampers at the tower engineering group at Vestas Wind Systems. The following activities are expected to be included:

- Theoretical assessment of correlation between internal wave and damping
- Experimental tests of the internal wave and flow patterns inside the damper and the corresponding damping from the damper unit
- Numerical modelling of the internal wave and assessment of damping
- Parameter study using numerical model with suggestions for design optimizations/improvements

Contact persons: Morten Kramer, Thomas Lykke Andersen
Theory: ☒☐☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☐ **short master:** ☐ **Long master** ☒

Simulation of wave energy conversion in a multi-use platform

Purpose: The company Floating Power Plant is developing a combined platform for harvesting wind and wave energy. The wave energy converters (WECs) are designed as pitching devices attached to the hull of the semi-submersible. Together with Floating Power Plant the project will perform detailed wave-body simulations and estimate the wave loads acting on the WEC and semi-submersible.



The wave energy converters are marked in red

www.floatingpowerplant.com

Main activities: The project will apply CFD modelling using the OpenFOAM® software (www.openfoam.com). The main topic relates to the treatment of the mesh motion. The WEC moves in close proximity to the semi-submersible making this a challenging task. Algorithms for the power transformation will be implemented in the OpenFOAM framework to accurately include the forces arising from the power take-off in the simulations. The main outcome of the project will be the forces and restoring moments acting on the WEC.

The calculations can, if wished by the students, be supplemented by laboratory experiments, which can be performed in the wave basin at AAU. The results can be used to validate the CFD calculations.

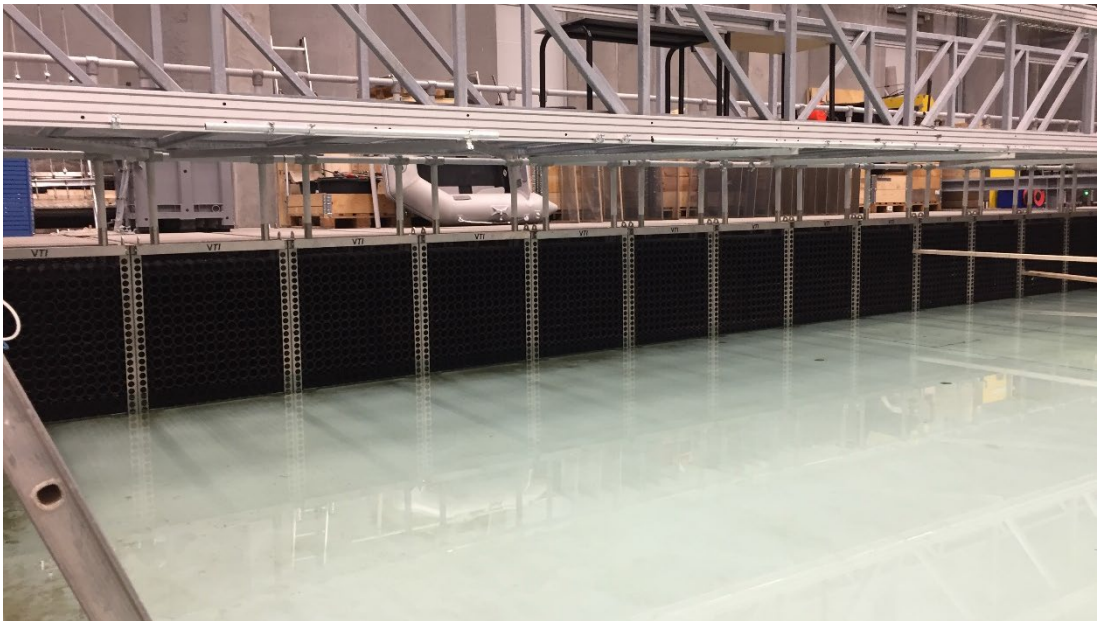
Contact persons: Morten Bech Kramer, Claes Eskilsson

Theory: ☒☐☐ **Experimental work:** ☒☐☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☐ **short master:** ☐ **Long master** ☒

Optimisation of passive wave absorbers

Purpose: The purpose is to optimise the current passive absorption system in the new laboratory at Aalborg University. In order to do that, individual plate absorbers are tested with respect to their performance in term of absorption, reflection and transmission properties for different wave conditions. The optimisation is made by performing laboratory tests in the flume and basin. The key objective is to reduce generation of high-frequency waves which occur for the present absorber layout. Configurations of an array with multiple plates are also tested, and a mathematical model is made to predict the performance.

Contribution: Preliminary tests have been performed, but a more in-depth study on the wave condition is wanted. The influence of the wave height, wave period and water depth is wanted.



Main activities:

- Clarify the absorption capability for an array of perforated plates and the influence of different wave heights, wave periods and water depths.
- Experimental study of the reflection coefficient for a passive absorber.

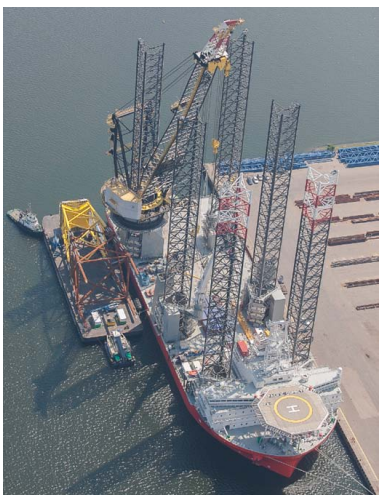
Contact persons: Mads Røge Eldrup, Thomas Lykke Andersen

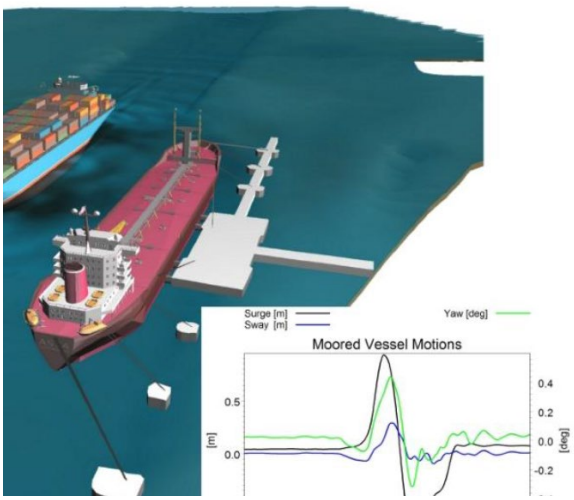
Theory: ☒☐☐ **Experimental work:** ☒☒☒ **Computer modelling:** ☒☐☐
Suitable project type(s): **3rd sem:** ☐ **short master:** ☒ **Long master:** ☒

Mooring behaviour of vessels in ports

Purpose: The purpose is to make use of a mooring analysis tool within the MIKE 21 MA suite and assess the suitability of the existing design guidelines in PIANC on allowable wave disturbance for assessment of downtime in ports.

A newly featured tool being available in the MIKE21 software toolbox from DHI is supposed to be used/ validated in combination with e.g. physical model tests and/or state of art knowledge for the evaluation of moored vessel response in ports. The tool can be coupled with a Boussinesq model to simulate the floating behaviour of moored vessels in a port. The most used guidelines on "allowable" wave disturbance in ports are relatively primitive and the present project should investigate alternative and more sophisticated methods.





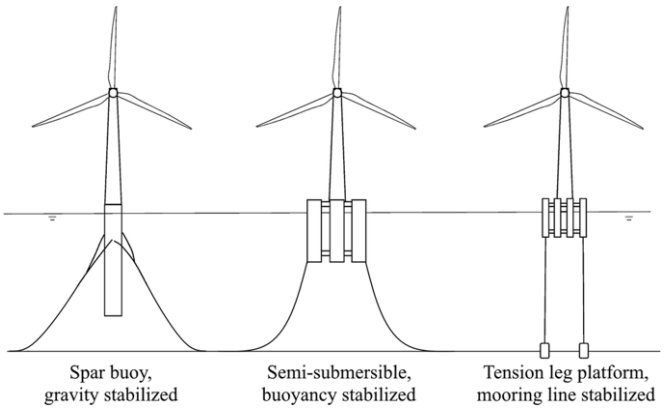
Main activities: The project will contribute to the on-going research and development on the subject and thus the following activities can be included:

- Combined numerical modelling of wave disturbance and floating behaviour of moored ships in a port
- Validation of MIKE 21 MA suite for modelling of moored ship movements

Contact persons: Jørgen Harck Nørgaard, Thomas Lykke Andersen

Theory: ☒☒☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☐ **short master:** ☒ **Long master** ☒

Unconventional shallow water mooring design for floating wind turbines



Purpose: To develop a concept and carry out a preliminary analysis of an unconventional shallow water mooring system for a floating substructure supporting an offshore wind turbine.

A relatively high development cost of the floating wind is still an important factor preventing this technology to expand and compete with bottom-fixed supporting structures in shallow and moderate depth waters. There is a large degree of experience from Oil & Gas installations but those solutions seem to be too expensive for the wind industry which is forced to seek cost optimizations along the whole value chain. Conventional catenary mooring designs for floating wind turbines in shallow water/moderate water depth are rather challenging and costly. In order to grow and effectively compete with other types of offshore wind structures, the floating wind desire unconventional, ground-breaking solutions, among others in the mooring system area.

Main activities: Considering a floating wind concept (semi-submersible floater) alternative mooring concepts shall be investigated under ULS conditions.

The foreseen water depth range is 60 to 100m. It is anticipated to study multiple configurations of e.g. hybrid catenary and synthetical lines but also to consider innovative elements in the mooring set-up. Among others this may in particular be the thermoplastic spring offered by TFI Marine.

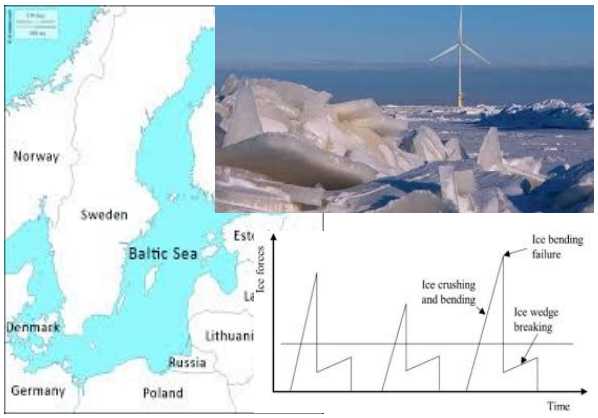
Vattenfall will contribute to the work and support the student with relevant inputs and experience.

Contact persons: Thomas Lykke Andersen, Dariusz Eichler (Vattenfall)

Theory: ☒☒☐ **Experimental work:** ☒☐☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

VATTENFALL

Floating offshore wind turbines with ice loading in the Baltic Sea



Purpose: To analyse performance of a floating offshore wind turbine foundation concept in the ice conditions in the Baltic Sea.

The Baltic Sea is an attractive area for offshore wind energy due to good wind conditions and the need of East European countries in this area to develop sources of renewable energy where offshore wind is a promising solution.

The area of the Baltic sea is however challenged by ice formations that introduce different boundary conditions for design of supporting structures compared to the North Sea where the most experience is derived from. For design of a supporting structure it directly means that some new load cases both in extreme and fatigue conditions need to be carefully considered. That calls for reliable ice load models which are still under development. It is essential for offshore wind developers like Vattenfall to understand an impact of different ice-structure-interaction models on the design loads in order to deliver optimised solutions.. Vattenfall has recently been involved in designs with ice loads on a bottom-fixed foundation. Vattenfall is however also looking at floating foundation concepts which in certain conditions have a potential to become highly competitive.

Main activities: The student shall investigate if floating foundations may introduce an advantage over bottom-fixed foundations for an existing site.

Two floating wind turbine concepts (i.e. a semi-submersible , the Saipem pendulum type or the Ideol barge type) shall be investigated towards their performance under sea ice loads.

Analyses are to be performed applying a coupled system i.e. comprising mooring system, floater and wind turbine together with the modelled environmental loads. The time domain ice load models may in particular be based on the DNVGL tool IceFloe or other models like e.g. Vanilla.

Vattenfall will contribute to the work and support the student with relevant inputs and experience.

Contact persons: Thomas Lykke Andersen, Dariusz Eichler (Vattenfall)

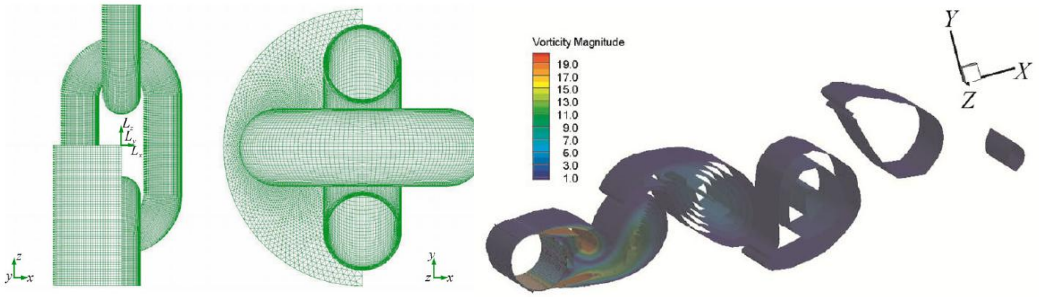
Theory: ☒☒☐ **Experimental work:** ☒☐☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

CFD study of mooring cables in waves

Purpose:

The goal of this project is to improve the knowledge of what happens when mooring cables move in the water and are subjected to waves, so engineers can better estimate mooring loads. Research carried out at AAU shows that current methods to determine loads on mooring cables, using Morrison's equation, might be inaccurate. We need a better understanding of the physics of turbulence, drag, and inertia of mooring cables.

Is it acceptable to use a single drag and inertia coefficient to model fluid forces along the whole mooring cable? Is it necessary to improve Morisson's equation to properly compute the fluid loads? These are some of the question that we need to investigate. The project will contribute to the on-going research on design methods for mooring systems of wave energy converters.



Images from: Zhengqiang Xu and Shan Huang. "Numerical Investigation of Mooring Line Damping and the Drag Coefficients of Studless Chain Links". J. Marine Sci. Appl. (2014) 13: 76-84
DOI: 10.1007/s11804-014-1235-0

Main activities: We expect the following activities:

- Numerical model of a mooring cable in OpenFOAM
- Simulation of different flow conditions around the mooring cable (uni-directional flow and regular waves)
- Assessment of the importance of drag and inertia phenomena for loads on mooring cables

Contact persons: Claes Eskilsson, Guilherme Paredes

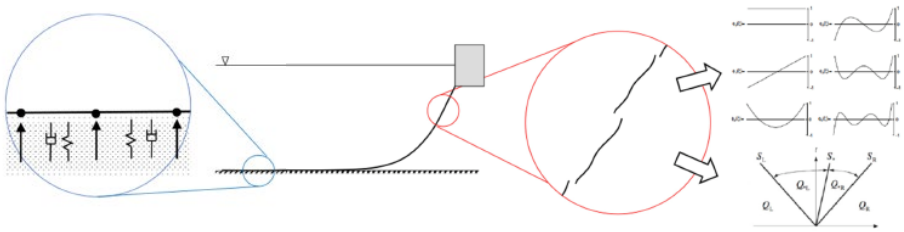
Theory:☒☐☐ Experimental work:☐☐☐ Computer modelling:☒☒☒
Suitable project type(s): 3rd sem☐ short master:☒ Long master:☒

Influence of ground models in mooring cable dynamics

Purpose: MooDy is a mooring cable dynamic solver based on *hp*-adaptive finite element techniques. It has been found that this numerical setting is more sensitive to the applied ground model (acting on the part of the cable lying on the seafloor) than mooring cable codes based on the lumped-mass method. Presently only a bilinear spring-damper ground model acting on the local nodes is implemented. The purpose of this project is twofold:

(i) to test other ground models proposed in the literature

(ii) to investigate a better way to incorporate the ground than directly on the local nodes as this is introducing noise into the higher order discretization.



Main activities: The project will contribute to the on-going development of the model and the following activities can be included:

- Study of used ground models in mooring dynamics codes
- Implementation into the numerical code (requires skill in matlab or c++)
- Estimation of uncertainties introduced by the ground models

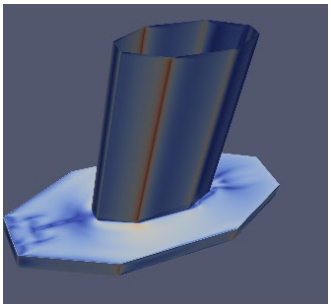
The project will involve co-operation with external parties (Chalmers, Sweden).

Contact persons: Claes Eskilsson, Guilherme Moara Paredes

Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☐ **short master:** ☐ **Long master** ☒

Floating platforms for renewable energy

Purpose: The company Floating Power Plant is developing a combined platform for harvesting wind and wave energy. The platform is moored in a single point, a so-called *turret mooring* (picture below on the left) about which it rotates freely 360°. The platform is designed to be facing the waves with optimal wave energy absorption for head-on waves. However, the orientation of the platform is governed by the complex hydrodynamic interaction of currents, wind-waves and swell-waves, which are generally coming from different directions. Together with the private company Floating Power Plant the project will develop new methodologies to calculate the restoring moments in combined waves and currents, and thereby predict the orientation of the platform.



www.floatingpowerplant.com

Main activities: The project will investigate the influence of currents and waves on the orientation of the device. A main outcome of the project will be drag coefficients to determine the forces and restoring moments depending on the orientation of the device. The CFD software OpenFOAM® will be extensively used to calculate the coefficients (www.openfoam.com).
The calculations can, if wished by the students, be supplemented by laboratory experiments, which can be performed in the wave basin at AAU. Currents can be applied in the basin and the forces and moments on the platform measured together with the current velocity. The results can be used to validate the drag coefficients by the CFD calculations.

Contact persons: Morten Bech Kramer, Claes Gunnar Eskilsson

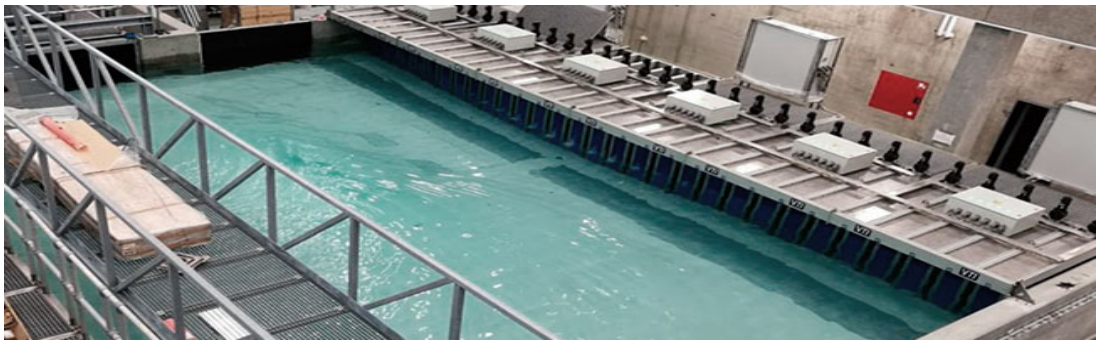
Theory: ☒☐☐ **Experimental work:** ☒☐☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☐ **short master:** ☐ **Long master** ☒

Methods to calculate Directional Wave Spectra

Purpose: The purpose is to evaluate different methods for calculation of Directional Wave Spectra. The objective is to implement and improve one of the existing methods. The implemented method will be assessed in the wave basin.

Waves are described by many parameters. The most important parameter used to describe a sea state is the significant wave height. Other parameters are the period, the wave spectra, skewness parameters etc. In the line of parameters comes the Directional Wave Spectra describing from which directions the wave energy comes. More and more offshore structures are designed taking into the directional spread of the waves. It is difficult to calculate a reliable Direction Wave Spectra, and the project will focus on doing that.

The project will require good mathematical as well as programming skills.



Main activities: The project will contribute to the on-going research on the subject and thus the following activities can be included:

- Review of existing methods being used around the world.
- Development of a new method – or rather a modified/updated existing method. Programming (Matlab or other language) of this method.
- Generation and measurement of waves in the wave basin.
- Assessment of the method.
- Assessment of the wave basin – in case more time is left.

Contact persons: Peter Frigaard, Thomas Lykke Andersen

Theory: ☒☒☒ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☐ **short master:** ☒ **Long master**: ☒

Coastal Protection of the Danish West Coast

Purpose: Evaluation of different methods for coastal protection. The west cost of Denmark has always suffered from coastal erosion but during the last 5-10 years is focus again increased because many houses have been lost.

Main activities: The project will contribute to the on-going research on the subject and thus the following activities can be included:

- Review of existing methods being used in Denmark and around the world.
- Analysis of wave data.
- Analysis of existing data for recession of the coastline.
- Measurements of beach profiles.
- Modelling of the sediment transport, using existing MIKE models.
- Developing a Coastal Zone Management plan for a part of the coastline.

The project will be in cooperation with the Danish Coastal Authority.

Contact persons: Peter Frigaard, Thomas Lykke Andersen, Lucia Margheritini

Theory: ☒☒☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☐ **short master:** ☒ **Long master**: ☒

Influence of Heat Pump based Heat Plants on surroundings.

Purpose: In Denmark are we used to have district heating. Several plants have been build, and can be found in the cities. Now is the sector changing. See https://www.danskenergi.dk/sites/danskenergi.dk/files/media/dokumenter/2018-11/Varme_Outlook_2018_perspektiver_for_fremtidens_varme_i_Danmark.pdf

Utilities are building large Heat Pump based power stations running on green energy. The project will focus on the influence of the air temperature in the neighbourhood of the plants. Still, it is not fully understood what the influence will be on the nearest surroundings, and where in the cities it is reasonable to place these plants.

The project will be very CFD based. The core will be modelling of the airflow around a power station. A commercial CFD software pack will be used.

Contact persons: Peter Frigaard, Jesper Ellerbæk Nielsen

Theory: ☒☐☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☐ **short master:** ☒ **Long master:** ☒

Wave climate at the Nissum Bredning test site

Purpose: The purpose of the project is to define the wave climate at the Nissum Bredning test site. The test site is located south west from Aalborg and is run by DanWEC in close collaboration with AAU. The test site is equipped with a network of pressure sensors to measure the surface elevation and a wind sensor, giving both speed and direction of the wind.

The Nissum Bredning is situated in the western Limfjord at the Danish North Sea coast. Predominant west winds make this location suitable for testing scaled wave energy devices in real marine conditions. In order to effectively design the machine for a particular location, detailed wave conditions are required. The network of pressure sensors enables the establishment of the wave climate including directionality of the waves, which is valuable information for future developer interested in testing their device at the test site.

Main activities: The project will contribute to the on-going research on the subject and thus the following activities can be included:

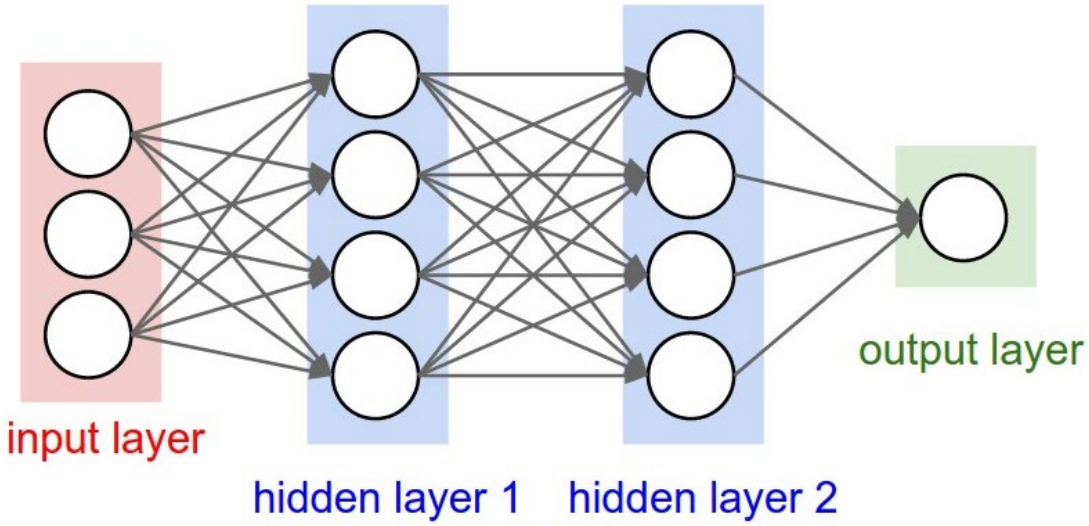
- Optimisation of the network sensor and gathering of data.
- Establishment of the wave climate at the test site based on the measurements including data quality control.
- Establishment of online monitoring of the wave climate

Contact persons: Amélie Têtu

Theory: ☒☐☐ **Experimental work:** ☒☐☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☐ **short master:** ☒ **Long master** ☐

Forecast of wave conditions at DanWEC test site

Purpose: Forecast of wave conditions is of primordial importance for planning installation, operation and maintenance of wave energy converters, which can account for more than 25% of the cost of energy. At DanWEC, the Danish test center for wave energy, a forecast model has been developed in collaboration with DHI group through an ongoing project. This model is run at DHI and is rendered available for DanWEC during the current project life time. In order to ensure that DanWEC has a reliable tool for predicting the wave climate at the test site, a forecast model needs to be developed. Autoregressive model or machine learning model are examples of models that could be developed for this purpose.



Main activities:

- Literature survey to give an overview of the different models that can be used for forecasting wave climate.
- Establishment of the model for forecasting wave climate at the test site.
- Establishment of online display of the wave climate forecast

The project will be connected to ongoing research projects.

Contact persons: Amélie Têtu

Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☐ **short master:** ☐ **Long master** ☒

Geotechnical Engineering Research Group

Research area:

The research of the Geotechnical Engineering group deals with the strength, deformation and hydraulic aspects of soils and numerical modeling of in relation to design of engineering structures such as buildings, bridges, offshore structures and renewable energy structures, with specific focus on wind energy structures.

The laboratory is specialized in model scale testing and dynamic loading. The laboratory has state of the art equipment to enable large model-scale testing of foundations and element testing under complex environmental loading scenarios. The equipment is well suited to experimentally analysing and defining soil behaviour taking into consideration the effect of climate change scenarios affecting Denmark. The laboratory is capable to performer geological and geotechnical classification experiments, In-situ testing, consolidation and triaxial experiments, test setup with pressure tank for offshore measurements, large-scale experiments with foundations and piles.

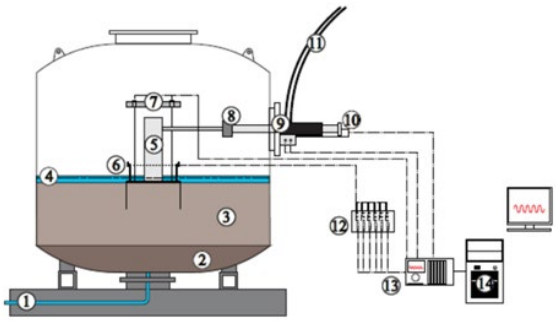
Key topics:

- Soil structure interaction both numerical and experimental.
- Innovative foundations - Screw Pile Foundation.
- Offshore foundations (Monopile, Bucket, Jacket).
- Effect of climate change scenarios.
- Earthquake.
- Constitutive modeling of soil.
- In –situ testing of soil.
- Element testing (Triaxial, Oedometer, Cyclic and dynamic) testing of Danish soils.

Supervisors:

Lars Bo Ibsen, Professor

Amin Barari, Associate Professor



Screw Pile Foundations

Purpose: You can be part of an Innovation Fund Denmark project there will revolutionize the way housing is constructed today. The project opens a whole new market for screw pile foundation, which will revolutionize and be a real alternative to the current foundation methods in all types of lightweight house constructions - and this with a green profile. There are currently no reliable and recognized design methods that can be used to design these foundations today. The overall aim of the project is to development and secure the implementation of screw pile foundation as a cost-effective technology for future housebuilding.

Main activities: The project will contribute to the ongoing understanding of Danish soils.

The activities will include:

- Lab testing in the new developed large scale sand Box of screw pile
- Or In - situ testing of screw pile
- Using CPT and in situ testing
- Theoretical assessment

Contact persons: Lars Bo Ibsen (lbi@Build.aau.dk), Mikkel Ibsen (mib@aogh.dk)

Theory: ☒☒☐ **Experimental work:** ☒☒☒ **Computer modelling:** ☒☐☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Aalborg Clay or other Danish clays

Purpose: To improve the knowledge about soil parameters for Danish soils.

In connection with the on-going projects a number of borings have been performed taking undisturbed samples in "Aalborg Clay" for laboratory testing in this project. CPT's and in situ testing make it possible to setup new interpretations of soil parameters.

Main activities: The project will contribute to the ongoing understanding of Danish soils.

The activities will include:

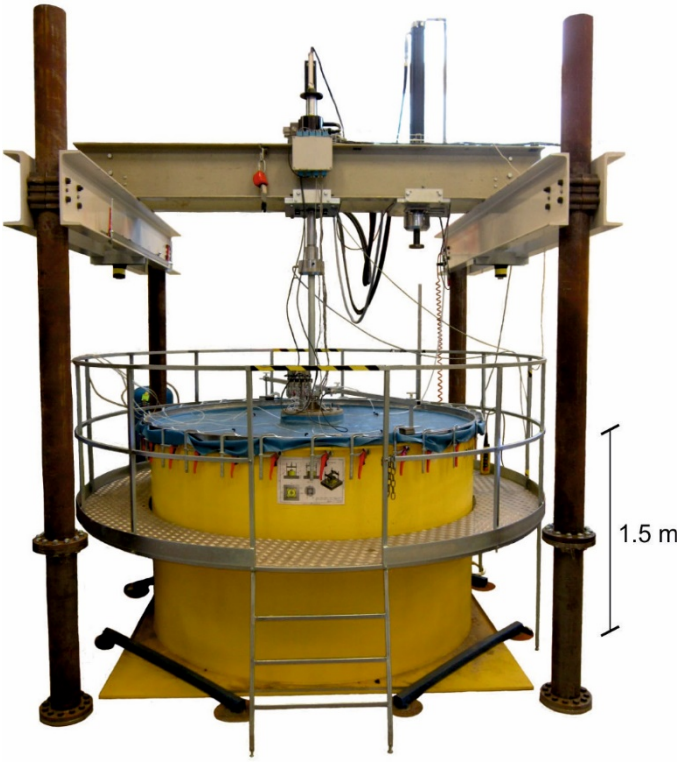
- Consolidation tests
- Triaxial tests
- Bender tests
- Using CPT and in situ testing
- Theoretical assessment

Contact persons: Lars Bo Ibsen (lbi@Build.aau.dk), Mikkel Ibsen (mib@aogh.dk)

Theory: ☒☒☐ **Experimental work:** ☒☒☒ **Computer modelling:** ☒☐☐
Suitable project type(s): **3rd sem** ☐ **short master:** ☐ **Long master** ☒

Design of indoor test facilities

Purpose: Take part in designing our new indoor test facility/sandbox that will be used for large scale model testing.



Main activities: The project will contribute to the on-going research on the subject and thus the following activities can be included:

- State of the art
- Boundary conditions
- Sand behaviour at low stress levels
- How to control the water level
- How to prepare and compact the sand in the box
- Numerical models of which foundations models that could be examined in the sand box

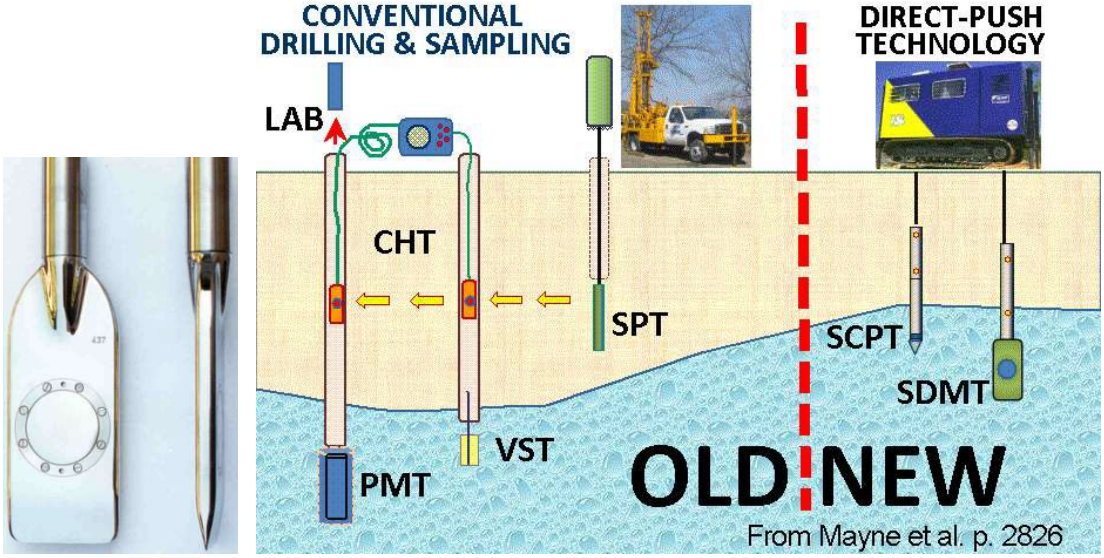
Contact persons: Lars Bo Ibsen (lbi@Build.aau.dk),

Theory: ☒☒☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Rock the soil: SDMT Flat Dilatometer

Purpose: Try the new in-situ soil testing. The SDMT (seismic) Flat Dilatometer offers measuring / interpretation of a series of soil parameters by direct-push technology (M, c_u, K_o, OCR, φ, γ).

Aalborg University has the first SDMT equipment in Denmark.



Main activities: The project will contribute to the introduction of the DMT and SDMT technology in Danish soils. The activities will include:

- Setup of equipment
- Interpretation of data
- Field and laboratory Tests
- Theoretical assessment
- Best practise.

It may be possible to perform experimental field tests together with external company.

Contact persons: Lars Bo Ibsen (lbi@Build.aau.dk),

Theory: ☒☒☐ **Experimental work:** ☒☒☒ **Computer modelling:** ☒☐☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

CPT based soil strength correlations

Purpose: Contribute to the geotechnical society by developing new approaches to determine soil strength parameters from CPT. Today the Cone Penetration Test (CPT) is increasingly being applied to geotechnical projects. Still, there exist no uniform methods on how to interpret strength parameters from the CPT measurements. Aalborg University has CPT rig which makes it possible to conduct CPTs and collect undisturbed soil samples at places where it is impossible for other boring rigs.

Watch the CPT rig at https://www.youtube.com/watch?v=zf_eRpbo1C0

Main activities: The project will contribute to the on-going research on the subject and thus the following activities can be included:

- State of the art study
- Setup of equipment
- Field and laboratory Tests
- Interpretation of data
- Theoretical assessment

Contact persons: Lars Bo Ibsen (lbi@Build.aau.dk), Mikkel Ibsen (mib@aogh.dk)

Theory: ☒☒☐ **Experimental work:** ☒☒☒ **Computer modelling:** ☒☐☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

New method for soil compaction

Purpose: To develop new methods for compacting sand in the laboratory and possibly also the field. Currently, different methods are used for compaction of sands. In the laboratory e_{max} and e_{min} (Relative density) is measured using a stamping method, and for model testing the soil is being compacted using rod vibrators, giving a possibly variating compaction. In the field, sand is compacted using a vibrating plate compactor. All methods however are time-consuming since they are performed manual.

Main activities: The project is relatively open with concern to the problem to be analysed and can include:

- State of the art study
- Laboratory Tests
- Field testing
- Reliability
- Design model creation / best practise.

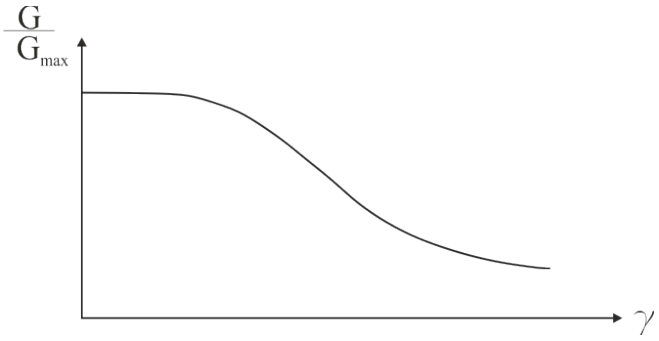
It may be possible to co-operate with Department of Mechanical and Manufacturing Engineering as regards to designing a robot that are able to perform the compaction.

Contact persons: Lars Bo Ibsen (lbi@Build.aau.dk)

Theory: ☒☒☐ **Experimental work:** ☒☒☒ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Determination of small-strain stiffness of soils

Purpose: In the design of some geotechnical structures, such as large diameter monopiles, a correct estimation of the soil stiffness is of high importance. However, soil stiffness is both dependant on the strain and stress level. For dynamic loading and for determination of a geotechnical structures natural frequency, the soil experiences very small strain-levels. Hence, the small-strain shear Modulus is a key-parameter in design. By using Bender elements, it is possible to determine the small-strain shear modulus.



Even though, a bender element test is a very simple test to perform, the analysis of the measured data can be relative complex. The main activity of this study could be:

Main activities:

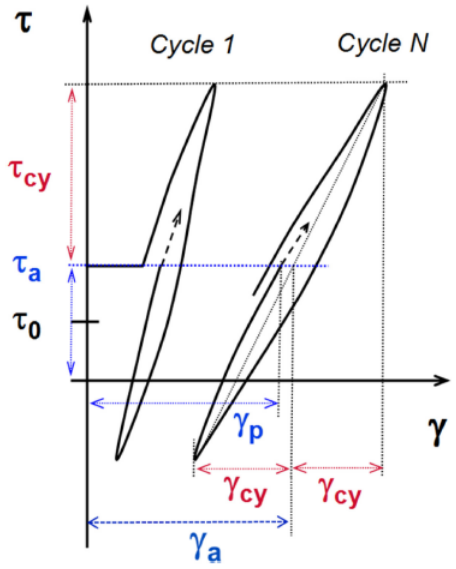
- Understand the bender element system
- Understand basic soil dynamics
- Investigate interpretation methods
- Investigate the effect of a more precise determination of G_{max}

Contact persons: Lars Bo Ibsen (lbi@Build.aau.dk), Amin Barari (abar@build.aau.dk)

Theory: ☒☒☐ **Experimental work:** ☒☒☒ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Cyclic Behaviour of Soil

Purpose: Offshore structures are exposed to cyclic loading, mainly from wind and waves. Therefore, the soil surrounding the foundation will experience cyclic loading as well. Cyclic soil behaviour is very complex and both strength and deformation parameters may change with cyclic loading. How they change depends on the nature of the cyclic load in terms of: load frequency, load amplitude and mean value. Even though research on the field has been carried out for the last 20 years, there is still no standardised guideline on how to predict the soil response from cyclic loading.



Main activities: The project will contribute to the on-going research on the subject and thus the following activities can be included:

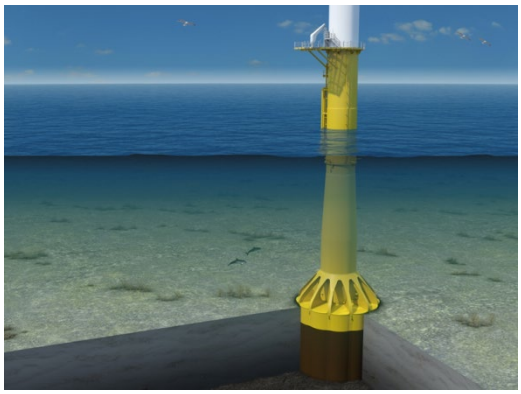
- Literature study on soil behaviour due to cyclic loading.
- Understanding how soil reacts to cyclic loading
- Performing cyclic triaxial tests.
- Calibrate one or more existing models to predict cyclic load effects.

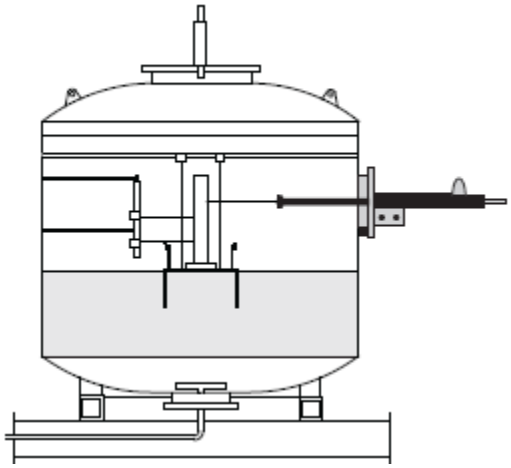
Contact persons: Lars Bo Ibsen (lbi@Build.aau.dk), Amin Barari (abar@build.aau.dk)

Theory: ☒☒☐ **Experimental work:** ☒☒☒ **Computer modelling:** ☒☐☐
Suitable project type(s): 3rd sem ☐ short master: ☐ Long master ☒

Cyclic Behaviour of Offshore Foundations

Purpose: Offshore structures are exposed to cyclic loading, mainly from wind and waves. Therefore, the soil surrounding the foundation will experience cyclic loading as well. Cyclic foundation behaviour is very complex and both strength and deformation parameters may change with cyclic loading. How they change depends on the nature of the cyclic load in terms of: load frequency, load amplitude and mean value. Even though research on the field has been carried out for the last 20 years, there is still no standardised guideline on how to predict the foundation response from cyclic loading.





Main activities: The project will contribute to the on-going research on the subject and thus the following activities can be included:

- Literature study on foundation behaviour due to cyclic loading.
- Performing cyclic model tests in the pressure tank.
- Calibrate one or more existing models to predict cyclic load effects.
- Develop new models to predict cyclic load effects.

The Project will be in close corporation with Universal Foundation.

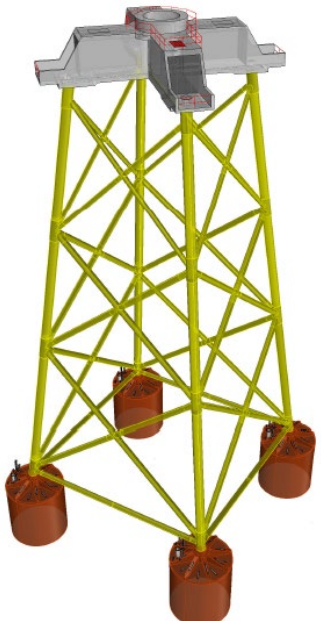
Contact persons: Lars Bo Ibsen (lbi@Build.aau.dk), Amin Barari (abar@build.aau.dk)

Theory: ☒☒☐ **Experimental work:** ☒☒☒ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☐ **short master:** ☒ **Long master** ☒

Offshore wind suction bucket on an industrial scale

Purpose: The project aims to develop a modular suction bucket design to the Siemens jacket concept for a +10 MW turbine. Objectives have been to create a modular bucket where modules can be produced in existing industrial manufacturing facility. In this project the aim is to demonstrate install-ability and in-place capabilities of design in laboratory environment.

Foundation costs of offshore wind including production and installation represent 20-30% of the total costs of deploying an offshore wind park. Lowering costs of foundations is a key element to lower the total Levelized Cost of Energy (LCoE) for offshore wind. Suction buckets are one of the most promising seabed interfaces technologies in the industry.



Siemens Jacket concept for +10 MW wind turbine.

Main activities: The project will focus on developing a working framework for the design of suction anchors used for the offshore wind industry, covering subjects such as, but not limited to:

- Installation of suction anchors using pressure and the challenges associated with this in various types of soil.
- The tensile and compressive capacity considering loading direction, loading rate and cyclic loading that are comparable to an offshore storm event.
- Laboratory testing to assess the impact of various types of loading (e.g. cyclic) to a typical offshore soil and the soil mechanics involved.
- Small-scale testing to assess the behaviour of the suction caisson/anchor during different loading and soil conditions.

The Project will be in close corporation with Siemens Wind Power and Universal Foundation A/S

Contact persons: Lars Bo Ibsen (lbi@Build.aau.dk), Amin Barari (abar@build.aau.dk)

Theory: ☒☒☒ **Experimental work:**. ☒☒☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Development of driveability model for piles for offshore wind turbines

A project with COWI

Purpose: An increased focus on renewables in general has ignited a spark in market for offshore wind turbines. The industry has a joint mission to lower the cost of energy from offshore wind turbines to make the solutions more competitive in the open energy market. The installation of piled foundations for offshore wind turbines is today governed by qualified guessing, since soil conditions may vary greatly throughout an offshore wind farm. The ability to predict and complete the driving campaign as effortlessly as possible is crucial for a successful project execution.

Up-close of installation of offshore piles (www.4coffshore.com).

A vessel used for installation of piles for offshore wind turbines (www.cape-holland.com).

Main activities: The project seeks to develop a method for accurate driveability predictions based primarily on theoretical considerations and back-calculation of driving logs from real-life installation of piles for offshore wind, secondarily to validate existing driveability prediction methods against said driving logs:

- Assess state-of-the-art research and methodology within the area of offshore driveability and understand the basic physical and theoretical principles involved in the driving of large-diameter piles.
- Based on available driving data from installed piles, complete back-calculation in order to validate existing methods.
- Based on existing methods and available data for back-calculation, develop a theoretically founded method for robust and accurate driveability predictions for various ground conditions.

Contact persons: Lars Bo Ibsen (lbi@Build.aau.dk), Martin Underlin Østergaard (muoe@cowi.com), Søren Dam Nielsen (sdnn@cowi.com)

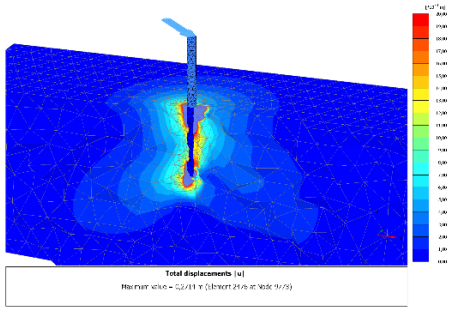
Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☐ **short master:** ☐ **Long master** ☒

Development of best practice for finite element modelling of monopiles for offshore wind

A project with COWI

Purpose: Due to a strong demand for optimization of the foundation structures for offshore wind turbines, new tools are incorporated in the design process, and finite element (FE) modelling has become increasingly important. Recent development in design methods for monopiles rely on FE analysis. As an example, the PISA methodology relies on a series of FE calculations, that is used to calibrate a 1D beam model to assess the pile response. For these kinds of projects, the computational time for the FE calculations and the reliability of the results is essential. These items are important when consultant engineers commit to use a specific FE software.

Sketch drawing of a monopile.



Finite element modelling of a monopile.

Main activities: The project aims at investigating the influence of using different FE softwares, e.g. Plaxis and OptumG3, and compare how these perform when used for the design of monopiles for offshore wind turbines. This includes considerations regarding theoretical soil behaviour and constitutive models as well sensitivity analyses of input and how e.g. soil-structure interfaces are modelled:

- Understand and establish the basic parameters for FE modeling of monopile foundations.
- Compare monopile design performed using different FE softwares.
- Based on assessment of suitability of available constitutive models and experience regarding modelling, develop recommendations regarding how applicable softwares are for monopile design incl. calibration of constitutive models.

Contact persons: Lars Bo Ibsen (lbi@Build.aau.dk), Amin Barari (abar@build.aau.dk), Martin Underlin Østergaard (muoe@cowi.com), Søren Dam Nielsen (sdnn@cowi.com)

Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☒

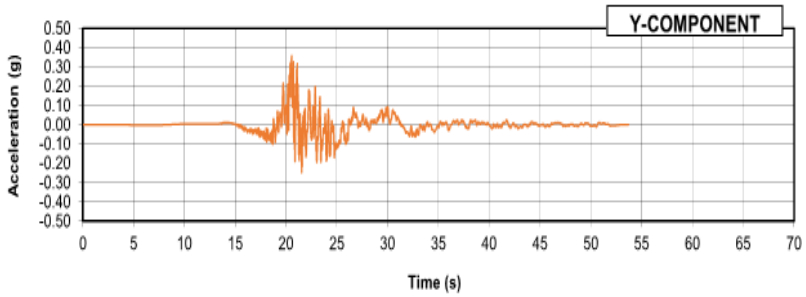
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Earthquake design of monopiles

A project with COWI

Purpose: The offshore wind farms are moving to new regions, and new design scenarios are continuously introduced due to shifts in environmental climate and loading. Especially the Asian market for offshore wind is growing rapidly and natural hazards, like earthquakes, need to be accounted for to a much greater extent compared to e.g. European wind farms. Depending on the soil conditions, an earthquake can have a large impact on the structure, through e.g. liquefaction of the supporting soil and kinematic soil-structure interactions. This impact needs to be accounted for in the design.

Sketch of a monopile.



Example of acceleration time series from earthquake.

Main activities: The project aims at investigating available methods for aiding the design of piled foundations for the offshore wind industry placed in regions with frequently occurring earthquakes. The following items can be considered in this investigation:

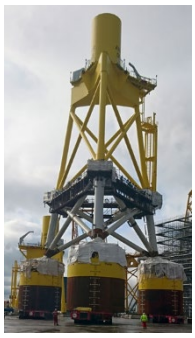
- Understand the concept of soil liquefaction and other earthquake-induced impacts on design of piled foundations.
- Conduct literature review and develop a state-of-the-art of existing methods for accounting for liquefied soil in design of laterally loaded piles.
- Using commercial software, like PLAXIS, conduct an assessment of the laterally loaded pile accounting for relative deformation between soil and pile caused by movement of the soil volume.
- Assess relevant constitutive models and their ability to model earthquake soil behavior, e.g. liquefaction.

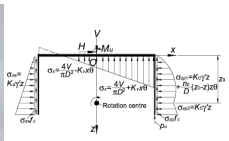
Contact persons: Lars Bo Ibsen (lbi@Build.aau.dk), Amin Barari (abar@build.aau.dk), Martin Underlin Østergaard (muoe@cowi.com), Søren Dam Nielsen (sdnn@cowi.com)

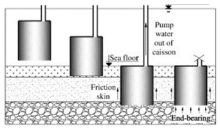
Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

VATTENFALL

Analysis of installation and bearing capacity of a suction caisson used as a base of an offshore wind turbine supporting structure







Purpose: To develop a simple tool for preliminary assessment of installation and capacity of a suction caisson used as a support of a jacket type of offshore wind turbine foundation.

Traditional way of installation of offshore wind turbine foundations, be it a monopile or a jacket, is driving piles into the seabed by large hydraulic hammers. The operation is time consuming and is associated with generation of noise that might be harmful to the ocean fauna. Furthermore, piling is not always available depending on ground conditions of the seabed. Application of suction caissons appeared to be an attractive solution to piles, especially for a jacket type of foundations. Designing a complete suction caisson is a complex process and sophisticated tools are used for predicting installation and operational in-place capacity. Typically, there are no resources and/or complete data to perform such a task at an early stage of design. Concept developers desire a simple tool for approximate assessment of feasibility and required size of a suction caisson.

Main activities: Based on detailed FE (or alike) simulations, an analysis of installation and bearing capacity of a suction caisson constituting a part of a jacket type of offshore wind turbine foundation will be perform. Simulations shall be conducted for typical soils suitable for application of a suction caisson. Analysis of results will be used to formulate a simplified rule for assessment of desired size of a suction caisson. The simplified formulation is anticipated to take into account magnitude of wind and wave loads, topology of the supporting structure and soil properties. Through a comparison of the suggested methodology with detailed analyses a degree of accuracy shall be evaluated. The tool shall be available in form of a piece of software.

The tool may be validated against results of the full scale tests performed by Vattenfall.

Formulation of the simplified tool may be accompanied by (or even fully based on) a novel soil-structure-interaction methodology that will prove to be less time consuming and/or more accurate than present standard methods.

Contact persons: Lars Bo Ibsen, Dariusz Eichler (Vattenfall)

Theory: ☒☒☐ **Experimental work:** ☒☐☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Reliability and Risk Analysis Research Group

Research area:
We focus on rational and sustainable decision-making for engineering structures such as buildings, bridges, offshore structures and renewable energy structures, with specific focus on wind energy structures.

Our research covers a broad range from theory to applications in the area of reliability-based and risk-informed methods for design, assessment, and planning of inspections and operation & maintenance. This includes methodologies and tools for probabilistic modelling of loads and resistances, inspections and monitoring, propagation of uncertainties, and estimation of reliabilities.

Key topics:

- Reliability analysis
- Uncertainty quantification
- Risk-based decision making
- Value of Information analysis
- Probabilistic design
- Application to wind turbines, bridges, new materials

Supervisors:
John Dalsgaard Sørensen, Professor
Jannie Sønderkær Nielsen, Associate Professor

Probabilistic Design of Wind Turbines

Purpose: To develop and investigate in case studies the use of probabilistic design of wind turbines, with focus on design with respect to fatigue.

Traditionally wind turbines and most other civil engineering structures are designed using safety factors and characteristic values to represent uncertainties of fatigue loads, fatigue resistances and models. This typically results in structures which are conservatively designed. During recent years, a large amount of data have been collected on both strengths and loads by wind turbine manufacturers and operators. This opens up for using this huge amount of data for more accurate stochastic modelling of the uncertain parameters and to design wind turbines (and other structures) directly using probabilistic methods. In this project, focus will be on the fatigue limit state.

In this project, the aim is to develop and describe the theoretical basis for doing probabilistic design of selected types of fatigue critical details of wind turbines. This probabilistic basis should be based the general recommendations in Joint Committee on Structural Safety 'Probabilistic Model Code' and the recently developed reliability basis for fatigue design according to the Eurocodes. The case studies includes statistical analysis of data, probabilistic design of selected details (e.g. welded details or cast steel details) and comparison to a design using the traditional safety factor approach. The project can also include how to include information from inspections and structural health monitoring in the probabilistic design.

Main activities: The project will contribute to the on-going research and development of a new standard for probabilistic design of wind turbines in cooperation with a large manufacturer with following activities:

- Describe a theoretical basis for probabilistic design with respect to fatigue for wind turbine components
- Statistical analysis of data for fatigue
- Case study with application of probabilistic design of a selected wind turbine component, and comparison with traditional, safety factor based design

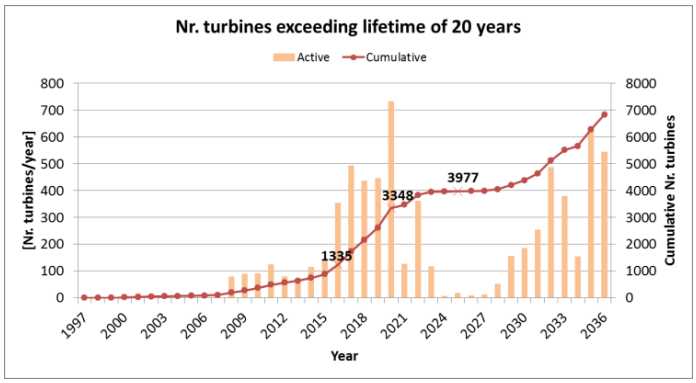
Contact persons: John Dalsgaard Sørensen, Jannie Sønderkær Nielsen

Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☐ **short master:** ☐ **Long master** ☒

Life extension for wind turbines

Purpose: The purpose of this project is to contribute to optimal decision making in relation to life extension of ageing wind turbines.

Within the next few years, thousands of wind turbines in Denmark will reach their design life time of 20 years. However, if it can be shown that the risk of structural failure upon continued operation is acceptable, the turbine should be allowed to continue operation. For example, the fatigue life usage can be estimated using load observations or SCADA data. Although not critical for safety, the condition of non-structural component influence expected maintenance costs, and is relevant to consider for profitability. Inspections and testing can also be used to assess the current health of components.



Main activities:

- Literature survey on life extension for wind turbines
- Assessment of fatigue life usage based on data
- Reliability analysis of wind turbines
- Reliability updating using data from tests

The project will be connected to ongoing projects with participation of industrial partners.

Contact persons: John Dalsgaard Sørensen, Jannie Sønderkær Nielsen,

Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Risk-informed operation and maintenance for offshore wind turbines

Purpose: The purpose of this project is to apply risk-based techniques and Bayesian statistical methods for planning of O&M activities in practical applications incl. modelling of costs and risks in connection with O&M for offshore wind turbines.

Costs to operation and maintenance (O&M) of offshore wind turbines are large, typically more than 25% of the cost of energy. The costs consist of planned maintenance and corrective maintenance due to failure of components such as gearboxes, electrical components and blades, due to e.g. wear and fatigue. One main contributor to the high offshore O&M uncertainty and costs is the dependence on weather windows. In other engineering areas such as the offshore oil & gas industry and civil engineering bridges, rational approaches to planning of O&M have been developed. These approaches are based on risk and reliability-based techniques where it is possible to plan rationally future actions based on available information at the time of decision and models for costs and uncertainties.



Main activities:

- Literature survey to give an overview of decision problems and methods for O&M planning
- Development of risk-based decision models and illustrative examples for selected problems e.g.
    - Optimal planning of inspections and maintenance for selected components
    - Combining several types of data for diagnostics using Bayesian methods
    - Short term decisions based on probabilistic weather forecasts

The project will be connected to ongoing research projects and can contain external collaboration.

Contact persons: John Dalsgaard Sørensen, Jannie Sønderkær Nielsen

Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Risk-informed decisions for up-classification of existing bridges

Purpose: The purpose is to develop a framework for risk-informed decision support, when existing bridges need to be up-classified to allow for passage of larger trucks, than they were originally designed for.

Bridges are designed to meet certain classes, which determines how large special truck that are allowed to pass the bridge. Often, large trucks need to find alternative routes, if the classification of bridges of the nearest route is insufficient. However, although the bridges were originally designed to have a lower capacity, it might have larger capacity than assumed in the design. Tests such as proof loading and material testing can be performed to reduce uncertainties of the bearing capacity, and an up-classification might be possible, without any strengthening. However, proof loading is expensive, and there is a risk that the bridge might collapse during the test, therefore cheaper tests might be preferable, although less accurate. To provide rational decision support for those decisions, a risk-informed decision framework can be made for testing of existing bridges considering e.g. costs of material testing, costs of proof loading, costs of advanced modelling, and risk of failure during proof loading.

Main activities:

- Reliability analysis of existing bridges
- Reliability updating using proof loading and material testing
- Inclusion of advanced nonlinear models through e.g. response surfaces
- Formulation of cost models
- Development of decision framework based on the Bayesian decision theory

The project will be performed in collaboration with COWI.

Contact persons: John Dalsgaard Sørensen, Jannie Sønderkær Nielsen

Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Tailored Carbon-FRP strengthening of concrete beams

Purpose: It is hypothesized that a tailored carbon fiber reinforced polymer (CFRP) strengthening systems, can be used to change a brittle structural response into a more controlled and ductile behaviour.

Conventional strengthening methods will be investigated to ensure that the students are informed concerning existing CFRP strengthening methods.
Consequently, this will provide the basis for research work involving some of the most novel strengthening systems in this field. The project will concern experimental and theoretical investigations, providing further knowledge into the field of tailored non- and pre-stressed CFRP strengthening applications related to existing concrete structures. Leading universities and industrial partners, in this field, will be used as collaborators in the project.

i) ii)

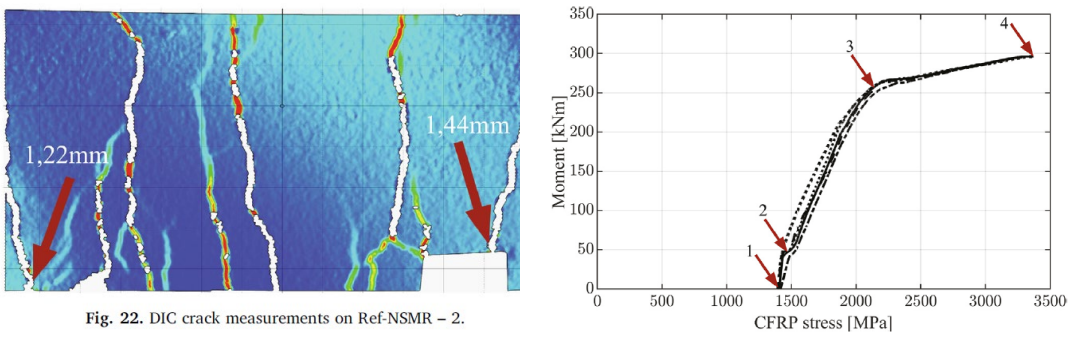


Fig. 22. DIC crack measurements on Ref-NSMR – 2.

i) Digital image correlation evaluation of crack initiation- and width measurements during testing, ii) Moment/CFRP stress development during testing identifying thresholds between the experienced response regimes [1].

Main activities:

- Experimental and/or theoretical analysis at several structural scales
- Concrete beam or slab capacity evaluations before and after strengthening
- Real life assessment to reflect the potential and use on existing structures
- Applied probabilistic evaluation to assess the structural safety

Contact persons: Jacob Wittrup Schmidt (Associate professor), John Dalsgaard Sørensen (Professor)

Theory: ☒☐☐ **Experimental work:** ☒☒☒ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☐ **short master:** ☒ **Long master** ☐

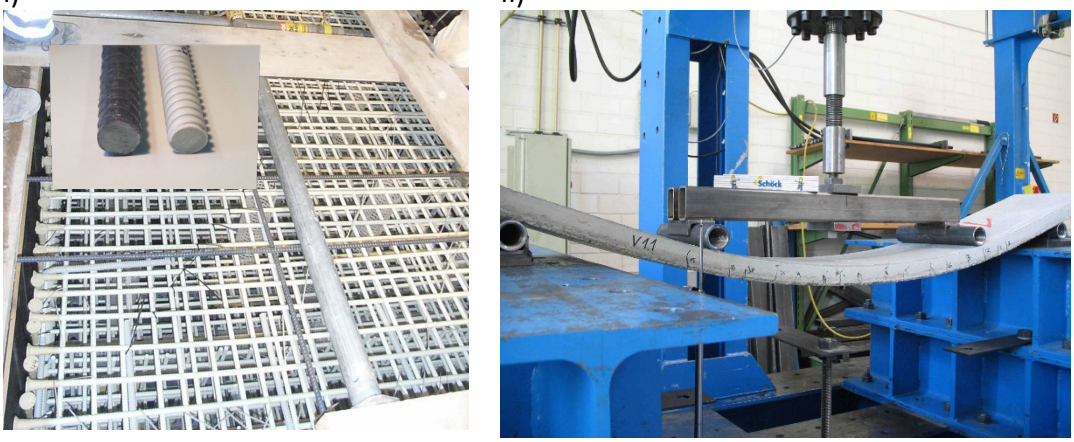
[1] Schmidt JW, Christensen CO, Goltermann P, Hertz KD. Shared CFRP activation anchoring method applied to NSMR strengthening of RC beams. Composite Structures. 2019;230. 111487. https://doi.org/10.1016/j.compstruct.2019.111487

Glass- and carbon FRP concrete reinforcement methods

Purpose: To research the structural short- and long term response when applying internal Glass- and Carbon FRPs as the outer reinforcement layer(s) in steel reinforced concrete beams.

Applying Glass- and Carbon fibre reinforced polymers (FRPs) as internal reinforcement in concrete is, research wise, well known. The materials have a high corrosion resistance but has very different material properties compared to steel. Especially, the Glass-FRP (GFRP) properties differs significant from steel due to the low E-modulus and the critical creep rupture levels. Testing and theoretical evaluation of beams with internally applied GFRP and/or CFRP will be done to evaluate the short- and long term effects when applying the FRP reinforcement. The work will undergo in collaboration with leading industrial partners in this field

i) ii)



i) Example of FRP reinforcement used in real life concrete structures, ii) Deflected concrete beam with internal GFRP reinforcement.

Main activities:

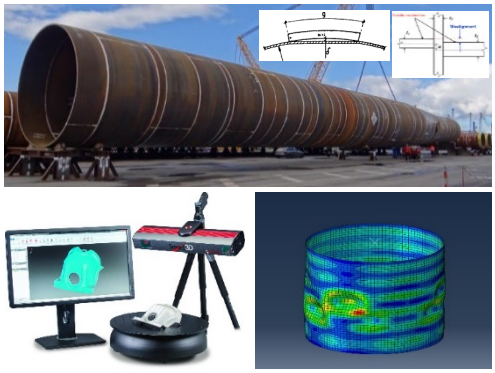
- Experimental and/or theoretical analysis at several structural scales
- Concrete beam response evaluation using novel theoretical- and test approaches
- Real life assessment to reflect the potential and use in real structural applications
- Applied probabilistic evaluation to assess the structural safety

Contact persons: Jacob Wittrup Schmidt (Associate professor), John Dalsgaard Sørensen (Professor)

Theory: ☒☐☐ **Experimental work:** ☒☒☒ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☐ **short master:** ☒ **Long master** ☐

VATTENFALL

3D scanning based systematisation of imperfections in monopile type of offshore wind supporting structure



Purpose: To develop a methodology for estimating and categorising imperfections of monopiles based on scanning.

Monopile has been by far the most popular type of offshore wind turbine foundation with ever growing number of application and sizes. And this is due to size, and particularly diameter to thickness ratio, that these structures are considered as thin-walled and as such are sensitive to fabrication imperfections. Both buckling and fatigue resistance can be to a large extent influenced by such imperfections. Monopile manufacturers are normally obliged to control tolerances under they Quality Assurance procedures. It is however unknown what a statistical representation of imperfections in newly produced structures is. Findings of measurement campaigns, if confirming anticipation of statistically smaller imperfections, might lead to evidence based reduction of safety factors in design and thus savings in material and overall cost of energy.

The easiest way of verifying a shape of a monopile and identifying imperfections is by scanning which is relatively quick and high fidelity process. Due to length of the pile it would be beneficial to mount a scanning device on a self-propelled vehicle like a robot tractor or a drone. The obtained images will depict actual geometry well but images cannot be directly used for a control purpose. Instead, geometry needs to be described in terms of standard dimensions like diameters and length, and imperfections as a measured ovality, flatness, indent or misalignment. Then imperfections can be categorised, put into statistical record and used for update of design procedures and safety factors.

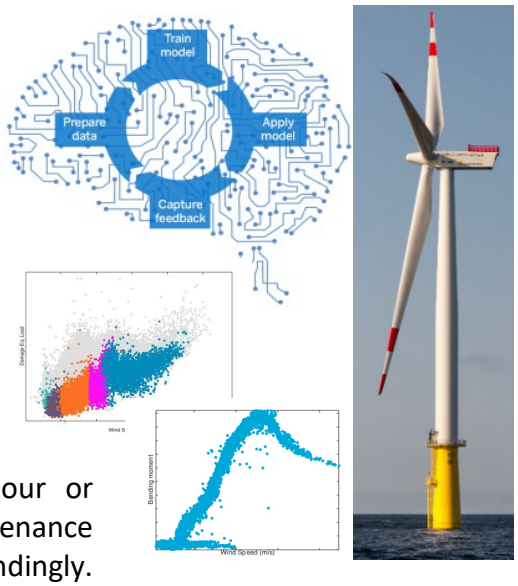
Main activities: Project will examine scanned geometries of monopiles and evaluate their applicability for the fabrication tolerance control purpose. The task will be to fit first order (primitive) geometries into particular parts of the scan representing monopile segments. And subsequently the fitted geometry will be compared with the scan and imperfections will be identified and measured. The results of the work shall be a semi or a fully automated procedure for determining fabrication imperfections. The work shall also include recommendations regarding scanning procedure and required resolution. The methodology may include compensation procedures for gravity caused deformations of the monopile in the scanning position.

Contact persons: John Dalsgaard Sørensen, Dariusz Eichler (Vattenfall)

Theory: ☒☒☐ **Experimental work:** ☒☐☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

VATTENFALL

Machine Learning for Structure Health Monitoring of offshore wind foundation structures



Purpose: Results of the project shall be a review of possible applications of Machine Learning to analysis of Structure Health Monitoring data collected at offshore wind turbine supporting structures.

Offshore wind turbines due to their large number in a windfarm and remote distance to shore are usually equipped with Condition Monitoring Systems. The role of CMS is to provide online data to control centres for surveillance and analysis. Sensors within a CMS are designed such that any abnormal behaviour or damage can be detected in time and a maintenance or repair work can be scheduled correspondingly. So far continuous condition monitoring has been covering the turbines and it was a rare case when the similar systems have been installed on supporting structures. Growing demand for clean and inexpensive energy forces however developers to cut costs and push designs to boundaries. In relatively uncertain offshore environment it means that surveillance of the structures becomes necessary. Usually Structure Health Monitoring systems are installed only on a few foundations within the windfarm. That imposes requirements that data collected from both CMS and SHM systems need to be used wisely in order to produce results valid for all windfarm foundations. The systems deliver a vast amount of data which demands large storage and processing capacity as well as complex analysis tools. But on the other hand, the amount of collected data opens not yet explored opportunities for obtaining conclusions and predictions that might bring direct benefits to the asset owner. Like a qualified assessment for lifetime extension, early warning on undesired development or verification of design methodologies, just to name a few.

Main activities: Project shall explore possibilities of application of Machine Learning or other Artificial Intelligence techniques for the purpose of structure integrity management. The applied techniques will utilise data obtained through a typical CMS and SHM systems installed at offshore windfarms. The goals of analyses will be defined taking into account benefits for either existing windfarms or new projects and might cover the whole lifecycle of an offshore wind turbine foundation including design, Operation & Maintenance as well as remaining operational life assessment.

Contact persons: Jannie Sønderkær Nielsen, Lars Damkilde, Dariusz Eichler (Vattenfall)

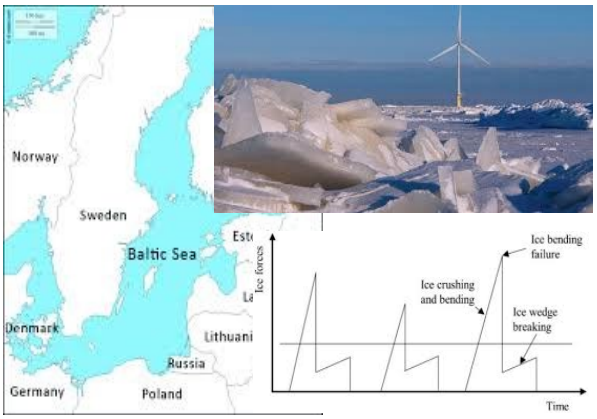
Theory: ☒☒☒ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

VATTENFALL

Offshore wind turbine bottom-fixed foundations under ice loading in the Baltic Sea

Purpose: Analysis of impact of ice-structure-interaction models on design of bottom-fixed offshore wind structures in the Baltic Sea.

The Baltic Sea is an attractive area for offshore wind energy due to good wind conditions and the need of East European countries in this area to develop sources of renewable energy where offshore wind is a promising solution.



The area of the Baltic sea is however challenged by ice formations that introduce different boundary conditions for design of supporting structures compared to the North Sea where the most experience is derived from. For design of a supporting structure it directly means that some new load cases both in extreme and fatigue conditions need to be carefully considered. That calls for reliable ice load models which are still under development. It is essential for offshore wind developers like Vattenfall to understand an impact of different ice-structure-interaction models on the design loads in order to deliver optimised solutions.. Vattenfall has been recently involved in designs where ice loads have been considered for both foundation and turbine.

Main activities: With offset in an existing project and structures the student shall uncover the behaviour of ice and the structural interaction with ice loads.

The student shall introduce ways to model the ice impact and make suggestions to reduce this. This may be with more accurate models, interactions with the turbine manufactures or changes to the foundation design.

The time domain ice load models may in particular be based on the DNVGL tool IceFloe or other models like e.g. Vanilla.

Vattenfall will contribute to the work and support the student.

Contact persons: John Dalsgaard Sørensen, Jannie Sønderkær Nielsen, Dariusz Eichler (Vattenfall)

Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

VATTENFALL

Reliability based planning of inspections of foundations in a large offshore wind farm

Purpose: To develop and demonstrate framework for planning of inspections of wind turbine foundations in a large offshore wind farm. The methodology shall be based on probabilistic approach and allow for determination of inspection schedule for individual foundations from the structure reliability point of view. The framework shall utilise effect of numerous foundations featuring similar design and subject to similar external conditions.

Normally foundations are designed in such a way that the inspections are not necessary. This is achieved by selecting relevant safety factors. However, there might occur extraordinary conditions that impose an inspection requirement. This could be on intention, where savings are anticipated by introducing an inspection regime in the design phase and thus allowing for reduction of safety factors. But this could be also due to unforeseen structural integrity issues of a serial character that invalidate design assumptions and where inspections are seen as a risk mitigation measure.

Inspections of offshore structures are relatively expensive and inspecting every foundation at a fixed interval and regardless of findings is impractical. The reliability based approach offers a methodology to plan inspection intervals according to change of structural integrity reliability level and allow for upgrades of reliability should inspection not reveal any failures or damages. Thus intervals can be designed such that reliability level is always kept above an allowable limit.

Main activities:

The main scope of work is to define a framework for planning of inspections of foundations based on probabilistic methodology. The framework shall include a timewise degradation model for reliability of structure integrity, shall utilise stochastic model of inspection quality in terms of failure detection and take advantage of a large number of foundations of the same type and exposed to similar external conditions.

Result of the work shall be demonstrated in form of an inspection plan designed for a specific wind farm optimised according to inspection quality and number of similar foundations. Options: Include in the model a variability of both designs and external conditions across the wind farm.

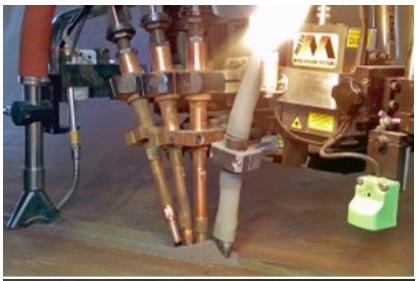
Contact persons: John Dalsgaard Sørensen, Jannie Sønderkær Nielsen, Dariusz Eichler (Vattenfall)

Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☐

Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

VATTENFALL

Welding technology for improvement of fatigue performance of thick plate butt welded joints in wind industry structures



Purpose: Review of welding procedures with potential to improve fatigue performance of thick plate butt weld joints by influencing weld parameters important for fatigue resistance.

Post-welding residual stresses and geometry of a weld reinforcement in butt weld joints are obvious parameters that influence fatigue performance of a welded joint. The former by contributing to surface crack opening and the latter by generating local stress concentrations.

It has been proven by the Joint Industry Project SLIC (fatigue test program targeting fatigue performance of thick plate butt welds) that number of cycles to failure can be directly related to geometry of the weld face. When looking at geometric parameters, it has been found that an angle and curvature of a weld toe (i.e. at transition between flat surface of the adjoining plate and the bumpy surface of weld face) contributed most to fatigue performance of a butt weld joint. Height and width of the weld reinforcement could also have played an important role. By designing a welding process such that all of this parameters are minimised, stress flow through the weld could be streamlined and fatigue performance of a welded connection would be improved.

Main activities: Project shall make a review of state-of-the-art technologies with respect to welding procedures for assembly of thick plates in wind industry structures. Review and analysis of various methods should focus on post-welding residual stresses, on geometry of weld face as well as other parameters potentially influencing fatigue performance. Project shall explore welding procedures with potential of improving parameters important for fatigue performance and suggest a complete welding procedure proposal. Reasoning presented in the thesis might be supported by respective simulations.

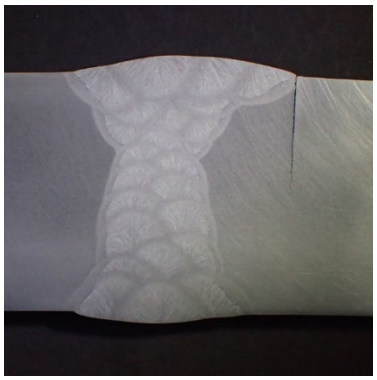
As an option a demonstration of the suggested improvement could be done by producing actual weld samples, performing measurements and tests.

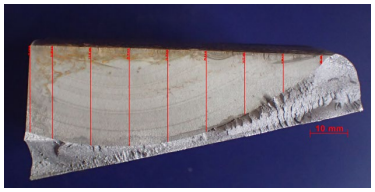
Contact persons: John Dalsgaard Sørensen, Dariusz Eichler (Vattenfall)

Theory: ☒☒☐ **Experimental work:** ☒☐☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

VATTENFALL

Surface crack growth magnification factor for assessment of thick plate butt weld joints by Linear Elastic Fracture Mechanics





Purpose: Results of the project shall be a set of formulas for evaluation of magnification factors specific for assessment of crack growth in a butt weld joint. Formulas shall be applicable for assessment of butt joints of topology and geometry common in wind industry, e.g. towers and monopile foundations.

Surface crack parameters for fracture mechanics assessment as well as specific methodology for cracks in a flat plate are well described in literature and appropriate standards. Challenges arise when an analysis has to be done for a flaw in a structure detail that features stress concentrations. It is acknowledged that stress distribution around a crack in a flat plate and in a detail with stress concentrations will be different. In order to be able to use the known methodology also to the latter group of details it is necessary to evaluate that difference and establish a set of dimensionless magnification parameters, known in literature as M_k factors. Such a work with application of Finite Element Analysis (FEA) has been done in the past for a general type of a welded joint detail. The analysis has been based on fillet weld connection for a variety of different geometries of attachment element and variety of weld toe angles. A set of formulations approximating results of FEA have been proposed. It is however uncertain whether the proposed methodology is sufficiently accurate and allows to represents real physics of crack propagation in a butt weld joint. As fracture mechanics analysis of butt welds is rather common in wind industry, it would be desired to have a methodology dedicated specifically to this type of joints.

Main activities: Project shall focus on topologies and geometries of butt welds used in supporting structures of wind industry. A FEA based parametric study of crack growth is to be performed for an applicable range of geometrical weld joint parameters and crack sizes. The results of FEA in form of respective magnification factors shall be approximated to analytical formulas with dimensionless parameters representing weld joint geometry as an input.

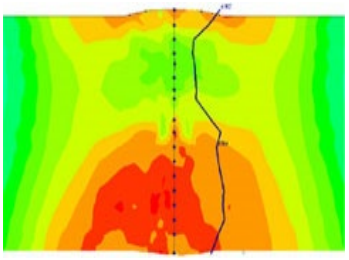
The work shall demonstrate differences in fatigue lifetime for various geometrical parameters of butt welds and compare to S-N based method of fatigue assessment.

Contact persons: John Dalsgaard Sørensen, Lars Damkilde, Dariusz Eichler (Vattenfall)

Theory: ☒☐☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

VATTENFALL

Fracture mechanics methodology for prediction of surface crack growth in thick plate butt joints with high post-welding residual stresses.



Purpose: To present a methodology for fracture mechanics based evaluation of crack growth in joints with high post-welding residual stresses. The project shall further describe uncertainties of the method with respect to evaluation of residual stresses and shall indicate existing knowledge gaps.

Post-welding residual stress in a welded joint is a common phenomenon but evaluation of stress level and distribution in a joint is challenging, given different welding procedures, stress shakedown effect and local plastic deformations under extreme loads. Nevertheless residual stresses in welded joints are usually very high, up to yield level, and unevenly distributed. A methodology for crack growth assessment available in the industry standards suggests to account for that by application of a crack growth curve for a higher R-ratio (maximum over minimum test stress ratio). It is though not clear how accurate the methodology is, given that the actual stresses and thus stress ratios along the crack front will change with crack depth and for different applied load ranges. Local plasticity of areas where combination of residual and operational stresses exceeds yield point, adds further complexity to the analysis. It would be then desired to work out a reliable methodology that takes into account realistic residual stress distribution and would allow for more accurate prediction of fatigue lives of welded joints.

Main activities: Based on study of literature and industry standards within fracture mechanics (FM) project shall establish state-of-the-art and identify gaps being a potential for inaccuracy of present methodologies. The study shall also cover distribution of post-welding residual stresses in butt weld joints of thick plates both without and with post-welding treatment/stress release.

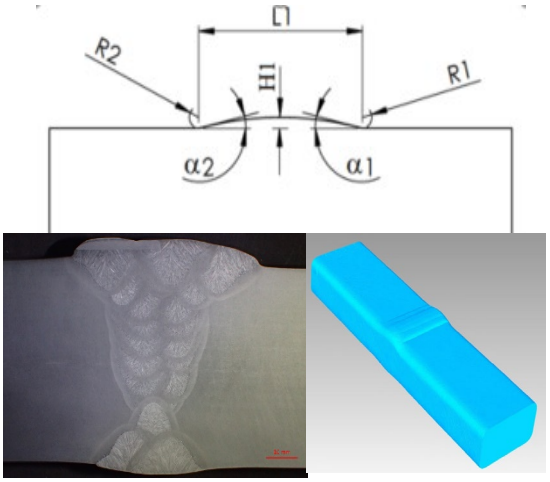
An analytical FM method or modification of an existing method taking into account residual stresses shall be suggested. The methodology shall be validated by finite element simulation of crack growth through the plate thickness and compared with existing benchmarks, if available. All assumptions shall be listed and knowledge gaps identified leading to suggestion for further work.

Contact persons: John Dalsgaard Sørensen, Lars Damkilde, Dariusz Eichler (Vattenfall)

Theory: ☒☒☒ **Experimental work:** ☒☐☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

VATTENFALL

Tool for extraction of butt weld face geometry features from 3D scanning



Purpose: To develop a software tool for extraction of geometric features from a 3D scan of a butt weld joint.

It is a well-known fact that weld geometry influences fatigue resistance of welded connection, weld toe shape being of particular importance. Geometrical features of a weld can be generally described by size of weld toe undercut, radius and angle, as well as weld face elevation and width.

Industry standards regulate size of some of the features and by this defining quality class of the weld and binding that quality to fatigue performance. Usually measurement of weld features are performed manually by means of templates. The method is not very efficient and obviously subject to individua inspector's judgment. Offshore wind industry is more and more looking into 3D scanning as an inspection method which bears potential for automation and offers high repeatability. Scanned surfaces of welds can be then subject to geometric evaluation with regard to size of their features more reliably.

Main activities: The student will develop a methodology for analysis of 3D scanned geometry of a welded joint that shall be based on an automatic detection of weld and extraction of the weld face features. The developed software should be able to work with both flat (flat plates) and circular (tubulars) joints. The geometric features shall be extracted along the weld at a regular distance. The software shall be able to carry out a statistical evaluation of results.

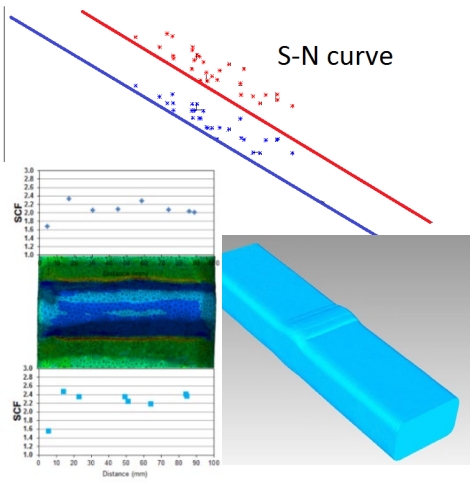
As an extension the software may accommodate joints of non-colinear tubulars of different diameters and joined at an angle, which is typical joint in jacket type of an offshore structure.

Contact persons: John Dalsgaard Sørensen, Lars Damkilde, Dariusz Eichler (Vattenfall)

Theory: ☒☒☐ **Experimental work:** ☒☐☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master:** ☒

VATTENFALL

Butt weld joint 3D geometry and notch stress approach to fatigue assessment based on S-N curves



Purpose: To establish a relationship between butt weld joint 3-dimensional (3D) geometry and its fatigue resistance. Evaluation of applicability of a generic notch stress S-N curve for the purpose of fatigue assessment.

Fatigue is one of the main drivers in design of offshore foundations. Fatigue resistance of a weld joint is to a large extent dependent on geometry of the weld face. It is particularly pronounced by comparison of "as-welded" joints and "ground-flush" joints where the weld face has been removed by grinding. It is anticipated that S-N curve based assessment could take an actual geometry of a weld into account. This could be accomplished by a generic local stress S-N curve where effects of stress concentrations in the weld would be normalised and such an S-N curve would be related to a stress in a very local weld detail. It is anticipated that such a curve could turn to be universally applicable for all welded joints but would require scaling upon weld geometry by a representative Local Stress Concentration Factor (LSCF) assessed by either a Finite Element Analysis (FEA) or a parametric formulation.

Main activities: Project shall be based on results and post-mortem data from fatigue test programme executed within the Joint Industry Project SLIC. A series of FEA using the actual geometry of tested joints will be performed to document distribution of local stress concentration areas and correlation with fatigue failure initiation points. Respective LSCF related to notch stresses will be calculated and a generic, local stress based S-N curve will be formulated. A methodology for extracting geometry from actual weld samples by scanning and a following FEA is to be investigated and presented in form of a guideline.

Another part of the project should focus on Fracture Mechanics (FM) model of crack propagation in the weld joint. Model of the weld joint will be 3D and will assume the crack initiation point at location with the highest LSCF. Results of the analysis shall demonstrate conformity of the FM with the SLIC test results. The FM analysis may be additionally performed for a specimen with multiple cracks and will demonstrate mechanism of the first crack arrest and new crack initiations and mobilisation of the first crack again until the final failure .

Contact persons: John Dalsgaard Sørensen, Lars Damkilde, Dariusz Eichler (Vattenfall)

Theory: ☒☒☐ **Experimental work:** ☒☐☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Risk, Resilience and Sustainability in the Built Environment

Our mission

In the Risk, Resilience, and Sustainability in the Built Environment Research Group (R2SBE), we contribute to building a safe, resilient and sustainable society through research, research-based education, technology development, and private and public sector services by providing risk-informed decision support for the management of the built environment.

Research areas

Our research activities may be categorized as:

- Probabilistic systems modeling
- Risk informed decision-making
- Resilience of systems
- Sustainability of systems
- Natural hazards risk management

Partners

We collaborate with JCSS Continuing Education & Advanced School, DTU (Technical University of Denmark), DTU Global Decision Support Initiative, Ramboll, Global Risk Forum GRF Davos, DBI Fire and Security, Alexandra Institute, Harbin Institute of Technology, Femern Belt, ATV – the Danish Academy of Technical Sciences, Politecnico di Milano, World Economic Forum, K-FORCE project, Tongji University

Group members

Michael Havbro Faber
José Guadalupe Rangel Ramirez
Linda Nielsen
Sebastian Tølbøll Glavind
Yue Guan
Kashif Ali
Henning Bruske
Akinyemi Olugbenga Akinsanya
Juan Gonzalo Sepúlveda Astudillo
Min Liu
Wei-Heng Zhang

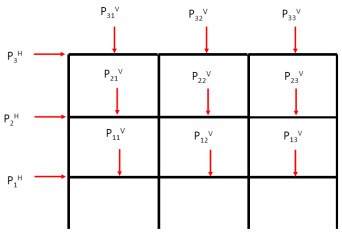
Robustness of Structures

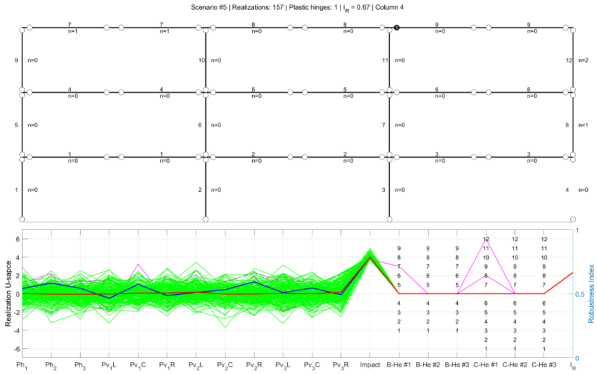
Purpose: Robustness of structures remains a challenge for the engineering profession. Whereas recent ideas developed in our research group show great promise in providing a basis for the quantification of structural robustness, there are still significant gaps in knowledge regarding the implications of these in the more practical contexts of engineering design.

The purpose of the present project is to close some of these gaps. To this end, it is suggested to put the focus on the probabilistic modeling and analysis of structural robustness accounting for one or more of the following exposure events:

- Human errors in design and construction
- Degradation such as corrosion and fatigue
- Explosions and fire
- Climate change
- Extreme environmental and operational loads

and to assess how insights established by modeling and analysis of selected examples involving typical engineering structures may be transformed into principles for the robust design of structures, which in turn may be implemented in structural design codes – such as the Eurocodes.





Main activities:

- Theoretical, methodical and technical (software) developments for the probabilistic modeling and analysis of structural robustness
- Formulation and probabilistic analysis of principal and generic example structures
- Synthesis of analysis results in support of practical design (design codes)

Contact persons: Michael Havbro Faber, Juan Gonzalo Sepúlveda Astudillo, and José Guadalupe Rangel Ramirez.

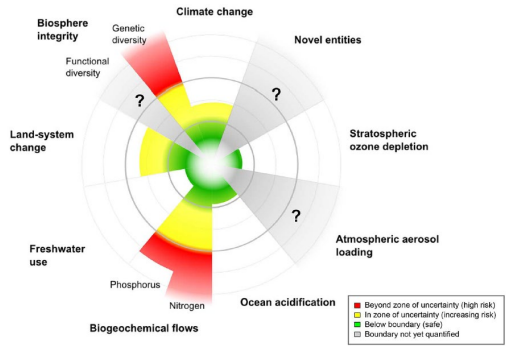
Theory: ☒☒☒ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☒

Suitable project type(s): **3rd sem** ☐ **short master:** ☒ **Long master** ☒

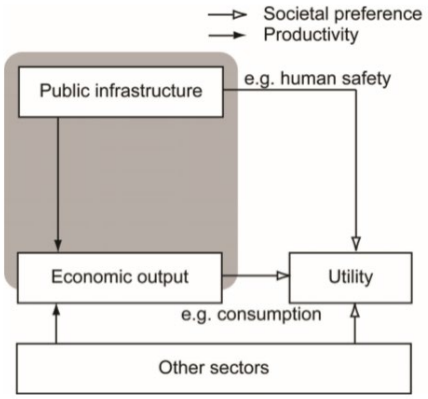
Sustainability of the Built Environment

Purpose: Sustainability of the built environment necessitates that we understand how choices regarding structural materials and concepts affect the environment. In the present project, we build on previous research results where we have modelled the tradeoffs between choices on the quality and quantity of societal economic developments.

The ambition of this project is to add to these finding how choices on quality and quantity of infrastructure also affect the consumption of materials and thereby CO_2 emissions from the built environment. This, in turn, will provide unprecedented knowledge on the tradeoffs between CO_2 emissions from the built environment and economic developments in dependency of different strategies for the further development of the built environment. Utilizing the results of the envisaged research in the context of the Planetary Boundaries, which define safe domains for the operation of the Earth system with respect to impacts/emissions from human activities, the knowledge established from the envisaged research will facilitate support of political decision making on the governance and regulation of the further development of the built environment.



Planetary boundaries, Steffen *et al.* 2015[1]



Main activities:

- Theoretical, methodical and technical (software) developments for the modeling of tradeoffs between amount and quality of infrastructure and emissions and societal economic developments
- Formulation and analysis of principal and generic examples
- Synthesis of analysis results in support of governance of the built environment

Contact persons: Michael Havbro Faber, José Guadalupe Rangel Ramirez.

Theory: ☒☒☒ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☐ **short master:** ☒ **Long master** ☒

Sustainability of the Structural Eurocodes

Purpose: There is a significant need and also political pressures throughout Europe and many countries in the Worlds, to ensure that the built environment is developed and maintained sustainably. The built environment at a global scale is estimated to contribute to total global CO_2 emissions by more than 40% in total. In total, more than 20% of global CO_2 emissions are estimated to originate from the fabrication of building materials and construction processes. In the light of the Paris agreement and the factual necessity that the global society must devise strategies for mitigating climate change, it is crucial that the structural engineering community help identify how we may reduce emissions from buildings and infrastructures.

Presently, the Eurocodes for the design of buildings and structures are being revised. Such revisions take place approximately every 20 years, and if we shall be able to take benefit of the present revision for reducing CO_2 emissions – and meeting the objectives of the Paris agreement - from the built environment, we need to react very soon.

The present project thus aims to establish a mapping of the potentials within the structural Eurocodes for reducing CO_2 and to rank these with respect to their technical feasibility and efficiency relative to safety and economy. The results of the project should include a grouping of potentials into two categories, namely those which may be rather easily implemented in the ongoing revisions and those which require more radical changes. The results of the project will support and interact with ongoing initiatives at both international and national scales to reduce environmental impacts and especially CO2 emissions from the built environment.

Main activities:

- Statistical, conceptual and methodical assessments of the CO_2 pressures originating from different design concepts and materials included in the Eurocodes.
- Review and mapping of technologies in the Eurocodes which pose immediate and more long term potentials for reducing CO2 emissions efficiently

Contact persons: Michael Havbro Faber, José Guadalupe Rangel Ramirez.

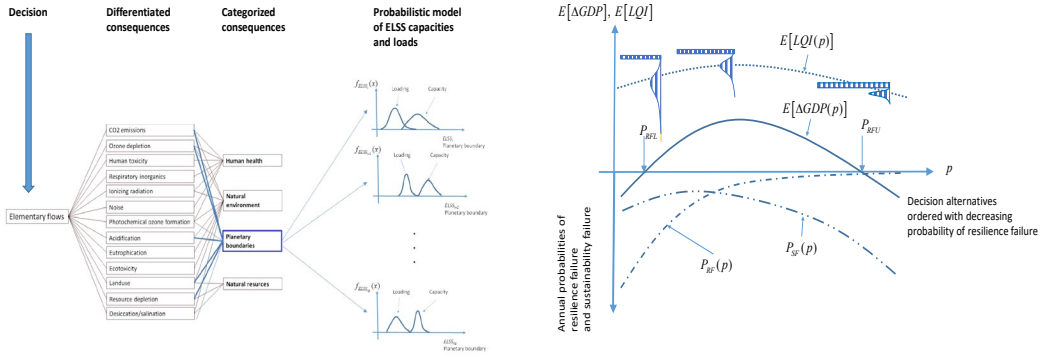
Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☐☐

Suitable project type(s): **3rd sem** ☐ **short master:** ☒ **Long master** ☐

Tradeoffs Between Safety, Resilience and Sustainability

Purpose: There is a global call for safe, resilient, and sustainable societal development. Around the World, the political focus, e.g., expressed through the Sustainable Development Goals of the United Nations is increasingly directed on finding ways in which nation states and the global society may increase welfare through efficient and preference coherent safety management, the resiliency of critical infrastructures and communities and reductions of human impacts on the environmental qualities facilitating long term societal existence. However, till now the research agendas around the World relating to governance with an integral consideration of safety, resilience, and sustainability have been and are (increasingly) strongly influenced by past developments and political agendas. This has unfortunately resulted in a situation where it is no longer fully clear what constitutes the conceptual scientific basis for the knowledge domain as such.

In the present project, building on research results of the research group, the objective is to identify the scientific basis for assessing the tradeoffs between safety, resilience, and sustainability void of or at least explicitly conditional of societal value settings. The overall purpose of this is to enhance the basis for societal decision making in a manner, which is fully transparent and unbiased towards past societal preferences and present and possible future political agendas.



Main activities:

- Thorough assessment of the knowledge domain, i.e., existing theory and frameworks relating to governance and understanding (modelling) of socio-ecological-technical systems, safety, resilience, and sustainability across the natural, technical, and social sciences.
- Synthesis and mapping of results in the form of organized (value neutral) concepts, frameworks, and methods which facilitate tradeoff assessments.
- Discussion of implications of possible different "values" on future governance.

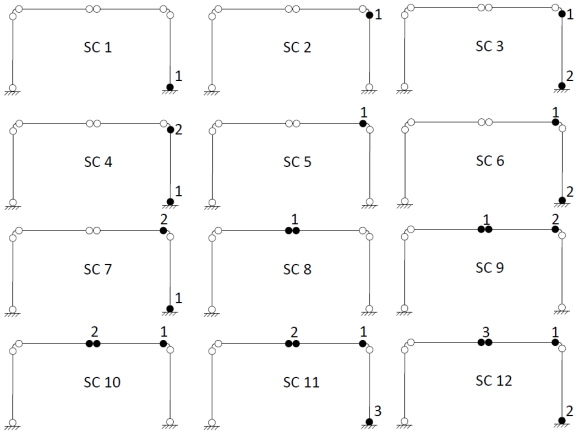
Contact persons: Michael Havbro Faber, Linda Nielsen.

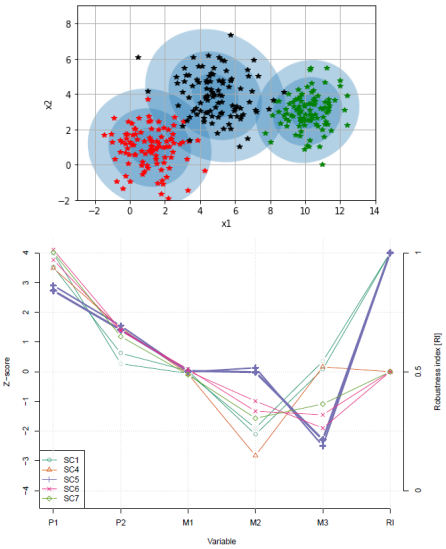
Theory: ☒☒☒ **Experimental work:** ☐☐☐ **Computer modelling:** ☐☐☐
Suitable project type(s): **3rd sem** ☐ **short master:** ☐ **Long master** ☒

Systems Analysis and Damage Identification

Purpose: Structural health monitoring (SHM) is currently a very active field of research, and our industrial partners are getting increasingly aware of the life-safety and economic advantages that follow SHM informed decision making. Probabilistic SHM is inherently a multidisciplinary topic, including elements of e.g., structural analysis, signal processing, detection theory, pattern recognition, and machine learning, where the main focus of this study is machine learning methods for the analysis of systems and potential damage identification.

As SHM is an active research topic, the theoretical developments are moving fast, and thus this study will review state-of-the-art methods for pattern recognition and machine learning, and benchmark these on a set of structural systems in order to gain insight on the most promising methods for SHM of structural systems in civil and/or offshore engineering.





Main activities:

- Review of state-of-the-art probabilistic methods for pattern recognition and machine learning.
- Formulation of principle examples for benchmark study.
- Theoretical, methodical and technical (software) developments for the probabilistic modelling and analysis of the structural systems

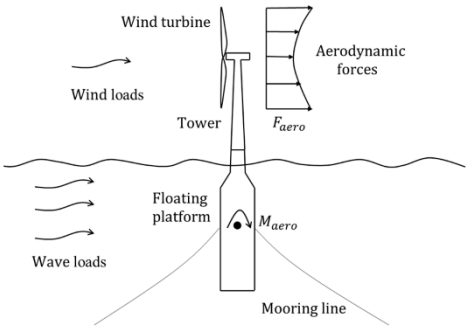
Contact persons: Michael Havbro Faber, Sebastian Tølbøll Glavind and Juan Gonzalo Sepúlveda Astudillo.

Theory: ☒☒☒ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☐ **short master:** ☒ **Long master** ☒

Probabilistic Based Structural Performance Assessment

Purpose: The wind energy section, which is becoming a sustainable alternative option to produce energy, facilitates the development of wind energy technology, and the floating offshore wind turbine (FOWT) is the major facility of such technology that has been deployed to generate the renewable energy. There are several influencing factors affecting the performance and reliability of the main structure of FOWT structure.
By considering the complex environment and operating conditions, FOWT has to be designed, taking the variation of waves into account to ensure sustainable performances during its lifetime. Due to the exposure of wave excitations, a wind turbine may suffer from highly dynamic and time-variant loads and may fail because of the wear of fatigue, and this can lead to unexpected shutdown repairs and maintenance, which are very costly.

Objectives: The major objective of this topic is to establish a probabilistic based reliability assessment framework for wind turbine blades where stochastic modeling of failure is expected to be performed. To this end, machine learning-based probabilistic modeling approaches could be applied to formulate the fatigue damage assessments and modeling of uncertainties.



Main activities:

- Theoretical, methodical and technical (software) developments for the modeling of fatigue damage of wind turbine blades
- Identification of the effects that led by the defects and the corresponding distribution
- Investigation of the reliability assessment on the top of the application of probabilistic modeling approaches.

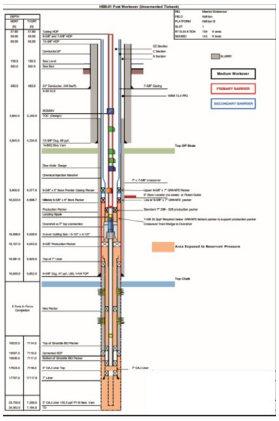
Contact persons: Michael Havbro Faber, Yue Guan.

Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☐☐
Suitable project type(s): **3rd sem** ☐ **short master:** ☒ **Long master** ☒

Risk Based Methodology for Integrity Management of Sub-Surface Oil and Gas Production Wells

Purpose: During the service life of oil and gas sub-surface wells, different failure mechanisms like scale and corrosion damage may arise. Therefore, high operating costs need to be incurred to confirm the functional and structural integrity of the sub-surface well system. This research deals with an enhanced Risk-Based Inspection (RBI) methodology to ascertain the integrity management of the top completion well system based on the rating of segments of the system by risk level.

The purpose of this present study is to divide the top completion system into several segments depending on the system components and the degradation type (e.g., scale type) and then determine the distribution of the probability of failure (PoF) or failure incident of each segment bound by cause (corrosion, scaling, others) and location on the one hand. On the other hand, the associated consequence of failure (CoF)are determined comprising of three phases as follows: (A) Classification (safety, economic, and environmental) (B) Criteria (Cost, Social, Environmental) and (C) Scoring/ranking (0-5 scale, Weighted). The PoF and CoF determine the risk level associated with each well segment. The risk levels of the sensitive locations are estimated based on the quantitative/qualitative RBI methodology. To prepare adequate inspection planning for the sub-surface well system, the high-risk locations are visualized for ensuring the integrity of the proposed methodology.



1	Very high	M	H	H	VH	VH
2	High	L	M	H	H	VH
3	Medium	L	L	M	H	H
4	Low	VL	L	L	M	H
5	Very low	VL	VL	L	L	M
PoF/CoF		A	B	C	D	E

Main activities:

- Theoretical, methodical and technical developments for the modeling of failure rate and consequence analysis and classifications and ultimately risk level by well system segment
- Formulation and analysis of principal and generic examples
- Synthesis of analysis results in support of the practical application

Contact persons: Michael Havbro Faber, Akinyemi Olugbenga Akinsanya

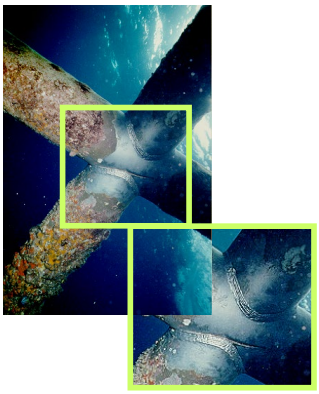
Theory: ☒☒☒ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☒

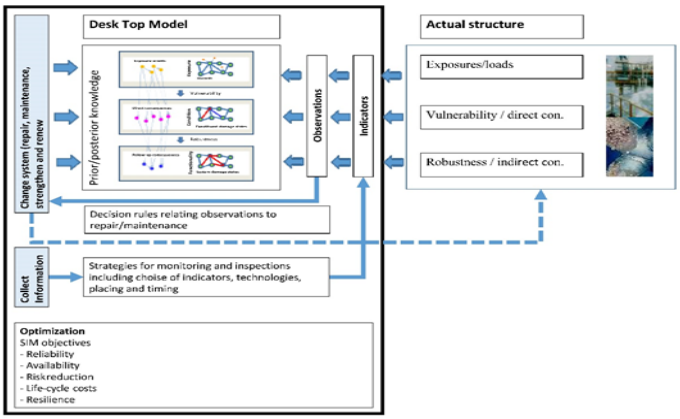
Suitable project type(s): **3rd sem** ☐ **short master:** ☒ **Long master** ☒

Resilience informed integrity management of infrastructure systems

Purpose: Resilience is an aggregate characterization of systems encompassing their ability to maintain their main modes and levels of services, and on their own to develop and mobilize resources to adapt to and sustain disturbances over time. In contrast to the traditional life-cycle risk integrity management, which focuses on reducing vulnerabilities and the life-cycle cost, resilience puts additional emphasis on the ability to rapid recovery and life-cycle benefits. During the past research of our group, resilience failure was proposed as a system performance indicator to quantify system resilience level, which is defined as the exhaustion of system reserve.

The purpose of the present project is to employ this concept in the context of integrity management for infrastructure systems and propose a general framework with a special focus on the operation and maintenance (O&M) planning. It is suggested to start with probabilistic modeling of the infrastructure systems, and then focusing on the resilience analysis and the optimal resilience-based decision making for the O&M planning, including the inspection and repair activities. Meanwhile, the value of the monitoring system could also be considered to make the optimal arrangement decision making to keep the resilience failure at an acceptable range.





Main activities:

- Probabilistic modelling and resilience analysis for the infrastructure systems.
- Resilience based operation and maintenance optimal strategy.
- Value of information analysis for the SHM system in the context of resilience informed integrity management.

Contact persons: Michael Havbro Faber, Wei-Heng Zhang and José Guadalupe Rangel Ramirez.

Theory: ☒☒☒ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☒

Suitable project type(s): **3rd sem** ☐ **short master:** ☒ **Long master** ☒

Integrity management for offshore structures

Purpose:
A large number of offshore structures are placed in the North Sea. These structures experience fatigue damage, marine growth, corrosion, scour and stresses due to a harsh load environment. The structural integrity management includes the mitigation of hazards, accidents while controlling the risk associated with human and organization error.
The aim of the present study is to formulate a framework that identifies the possible factors that may influence the operation and maintenance process and life cycle cost. The framework supported by examples with modeling of costs and risks in connection with Operation and Maintenance (O&M). The framework will be using techniques based on risk and reliability.

Main activities:

- Literature review and codes (NORSOK, DNVGL, API) regarding the O&M in offshore structures.
- Identification of parameters and factors contributing most in O&M.
- Propose an effective and novel approach for integrity management while incorporating new ideas for information flow.
- Implement and present generic examples.

Contact persons: Michael Havbro Faber and Kashif Ali.

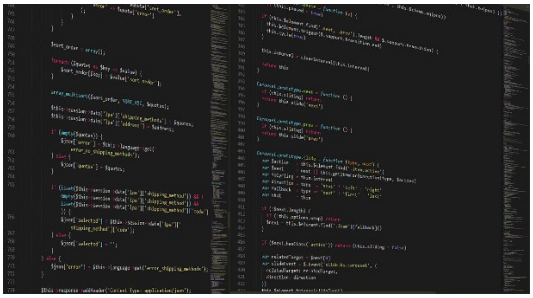
Theory: ☒☒☒ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☐ **short master:** ☒ **Long master** ☒

Web-based Structural and Reliability tools

Purpose: Nowadays, 59% of the world population uses the internet, and current statistics show that up to 95% of websites used JavaScript (JS) to access the user's CPU-RAM capacity instead of server capacity. The use of client-side resources allows civil engineers to think about opportunities in the creation of tools for designing, assessing, research, and estimating quantities within the structural and reliability area.

Currently, the task of embedding calculations for structural reliability assessment into web content management systems (CMS) becomes a transdisciplinary task that only a few specialists can do. There are opportunities in development web-context in civil engineering and JS, such as:

- Creation of libraries for:
  - Structural design for the context in Denmark.
  - Probabilistic simulation in fire and evacuation.
  - Structural reliability of simple systems and components
- Interfacing web-development and software in engineering:
  - OPENSEES for structural analysis and reliability.
  - FDS+Evac, Fire and Evacuation simulations
- Embedded applications into CMS for assessing reliability and design structures.



Main activities

- Increase the understanding of definitions and tools of the chosen web-development opportunity in civil engineering and JS.
- Make a technical study to find a suitable tool to be developed.
- Elaborate the theoretical, methodological and technical framework for directing the work of developing a web-tool
- Program the tools in a web environment in a very hands-on, realistic context.
- Search for partners, specialists, or companies for testing the tools.

Contact persons: Michael Havbro Faber and José Guadalupe Rangel Ramirez.

Theory: ☒☒☐ Experimental work: ☐☐☐ Computer modelling: ☒☒☒
Suitable project type(s): 3rd sem ☐ short master: ☒ Long master ☒

Probabilistic Risk Assessment of structures under Macro and Micro Thermal Damaging Agents

Purpose: The corporate risk survey of Allianz 2019 reported that fire and explosions incidents are ranking in the second most feared causes of business interruption (BI). Even a small fire event in the industry brings considerable losses in the supply chain interruption, costing up to 50% more in claimed-BI than storms and four times more than earthquake events. In the same way as a fire incident, radiation is modifying the inner structure of materials causing long term effects in structural components such as void nucleation, loss of ductility, and swelling.

Today, there is a fair amount of work in thermal effects on structures; however, most of the current work is focused on deterministic approaches not combining structural modeling and probabilistic simulation of cross-sectional and through-length fabrication defects and residual stresses, non-uniform volumetric and micro-structural damage in structures and components due to fire or radiation exposure.
The topics of opportunity to work with are:

- Probabilistic models for simulating steel and reinforced concrete members with cross-sectional and through-length variability from residual stresses and fabrication defects for fire modeling.
- Steel Building modeling of stochastic steel member model using OPENSEES and FDS for fire modeling.
- Macro-probabilistic characterization of radiation micro-damage in steel members.
- Fire events in bridges and tunnels affecting random modeled structures and components.



Main activities:

- Theoretical, methodical, and technical (software) developments for probabilistic modeling of structures in OPENSEES with the support of MATLAB/R/Python.
- Modeling fire scenarios using FDS and OPENSEES.

Contact persons: Michael Havbro Faber and José Guadalupe Rangel Ramirez

Theory: ☒☒☒ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☐ **short master:** ☒ **Long master** ☒

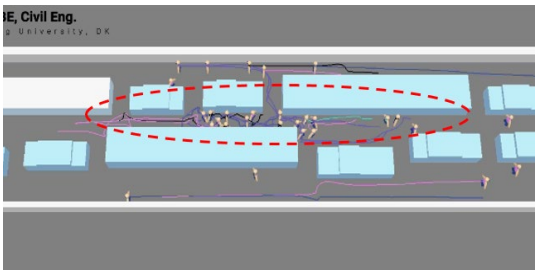
Agent-Based Modeling in Hazardous scenarios in buildings

Purpose: A way to represent the human decision process and behavior in hazardous scenarios is Agent-based modelling (ABM). ABM is a composed computational model to represent the autonomous humanoid agents as individual and/or as collective entities in order to interact within a proposed spatial constraint and hazard.

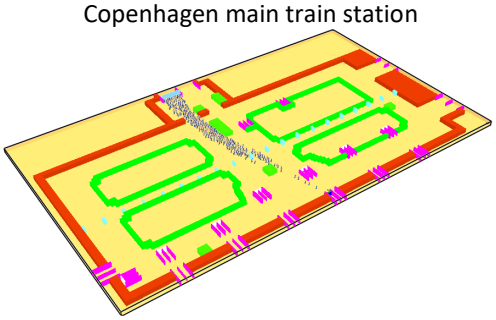
Scenarios such as fire and smoke incidents, explosions, toxic fumes, and radioactive releases demand users' utmost cognitive, physical, and interactive capacity to escape. One could related expected hazardous scenarios for specific public spaces or buildings; however, places with generalized access to the public may have exposure to non-intentional and intentional harmful actions. Considering ABM will support engineers on the quantification of rescue-tactical actions and emergency resources within a scheme for operational risk management in multiple hazardous scenarios. The topics of opportunity to work with ABM are:

- Fire and agent-based modeling in public spaces.
- Agent-based modeling in public spaces for risk in disease transmission.
- Agents' characterization in roadway tunnels and buildings during fire events.

Fehmarn Tunnel



Copenhagen main train station



Main activities:

- Theoretical, methodical, and technical (software) developments for probabilistic modelling of ABM
- Probabilistic simulation and modelling fire scenarios using FDS+Evac

Contact persons: Michael Havbro Faber and José Guadalupe Rangel Ramirez.

Theory: ☒☒☒ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☐ **short master:** ☒ **Long master** ☒

Advanced Structures Research Group

The research group deals with design and analysis of structures in order to make more optimal structure improving the sustainability of structures. The research group contributes by making more realistic modelling of structures leading to e.g. reduced material costs or new efficient concepts.

Modelling of structural behavior is the backbone of the activities. Finite Element is the dominating numerical tool, and can handle linear as well as non-linear problems. The non-linear effects can be due to several mechanisms such as large deflections (stability), material behavior e.g. plasticity, dynamics e.g. moving loads from trains. The research group has contributed within all fields and material behavior is presently the focus area.

Optimization An advanced numerical model enables optimization of the material layout e.g. reinforcement in concrete or layout in composite structures such as wind turbine blades. The research group has contributed in different areas.

New structural concepts In modern design efficient connections between structural element is central combined with new principles for structural layout. The research group has contributed within different fields.

Material modelling Major focus is more realistic modelling of soil, and presently the focus on improving the traditional Mohr-Coulomb models. The numerical modelling is communicated through simplified load bearing formulas for typical geotechnical structures.

Monitoring of structures Optimized structures can be achieved in different ways, and by online monitoring of the structural behavior the safety level can be reduced. The research group has contributed within Structural Health Monitoring of especially wind turbine blades. The approach is a combination of measurement, signal processing and interpretation of changes in the signals.

Supervisors:

Lars Damkilde, Professor

Lars Pedersen, Associate Professor

Christian Frier, Associate Professor

Advanced non-linear modelling of structural behavior

Students interested in numerical modelling of structural behavior can contact Lars Damkilde.

Based on the interest of the students and current research/development projects the students will be offered a tailor-made project.

The projects will typically be related to companies and practical applications.

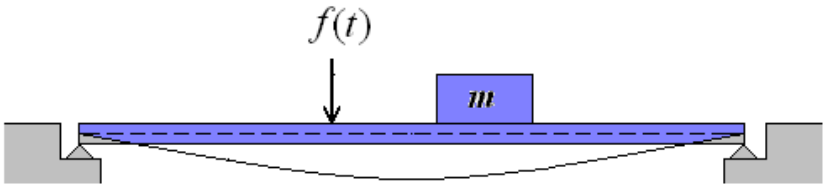
Contact person: Lars Damkilde

Theory: ☒☒☐ **Experimental work:** ☒☐☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Dynamic human-structure interaction

Background: In static calculus, passive (sitting/standing) humans are modelled as a rigid mass attached to the structure. In dynamics, humans in motion (people walking or jumping) are modelled as a dynamic load bringing the supporting structure into vibration.

Human in motion Passive person



In assessments of vibration levels of slender structures carrying humans (such as footbridges, stadia-structures, or office floors) these models are conventionally employed. But are they reasonable?

Purpose: The aim of the project is to study mechanisms of human-structure interaction focusing on areas where the models mentioned above are inadequate. Prior to codifying new models describing the phenomena, they need to be properly researched.

In the project you will plan and conduct experiments striving to highlight the true mechanisms of human-structure interaction on slender structures. Measured vibration data will allow you to calibrate alternative models of the interaction accounting for the flaws in existing models.

Implications of findings (new models of the interaction) you may illustrate through computer simulations of structural response to the dynamic loads generated by humans.

Contact person: Lars Pedersen

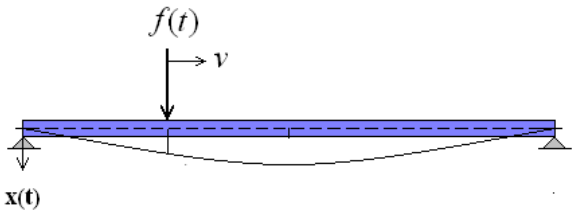
Theory: ☒☐☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☐
Suitable project type(**s**): **3rd sem** ☒ **short master:** ☒ **Long master** ☐

Dynamic human loading and stochastic models for estimating structural responses

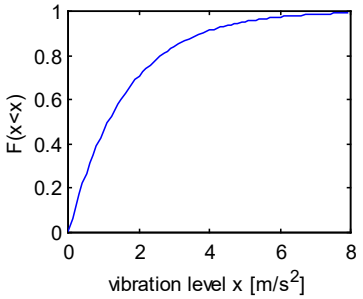
Background: Some civil structures are so slender that their modes of vibration may be excited by the basic frequency of human motion resulting in resonant structural action. The undesired resonant action may for instance occur in footbridges, stadia structures or in open-space office floors as a result of walking or jumping.

Codes and standards handle the phenomenon semi-empirically or even fully deterministic although fundamentally the loading generated by humans in motion is stochastic.

Purpose: The aim of the project is to develop and test stochastic models describing the loading and the structural response. An essential contribution would be to derive statistical distributions of structural responses to human-induced loading, as this would provide valuable information for assessing structural safety or serviceability. Specifically, the risk of exceeding various vibration levels is of interest although it is actually a parameter not given much/any focus in existing design codes.



Walking load when v > 0 m/s, "Jumping load " when v = 0 m/s



Statistical distribution of response

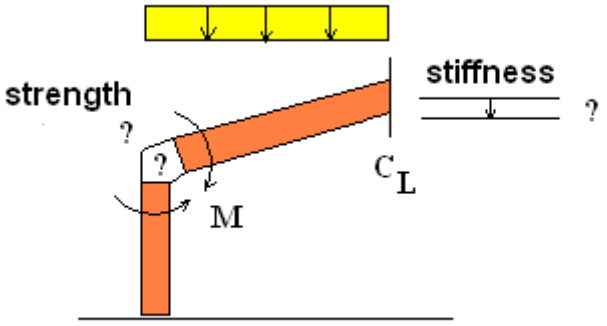
Through the project you will learn how to model the dynamic excitation of humans in motion, deterministically as well as stochastically. You will conduct parametric studies and numerical simulations to highlight essential implications of stochastic modelling of the phenomenon. Experimental verification of models is a possibility if so desired.

Contact persons: Lars Pedersen, Christian Frier

Theory: ☒☐☐ **Experimental works:** ☐☐☐ **Computer modelling:** ☒☒☒
(The amount of experimental work can be decided during the project)
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☐

The corner of laminated timber frames

Purpose: Laminated timber frames are, for instance, desirable in structures where the aesthetics of the structure is in focus. A weak point in a timber frame is the frame corner and its strength and stiffness. But perhaps the corner does not need be made of wood?



Could a reinforced concrete structure or a steel structure be employed in the corner instead? At least the drawbacks of a corner made of wood might be removed and by employing wood in the remaining part of the frame, the frame would still visually appear much like a full wooden frame.

Main activities: The aim of the project is to explore the stiffness and strength of a timber frame employing different solutions in the corner of the frame (steel and/or reinforced concrete and using the full timber frame as reference).

In the project you will develop numerical and analytical models for the various solutions and full-scale tests will be conducted aiming at verifying the strength and stiffness predicted by your models.

Should your investigations reveal that solutions with steel or reinforced concrete in the corner of the frame are feasible (in terms of strength and stiffness) it might indicate a potential for a new type of frame structures.

The project might involve co-operation with external parties having an interest in mapping the potential of alternative solutions for timber frames.

Contact persons: Lars Pedersen, Christian Frier

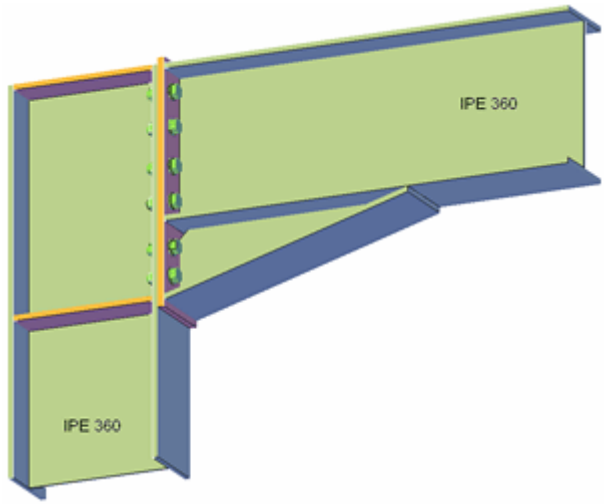
Theory: ☒☒☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☐

Analysis of Joints in Steel Structures

Purpose: Joints in steel structures are frequently made using fasteners. These are not fully rigid which may play a role in terms of behaviour of the steel frame.

The purpose of the project is to investigate how flexibility in joints influences various global characteristics of the steel frame, and to study how Eurocode models these influences.

Another item of interest is to explore the load bearing capacity of joints made using fasteners (analytically, numerically, and experimentally) and to compare results with Eurocode models.



Main activities: The project is relatively open with concern to the problem to be analysed. However, in any case the activities will include:

- A mixture of analytical, numerical and experimental investigations
- Comparison of results with Eurocode models.

Contact persons: Lars Pedersen

Theory: ☒☒☐ **Experimental work:** ☒☐☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☐

Advanced Analysis of Steel Frames

Purpose: In ultimate limit state analyses of steel frames compression forces and bending moments are of concern, as they may lead to global instability manifested in either buckling or lateral torsion failure.

The design guide Eurocode sets up procedures for evaluating the ultimate limit state and actually, Eurocode (EC) suggests a number of different design approaches to choose from. Some EC-approaches are more simplifying than others, and this means that the final evaluation of the ultimate limit state depends on the method chosen for the evaluation. Or does it?

The purpose of the study is to highlight and quantify load carrying capacity of steel frames employing different methods, ranging from basic methods to more advanced methods (in all methods FE-analyses are required but to various degree of complexity).

In the initial part of the study, focus will be on analysing a reference steel frame, but in order to highlight the degree of differences in calculated load carrying capacities it is useful to extend the study. This, for instance, by studying a range of steel frame configurations or to conduct some other type of parameter study focusing on sensitivity of outcome of your calculations to input assumptions related to structural modelling.

Main activities: Besides, from a literature review focusing on the background for EC-guidance focus will be on

- Implementing and describing procedures
- Finite element modelling and analyses
- Parameter and sensitivity studies

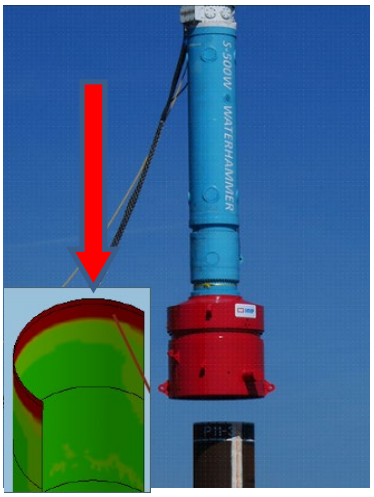
so as to provide an overview of load carrying capacities of steel frames as computed using different methods.

As part of the study it might be useful also to analyse one of the steel frames which recently collapsed due to heavy snow loads.

Contact persons: Lars Pedersen
Theory: ☒☐☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☐

VATTENFALL

FE based dynamic analysis of driving of a pile into soil with an impact hammer



Purpose: To develop a methodology for FE based dynamic analysis of pile driving into soil. The methodology shall preferably be based on implicit solver solution and should allow for analysis of stresses in the pile structure during pile driving.

Installation of a monopile in seabed by driving with an impact hammer is a process where the pile structure is subject to repeatable high dynamic stresses. That imposes on the structure a degree of fatigue accumulation that in the design stage is usually assumed to reach a level that would correspond to up to 10% of fatigue accumulation allowed during the life time of the structure. That obviously has an impact on design where one of the objectives is to assure an operation lifetime.

The other uncertainty during pile driving is buckling stability of a pile under high dynamic stresses. Specially the lower part of the pile which is embedded in the soil is usually optimised thanks to low utilisation under ordinary operation loads but is subject to high dynamic loads under installation. In order to properly assess risk of buckling of the embedded part of the pile a reliable method for assessment of stresses and pile stability would be highly desired.

Main activities: The main scope of work is to simulate pile driving under highly dynamic loads induced by impact hammer and including friction forces of the soil. The simulation model shall reflect realistically properties of dynamic forces and behaviour of the structure. The analysis should allow for retrieval of stress time series for further fatigue and buckling analyses.

It is assumed that explicit solver might need to be used. As a target however it is anticipated that a corresponding methodology with application of an implicit solver is developed. Should a study of differences between this, two approaches demonstrate deficiencies of the implicit solver, a method for overcoming them shall be suggested.

Yet another challenge is a simulation of a case with a hammer delivering a longer impact and with higher energy like e.g. Blue Piling by Fistuca. Then a risk of buckling and fatigue exposure might be different due to less dynamic character of the impact and thus different effect on pile structure.

Contact persons: Lars Damkilde, Dariusz Eichler (Vattenfall)

Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☒
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

VATTENFALL

Revision of formulations for assessment of buckling resistance of wind turbine supporting structures built of large thin-walled tubulars

Purpose: To investigate a possibility of an update of present methodology for evaluation of buckling resistance of large thin-walled tubulars used in supporting structures in wind industry, e.g. towers and monopile foundations.

There is a notion in wind industry that the buckling assessment methods used nowadays might be overly conservative and not reflecting the load patterns encountered by a wind turbine supporting structure. Moreover, the production processes constantly improve accuracy of an assembly resulting in smaller geometrical imperfections. It would be desired to capitalise on that development and directly include fabrication tolerances as a part of the buckling assessment equation.

Main activities: Project shall focus on topologies, dimensions and fabrication tolerances of supporting structures common in wind industry at present and with an appropriate projection into future. A study of loads and associated buckling failure modes shall be presented along with review of present buckling resistance assessment methods used in wind industry.

A series of Finite Element (FE) parametric studies of buckling, covering a range of structure dimensions and including fabrication tolerances as well as different load patterns is to be performed. The collected result database shall be used to draw general conclusions and, if possible, to obtain generic formulations that will be used along with present buckling assessment methods or will replace them completely. Such defined methodology shall be further validated against known benchmarks. If deemed desired, a scope of necessary tests to validate applicability of the method is to be formulated.

Additionally the project may have a look at buckling assessment of a structure embedded in soil both while driving into a ground by high impact hammers and later in operation. Here both large highly dynamic forces as well as elasticity of the surrounding soil create different boundary conditions compared to the over-ground part of the structure.

Contact persons: Lars Damkilde, Dariusz Eichler (Vattenfall)

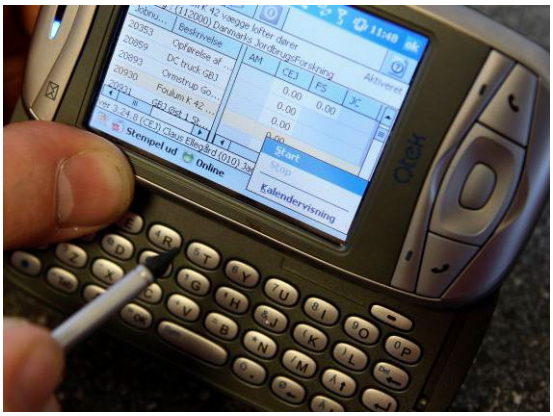
Theory: ☒☒☐ **Experimental work:** ☒☐☐ **Computer modelling:** ☒☒☐
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒

Other proposals

Future information technology at the construction site

Purpose: In recent years, the construction industry has started changing from traditional 2D CAD drawings to more intelligent 3D object based models of the entire building. Such models give us a number of new possibilities for planning and controlling the activities at the construction site through advanced 4D models and possible links between the physical construction components and the virtual building model. New information and communication technology can improve the communication of correct instructions at the right time for the construction work as well as capturing information for quality assurance and as-built documentation.

The purpose of this project is to identify important problems within the area and propose solutions for future use of state-of-the-art information technology at the construction site.



Main activities:

- Identify current practices and problems in traditional construction projects
- Review of enabling technologies, software, hardware, international initiatives
- Test existing methods, software, hardware
- Identify needs and requirements for new solutions
- Build early prototypes with more or less functionality for initial tests

The work may be carried out in collaboration with a construction company.

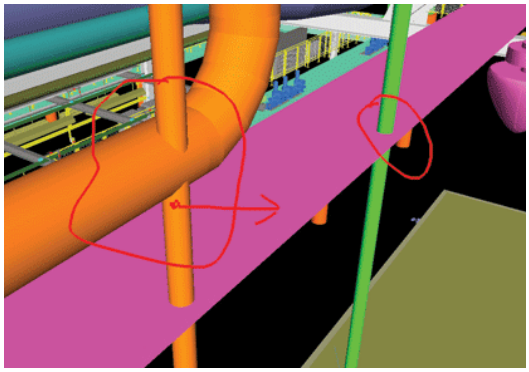
Contact persons: Kjeld Svidt

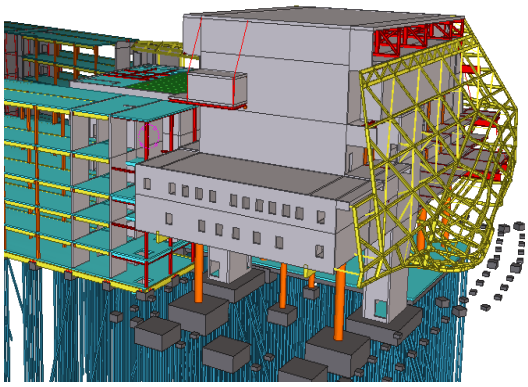
Theory: ☒☒☐ **Experimental Work:** ☒☒☐ **Computer Modelling:** ☒☒☐

Structural modelling and design coordination

Purpose: The construction industry is changing from traditional CAD drawings to more intelligent 3D object based models of the entire building. There are many attempts to improve the structural design process by making a better connection between object based CAD systems and structural simulation tools. The simulation tools can be more or less integrated with specific CAD systems or they may exchange data through open international standards. An important issue for the structural engineer is also the often complicated coordination with requirements from other disciplines such as architecture, HVAC etc. New IT tools are introduced to assist this coordination.

The purpose of this project is to identify critical elements of the integrated design and coordination process and examine how new methods and information technology can assist us in the future construction industry.





Main activities:

- Identify strength and limitations in current practices and identify opportunities with upcoming technologies in the area
- Review of enabling Information and Communication technologies (ICT), including software, data models, international standards, and human computer interaction tools
- Examine today's possibilities with existing tools
- Identify needs for new ways of working and from that derive a list of requirements on technical solutions
- Demonstrate possible solutions for the near future and describe issues for future development

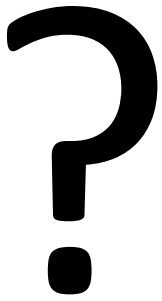
The work may be in collaboration with a consulting engineering company.

Contact persons: Kjeld Svidt

Theory: ☒☒☐ **Experimental Work:** ☒☒☐ **Computer Modelling:** ☒☒☐

Your own idea

Purpose: The purpose of a masters thesis is to study a specific topic within Engineering. As it demands a lot of work, it is important the topic is of interest. Therefore, students are encouraged to come and present their own ideas for a masters thesis. The main activities can therefore include various tasks, whereof some are listed below.



Main activities:

- State of the art study
- Case study
- Numerical modelling
- Programming
- Laboratory testing
- Field tests
- Analysis of monitored data
- Combinations of above

Contact persons:
Who ever you think could be relevant

Theory: ??? **Experimental work:** ??? **Computer modelling:** ???
Suitable project type(s): **3rd sem** ☒ **short master:** ☒ **Long master** ☒