M.Sc. in Civil and Structural Engineering

3rd Semester and Master’s Thesis Ideas 2014

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Edited by Lars Vabbersgaard Andersen

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Aalborg University
Department of Civil Engineering
School of Engineering and Science

DCE Latest News No. 42

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June 2014

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M.Sc. in Civil and Structural Engineering: 3rd Semester and Master's Thesis Ideas

The following pages contain a list of project ideas proposed by the scientific staff at the Department of Civil Engineering, Aalborg University, and a number of companies. Most of 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.

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 act as primary supervisors. Questions regarding details about each proposed project should be asked to these persons. The contact details can be found via a person search on the university home page. Furthermore, other ideas for projects may be discussed with a potential supervisor.

Many private engineering companies have state on their homepage that they would like to collaborate with students on a master's thesis project. Examples are:

- Cowi, http://www.cowi.dk/menu/jobs/ungicowi/praktikspecialeogstudiejob/byggeri/Pages/byggeriogdriftforstuderende.aspx
- Grontmij, http://www.grontmij.dk/DK/job-karriere/Studerende/Pages/speciale-projektskrivning.aspx
- Moe, http://www.moe.dk/Karriere/Ledige-Stillinger.aspx?hr=show-job|852?expandform=1
- Niras, http://www.niras.dk/Ung-i-NIRAS/Specialesamarbejde.aspx

The preferred group size for master projects is two to four students. In the interest of students as well as supervisors, single-student projects are generally not recommended. In a short 3rd semester project the minimum group size is three students.

At the third master semester the students have the option of doing a company stay. It is important to notice that this is not a traditional internship, but rather a third semester project carried out in cooperation with a private or public company. An example of a successful subject for such a company stay is also given in this catalogue in the last page.

As a final remark, a signed project plan must be handed to the head of the School of Engineering and Science at latest one month after the initiation of the project. This project plan must contain information about the project, in particular regarding the educational goals of the project. These must be defined in accordance with the

Master Curriculum (Danish: Studieordningen) for the M.Sc. Programme in Civil and Structural Engineering at the School of Engineering and Science, Aalborg University. The curriculum can be found at the Study Board of Civil Engineering homepage at http://www.ses.aau.dk/digitalAssets/14/14964_msc_k_250610.pdf. A document template for the project plan is available at the homepage of the School of Engineering and Science at http://www.ses.aau.dk/digitalAssets/32/32582_projektplan_word.doc (Danish version) and http://www.en.ses.aau.dk/digitalAssets/32/32588_project-plan_word.doc (English version).

Aalborg, May 12, 2014 Lars Vabbersgaard Andersen

Creating a numerical model of the Weptos wave energy converter and validation by experimental tests.

Purpose: The purpose is to create a numerical model that can describe the movements of the rotor of the Weptos wave energy converter. This would be very useful as it could for example be used to further enhance its performance and reduce structural loads by improving the design and/or setup of the rotor.

The numerical model will not have to be started from scratch, but will be a continuation of a previous similar project that was based on the same setup. However the numerical model will have to be improved and expanded and new experimental tests will have to be performed in order to provide more and better comparable data, which should validate the numerical model and indicate the limitations of the numerical model.

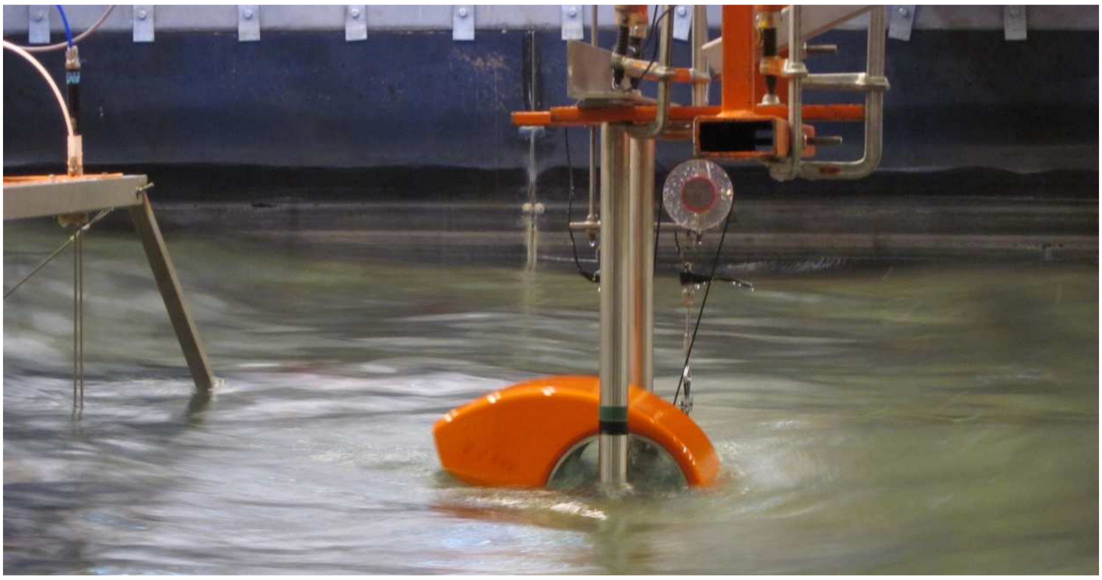


Figure 1: Picture of the rotor during experimental tests.

Main activities: The project will contribute to the on-going research on the subject and thus be very relevant. This project includes the main following activities:

- Further development and enhancement of an existing numerical model.
- Experimental test aiming at validating and showing the restrictions of the numerical model
- Look into the effect of various variables on the performance of the rotor.

Contact persons: Arthur Pecher, Jens Peter Kofoed

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

Control of the Weptos wave energy converter

Purpose: The development of the Weptos wave energy converter (WEC) is gaining momentum and it is time to develop a suitable control system. This control system will be composed out two parts, the adaption of the opening angle between the legs, which regulated the available incoming wave power, and the damping presented by the electrical generator system.

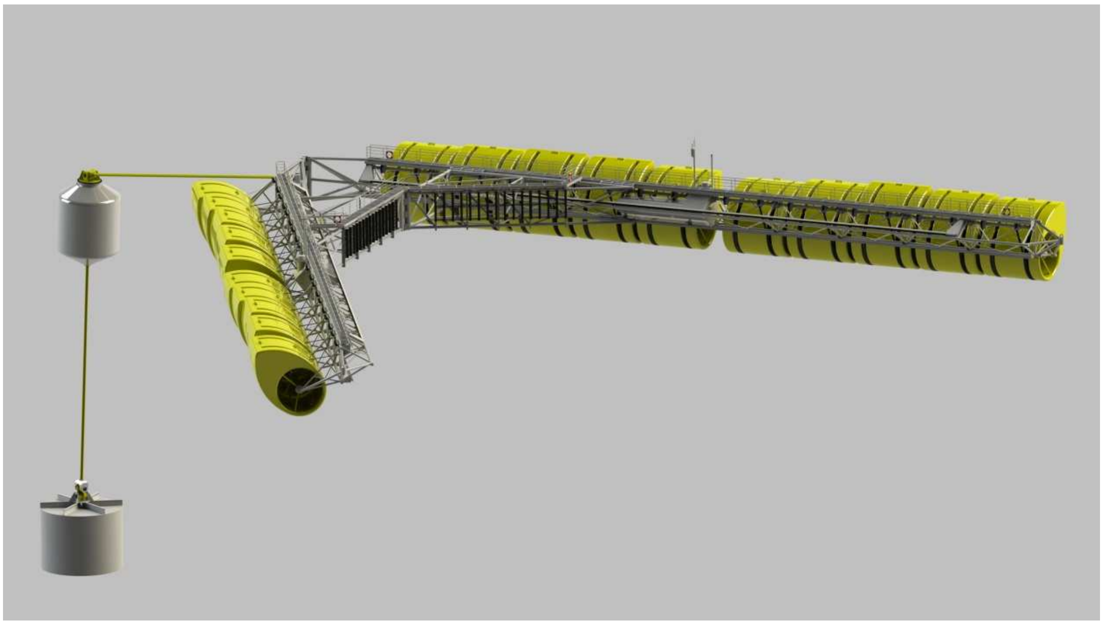


Figure 2: Artist impression of the Weptos WEC

Main activities: The control system of renewable energy systems is not a new topic, however it has not been optimised yet for this particular application. Therefore first a thorough literature review has to be performed. Based on previous laboratory test results, smart control systems have to be presented. These can then be tested and further improved by performing experimental tests in the wave basin on real laboratory models.

Contact person: Arthur Pecher – afsp@civil.aau.dk

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

Experimental study on SALM mooring system for wave energy converters

Purpose: The experimental investigation the influence of various parameters of a "single anchor leg mooring" (SALM) system on the response and loads on a floating wave energy converter.

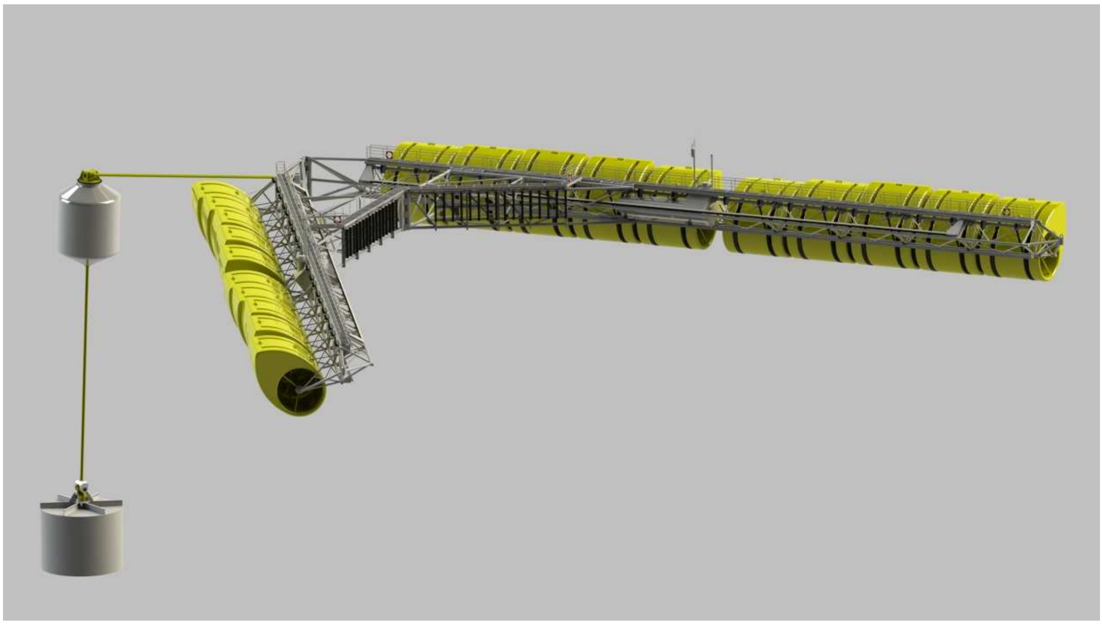


Figure 3: Artist impression of the Weptos WEC moored by a SALM system

Main activities: The investigation will be composed out of a preliminary quasi-static analysis of the different mooring configurations (depending on the parameters of interest). Possible parameters could be:

- Water depth
- Size and design of the WEC
- Length of the hawser
- Volume of the buoy.

These different mooring configurations will then be tested experimentally in the wave basin. The results and comparison of the both investigations will contribute to the design of the SALM system for the wave energy converters and indicate the reliability of the quasi static analysis. In this case, the results will especially be beneficial for the Weptos WEC and will indicate the response of the device under various conditions and give a feeling on the required safety factors.

Contact person: Arthur Pecher – afsp@civil.aau.dk

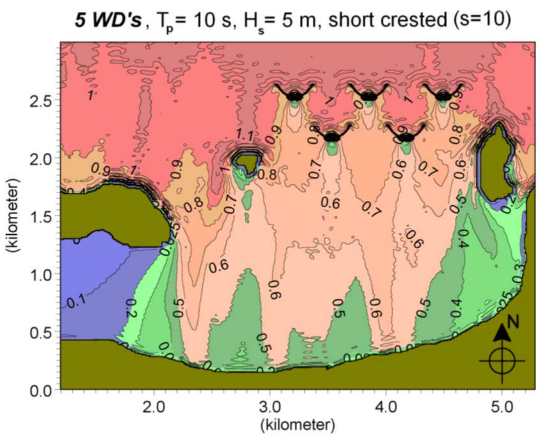
Theory: ☒☐☐ **Experimental work:** ☒☒☒ **Computer modelling:** ☐☐☐

Wave energy converters for use in coastal protection

Purpose: The purpose is to adopt wave energy converters for mitigation of flooding and coastal erosion hazards in the context of increasing storminess and sea level rise. A proposal is to place wave energy converters close to the shoreline for contemporary attenuating wave attacks and thereby produce a secondary benefit.

Physical model tests on a single Wave Dragon wave energy converter have already been performed at AAU in scale 1:50 to measure the wave height reduction behind the device. Measurements from the tests have been used in the calibration of a numerical wave propagation model.

However, additional tests are still needed to perform more detailed analysis on the wave scattering from the devices. Moreover, numerical simulations should be performed to evaluate the influence from the Wave Dragons on the sediment transport in a specific bathymetry.



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 2D/3D numerical modelling of wave scattering from floating devices positioned in different arrays
- Case study on the influence on wave climate at specific site
- Case study on the influence on sediment transport at specific site
- Theoretical assessment of wave transmission through a wave energy converter.

Contact persons: Jørgen Harck Nørgaard, Thomas Lykke Andersen, Thomas Ruby Bentzen

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

Modification of existing formulae for design of breakwater crown walls in long and oblique waves

Purpose: State of art design formulae for estimation of wave loads on rubble mound breakwater crown walls solely covers perpendicular wave attack, which are relatively steep. However, many sites have oblique waves and conditions with relatively low wave steepness.

The purpose of this study is to derive modifications to existing design formulae based on physical model tests to increase the range of validity of the existing design formulae.

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

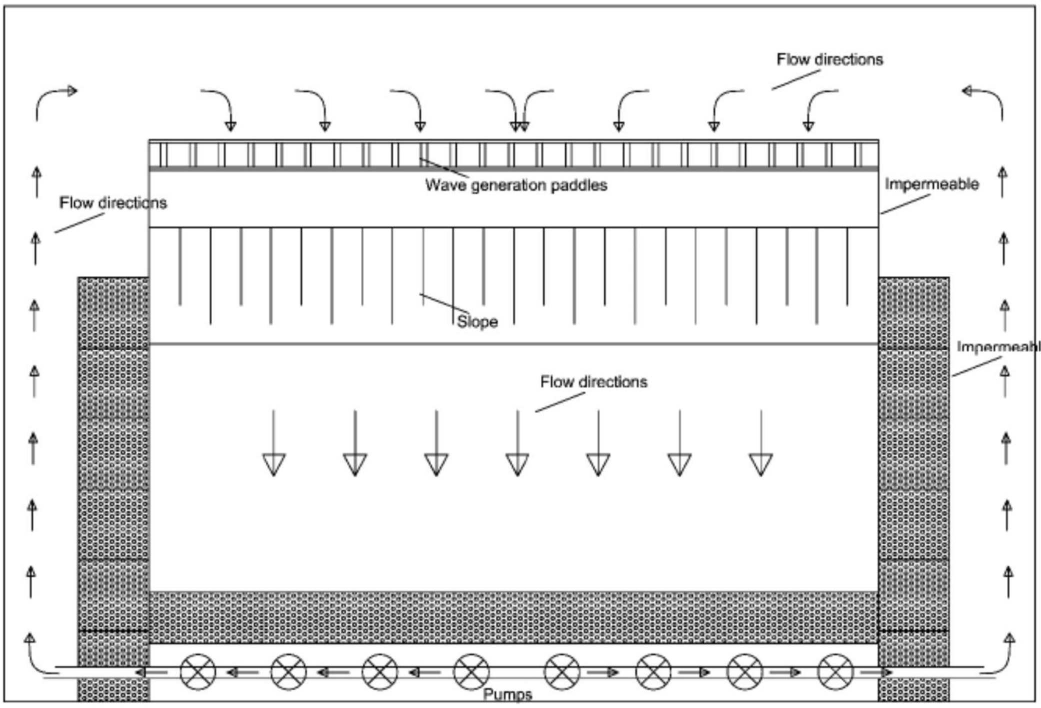
- Experimental modelling of wave run-up on rubble mound breakwaters
- Experimental modelling of dynamic wave loads on rubble mound breakwater crown walls
- Influence from oblique and short-crested waves on wave loads on rubble mound breakwater crown walls.

Contact persons: Jørgen Harck Nørgaard, Thomas Lykke Andersen

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

Design and optimization of current generation in wave basin using CFD

Purpose: The department of Civil Engineering is planning a new basin in the laboratory for simulation of combined waves and current. Previous model tests with waves and current have been performed in the present basin using traditional pumps at the back end of the basin. However, it has been very difficult to obtain a homogeneous flow. Therefore, numerical CFD simulation is needed to optimize the current generation system and to determine how to adjust the pumps etc.



Main activities: The study will contribute to the design of the wave basin, which will be constructed at the main AAU campus. The following activities can be included:

- 2D and 3D numerical modelling of flow in the wave basin
- Optimization of combined current and wave generation system.

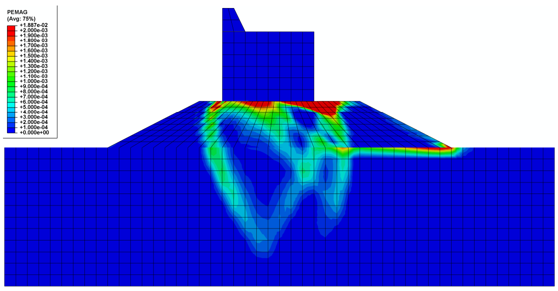
Contact persons: Thomas Lykke Andersen, Jørgen Harck Nørgaard,

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

Stability of monolithic coastal protection structures subjected to impulsive wave loads

Purpose: Monolithic structures such as caisson breakwaters or rubble mound breakwater crown walls are in most cases designed using quasi-static design loads to remain stable during the design conditions. However, since the design loads are in nature very impulsive this procedure may be too conservative. The goal of this project is thus to evaluate existing and new tools for ensuring the stability of such structures.

The study can include both scaled model tests in the laboratory and numerical finite element modelling in e.g. ABAQUS or other 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 modelling of structural response of monolithic coastal protection structures
- Numerical modelling of structural response of monolithic coastal protection structures and elastic/plastic deformations in foundation material.

Contact persons: Jørgen Harck Nørgaard, Thomas Lykke Andersen

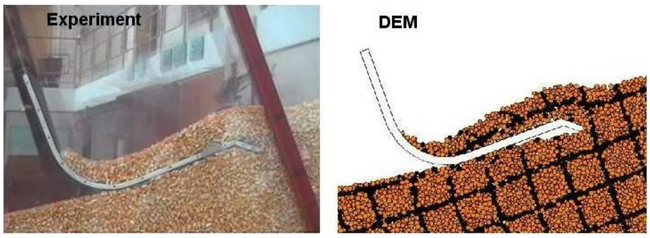
Theory: ☒☒☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☐

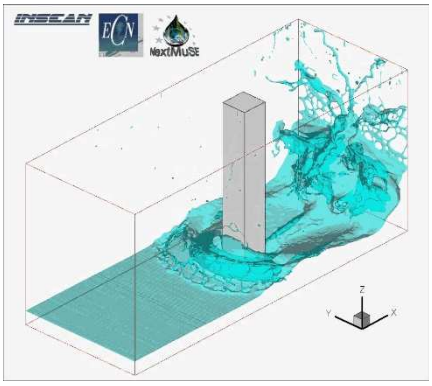
Numerical modelling of fluid–soil–structure interaction

Purpose: Finite-Element Analysis (FEA) is the industry standard for analysis and design in many fields of engineering. However, the standard formulation based on continuum mechanics and a Lagrangian description (elements follow the material) can be very inconvenient for problems with large deformations. This is, for example, the case in many problems related to interaction of fluid, soil, and/or structures.

Over the last few decades, some alternatives to standard Lagrangian FEA have immerged, including Smoothed Particle Hydrodynamics (SPH), the Discrete Element Method (DEM) and Arbitrary Lagrangian Eulerian (ALE) FEA. SPH and ALE are still based on a continuum theoretical framework, but allow (in two different manners) material to deform infinitely, whereas standard FEA has difficulties even at moderate deformations due to severe entanglement. It the DEM, the idea is on the other hand to model each separate grain or particle as an individual (discrete) element.

The idea is to pick up one or more of the novel methods and analyse its advantages, disadvantages and limitations compared with standard FEA. Focus can be on failure of breakwaters, pile driving, slope failure, or another problem involving large deformation and/or fluid–soil–structure interaction.





Main activities: The project will contain some (but not all) of the following:

- Learning the key aspects of Smoothed Particle Hydrodynamics (SPH)
- Learning the key aspects of the Discrete Element Method (DEM)
- Learning the key aspects of Arbitrary Lagrangian Eulerian (ALE) FEA
- Studying the differences between selected methods and standard FEA
- Anlysing example cases, e.g. wave impact on a rubblemound breakwater, flow of granular material, or identation or penetration of a pile or cone into soil.

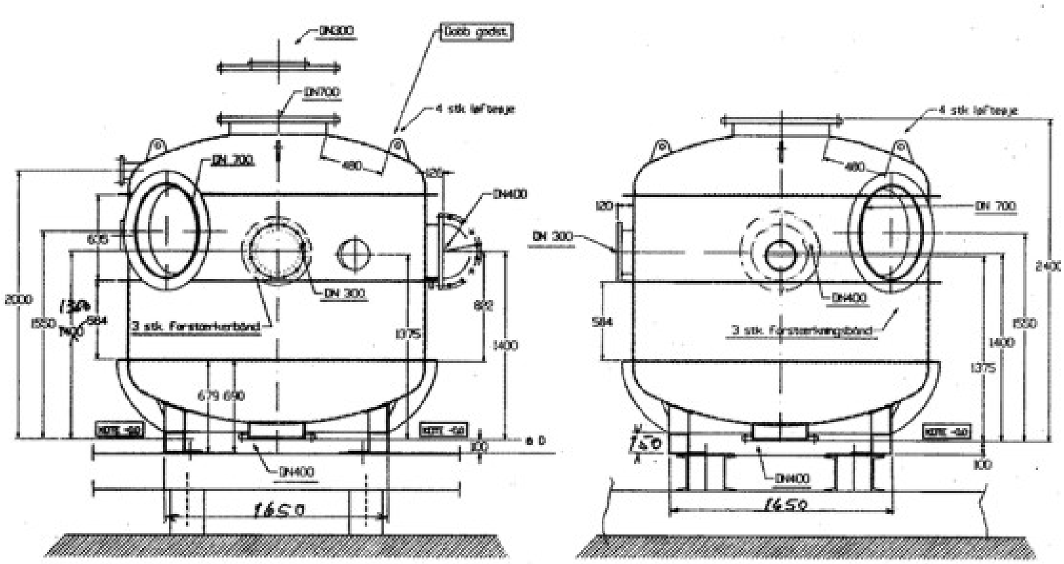
The various methods are all implemented in the commercial program Abaqus that will be used for analysis. The numerical studies and theoretical work can be combined with simple or more advanced laboratory tests to verify or falsify the various models.

Contact person: Lars V. Andersen

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

Bøttefundamentets styrke- og deformationsegenskaber ved cyklisk belastning

Purpose: De kræfter der virker på vindmøller, transient og cykliske i natur, giver anledning til elastiske oscillationer og muligvis til liquefaction af sandet inde i bøtten. Sådan sand liquefaction vil sandsynligvis føre til fuldstændige bæreevnesvigt, hvorfor liquefaction skal undgås.



Main activities: Forholdene, der kan føre til sådanne tilstande, skal undersøges og fastlægges ved eksperimenter. En forsøgstank indeholdende faciliteter til udlejring af jorden samt mulighed for statisk og transient og cyklisk belastning er udviklet i dette forår ved laboratoriet for fundering, Aalborg Universitet, se figuren. Tanken ønskes gennem dette projekt at blive gjort fuld operationel. Tankens belastningssystem er opbygget således, at det kan benyttes til cykliske udmattelsesforsøg. Herved kan risikoen for liquefaction undersøges:

Resultaterne af disse forsøg sammenholdes med resultaterne fra de statiske forsøg. Herved kan det evalueres, om den varierende belastning har indflydelse på fundamentets bæreevne, stivhed samt plastiske deformationer.
Den elastiske opførsel under cyklisk belastning er vigtig for interaktionen med tårnet, og dette skal kortlægges ved hjælp af eksperimenter, analyse og beregning på baggrund af elasticitetsteori udfra de udførte forsøg noget til sidst.

Contact person: Lars Bo Ibsen

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

Bøttefundamentets styrke- og deformationsegenskaber ved installation i ler

Purpose: 3-D numerisk simulering af forskellige typer af bøttefundamenter installeret i ler foretages. Deres anvendelighed til offshore vindmøller undersøges med henblik på forståelse af deres opførsel under normale og ekstreme laster når den funderes i ler.

Main activities: Resultater fra en række modelforsøg (fra afsluttet afgangsprojekt) skal simuleres numerisk og sammenlignes med resultater fra analytiske modeller. I de numeriske simuleringer vil der blive arbejdet med en avanceret konstitutiv model for jorden, Single Hardening modellen, og det tilsigtes at jord/struktur behandles så realistisk som muligt. Denne model er implementeret i det kommercielle finite element program 3D PLAXIS som eksternt defineret materialemodel. Materialeparametre findes fra triaksialforsøg udført på jordprøver fra de relevante offshore lokaliteter og fra kalibrerede CPT-forsøg udført ved siden af borehullerne.

De simulerede bøttefundamentforsøg er de ovenfor beskrevne modelforsøg og de forsøg. Disse inkluderer udrænede forsøg, i hvilke bøtterne er påvirket af moment, horisontale og vertikale kræfter. De numeriske analyser er i stand til at simulere ændringen i størrelse og form af brudfladen i H-M/D planet, svarende til de eksperimentelle observationer.

Contact person: Lars Bo Ibsen

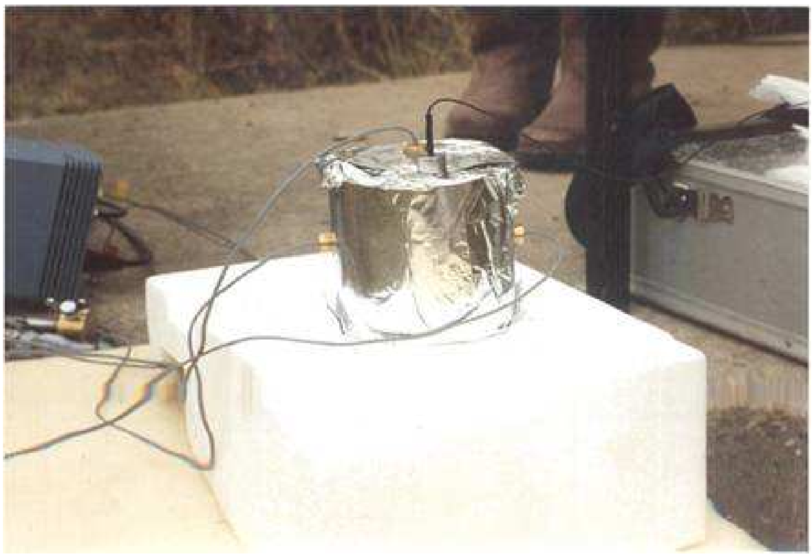
Theory: ☒☒☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☐

Bender elements for the measurement of soil stiffness

Purpose: Using Bender elements to determine the dynamic elastic shear modulus Gmax, for soils.

The measurement of soil stiffness is of great importance to geotechnical design. Especially for analysing and designing constructions such as wind turbines the soil stiffness is a key-parameter.

Resent research have provided dynamic methods for the measurement of soil stiffness at very small strains using piezo-ceramic plates called bender elements.



Main activities: The project can include:

- Getting to know bender elements
- Gathering and analysis of current design material
- Determination of focus areas
- Laboratory tests and theoretical assessment
- Computational modelling
- Design model creation.

Part of the project may be carried out together with geotechnical firms taking soil samples and making input for actual design problems.

Contact persons: Benjaminn Nordahl Nielsen and Lars Bo Ibsen

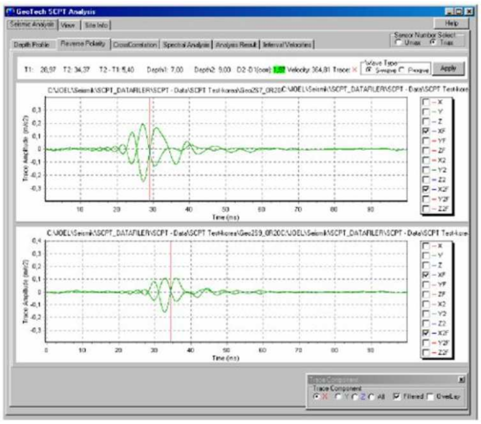
Theory: ☒☒☐ **Experimental work:** ☒☒☒ **Computer modelling:** ☒☐☐

SCPT - Seismic CPT

Purpose: For onshore and offshore constructions there is a growing need for analysing and determination of the elastic soil parameters.

With the seismic CPT adapter mounted on the CPT probe it is possible to carry out CPT and seismic test during the same penetration.

Best practice is needed to be carried out.



Main activities: The project is open with concern to the problem to be analysed. However the focus is on field testing. The project may include:

- Getting to know SCPT – seismic CPT
- Gathering and analysis of current design material
- Determination of focus areas
- Field tests
- Theoretical assessment
- Computational modelling of SCPT.

The project can include experimental field testing on different locations in Denmark togheter with geotechnical engineering firms.

Contact persons: Benjaminn Nordahl Nielsen and Lars Bo Ibsen

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

Light Weight Deflectometer

Purpose: The Light Weight Deflectometer offers measuring of the bearing capacity for subsoil and foundation layers directly in the field.

Currently the equipment used is isotope measuring using radioactive sources with is not especially environmental friendly and safe. The LWD gives at direct output for the soil stiffness, however no systematic use for design and analysing have been setup.

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

- Getting to know Light Weight Deflectometer
- Gathering and analysis of current design material
- Determination of focus areas
- Field and laboratory Tests
- Theoretical assessment
- Design model creation / best practise.

The project may be carried out as engineering practice, and it may be possible to perform experimental tests together with Grontmij/Pavement who have introduced the equipment on the Danish market.

Contact persons: Benjaminn Nordahl Nielsen and Lars Bo Ibsen

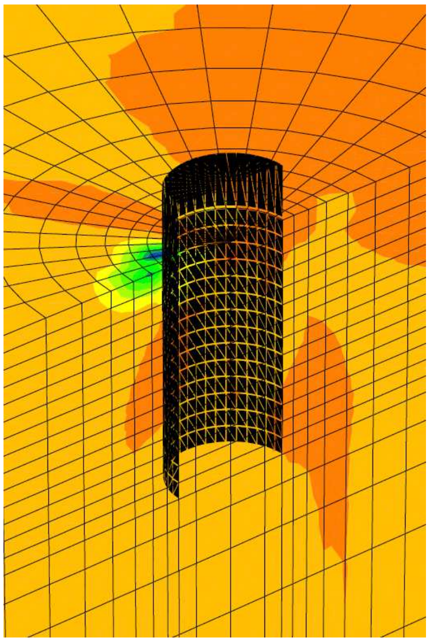
Theory: ☒☒☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☐☐

Offshore Wind Turbine Foundations: Numerical evaluation of *p-y* and *p-Q* curves for piles in sand

A project in cooperation with

Purpose: The interactions between soil and laterally loaded piles are typically accounted for by use of *p-y* curves. A *p-y* curve defines the relationship *p*(*y*) between the soil resistance *p* arising from the non-uniform stress field surrounding the pile mobilised in response to the lateral pile displacement *y*, at any point along the pile. The *p-y* curves adopt the Winkler approach by uncoupling the response of various layers in the soil and can therefore easily include effects of non-linearity, soil layering and other soil properties.

Currently, *p-y* curves represent the state-of-the-art for design of monopiles in the offshore wind industry. However, the currently used p-y curves are clearly inadequate. Firstly, the current stiffness-formulation does not include diameter effects. This is of great importance since pile stiffness for often becomes the primary design driver for offshore wind turbine foundations. Secondly, the resistance of the pile toe is not considered in the current *p-y* methodology. Simple analytical considerations indicate that the ultimate moment resistance of a stiff monopile may increase by 25% if the pile toe resistance is included. Thus, the main emphasis of this project is to numerically evaluate diameter effects of p-y stiffness and evaluate the pile toe resistance in terms of *p-Q* curves.



Main activities:

- Develop a 3D finite element model of a monopile in PLAXIS (or ABAQUS).
- Calibrate constitutive behaviour to simulate Aalborg University Sand no. 1.
- Verify model by comparison to small-scale model tests performed in the pressure tank. (note: the scope of work does not include the model testing)
- Use numerical model to evaluate representative *p-y* and *p-Q* curves.

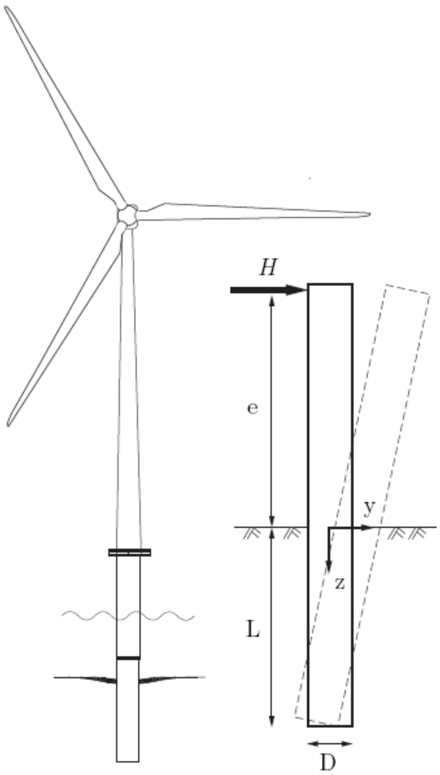
Contact persons: Lars Bo Ibsen

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

Offshore Wind Turbine Foundations: Response of Stiff Piles to Long-term Cyclic Loading

A project in cooperation with

Purpose: There are several foundation concepts for offshore wind farms. Most current foundations are monopiles, which are stiff piles with large diameters, installed 20 m to 30 m into the seabed. The design of monopiles relies on standards and empirical data originating from the offshore oil and gas sector. However, the loading of an offshore wind turbine is very different in both magnitude and character to oil and gas installations. It is characteristic for offshore wind turbines that the sub-structure will be subjected to strong cyclic loading, originating from the wind and wave loads. This leads to accumulated rotation of the wind turbine tower, adversely affecting its ultimate strength or fatigue life. The long-term movements of the foundation may significantly impact all parts of the wind turbine, including the support structure, machine components and blades. Therefore, it is of great importance to investigate the effects of cyclic loading.



Series of laboratory tests shall be conducted using the pressure tank at AAU. The model tests must be conducted on a stiff pile installed in saturated sand and subjected to between 100 and 1000 cycles of combined moment and horizontal loading. A typical design for an offshore wind turbine monopile should be used as a basis for the study, to ensure that pile dimensions and loading ranges are realistic. A non-dimensional framework for stiff piles in sand must be applied to interpret the test results.

Main activities:

- A series of laboratory tests should be conducted on stiff piles in the pressure tank at AAU.
- Results should be used to develop methods assessing the change in stiffness and the accumulated rotation of a stiff pile due to long-term cyclic loading.

Contact persons: Lars Bo Ibsen

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

Advanced probabilistic geotechnical site assessment for offshore wind farms

Purpose: Ved opførelse af store vindmølleparker til havs udgør funderingen ikke kun en betragtelig del at anlægsudgiften 25 - 35%, men er også den del af projektet, der indeholder de største usikkerheder. For at reducere disse usikkerheder foretages et omfattende geotekniske undersøgelsesprogram, hvilket kræver en stor investering tidligt i projektforløbet. Kravet til minimering af fundamenternes deformationer gør, at det altid er anvendelsesgrænsetilstanden, der bliver dimensionsgivende, dvs. at de elastiske parametre styrer designet. Ved in-situ forsøgene bestemmes de plastiske materialeparametre, der anvendes til brudanalyse, med stor nøjagtighed, mens de elastiske parametre bestemmes med stor usikkerhed. Der er derfor i dag en konflikt mellem de parametre, der driver designet, og det man får ud af de udførte in-situ forsøg. Fokuset er i dag forkert og bør drejes mod en bedre bestemmelse af de elastiske parametre. Dette projekt fokuserer på at udvikle en in-situ test metode, der sikre bedre bestemmelse af de elastiske designparametre. Ideen er at udvikle en "intelligent sandsynlighedsbaseret teststrategi", der kombinerer informationen, som er indhentet ved seismiske undersøgelser, med in-situ forsøg i form af "Seismic Cone Penetration Test". Herved kan de elastiske parametre fastlægges med stor nøjagtighed. Dette vil resultere i mere økonomiske funderingsløsninger idet de elastiske parametre i dag fastlægges alt for konservativt - dermed overdimensionerede fundamenter. Samtidigt forventes den nye teststrategi, at bidrage til en reduktion af det nødvendige antal in-situ målinger, hvorved den samlede omkostning til fundering af havbaserede vindmøller kan reduceres markant.

Main activities: Med projektets mål for øje vil forskningen fokusere på følgende:

- Udvikle og teste SCPTu målemetoder.
- Formulerer en metode til tolkning af SCPTu forsøgene. Tolkningen skal sikre pålidelig fastsættelse af både de elastiske og plastiske materialeparametre.
- Udvikle en metode der kan beskrives de målte parametre som stokastiske variabler og fastlægge variationen med dybden.
- Tilvejebringe tilstrækkeligt statistisk grundlag for at kunne udtale sig om variationen af materiale- parametre i horisontal retning.
- Formulering og opstilling af den sandsynlighedsbaserede teststrategi.

Dette projekt kan også gennemføres i relation til motorvejsbyggeri hvor samarbejdspartnerne vil være Vejdirektoratet.

Contact person: Lars Bo Ibsen

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

Improved FEM-modelling of non-associated plasticity

Purpose: The most common material model for soils is the Mohr-Coulomb model where the soil strength is controlled by the cohesion strength and the friction angle. The deformation during plastic flow is controlled by the dilation angle. When the model is associated, i.e. friction angle = dilation angle, reliable calculation methods are abundant both in the elasto-plastic as well as the rigid-plastic case. Experimental observations, however, predicts that the dilation angle should be much lower (often ~30°) than the friction angle. Unfortunately this causes a lot of computational problems. Random errors seem to occur and simulations break down.

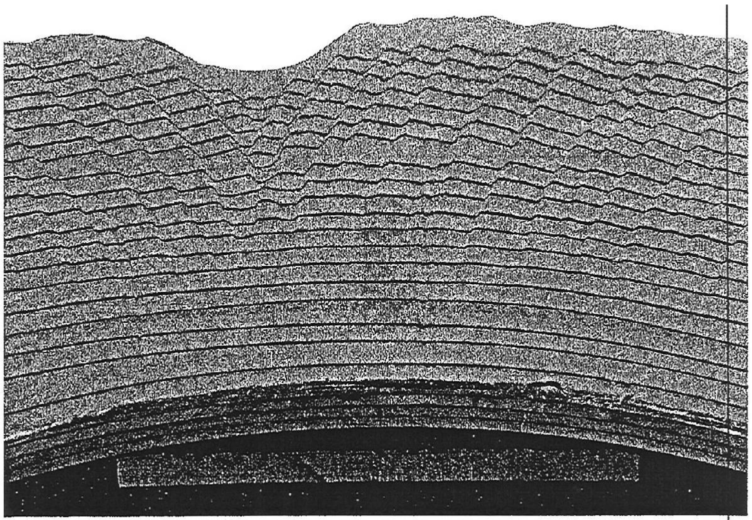


Fig. 8.2 Crestal faults over arch of uniform curvature, simulated in a sand box (Mandl, 1984).

In this project the goal is to examine how we should model non-associated soil behaviour with the finite element method. The different result of different methods could be quantified using simple benchmark calculations, e.g. a surface footing or a sheet pile wall. This project will involve a considerable amount of MatLab-programming.

Examples of main activities:

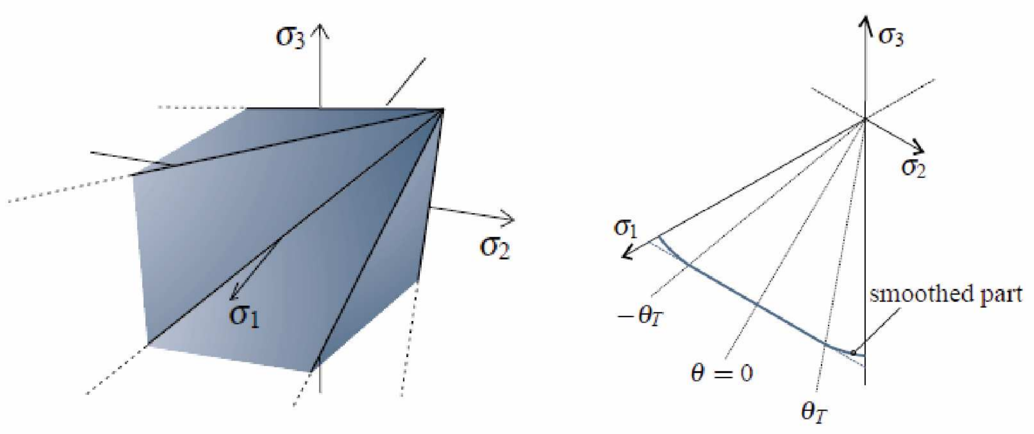
- What are the symptoms of non-associated problems? A computational and literature review.
- What do the commercial codes do (e.g. Abaqus, Plaxis, Ansys)?
- Do we have other methods of remediating the problem?
- Quantification of different results with different methods using own MatLab code

Contact person: Johan Clausen

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

Implementation of a plasticity model into the finite element method 1: Rounded Mohr-Coulomb

Purpose: The most often used material model for geotechnical materials is the Mohr-Coulomb material model. For calculation involving more than very simple geometries the finite element method is used for obtaining the solutions to the arising boundary value problems (i.e. load-displacement curves, bearing capacities, etc.). Originally the corners and the apex of the Mohr-Coulomb yield surface caused problems in the numerical implementation, so an approximate yield surface with smoothed, or rounded, corners were used. Today methods for implementing the corners explicitly exist, but the use of the rounded surfaces is still widespread. The implications of using these approximations, however, are not documented in literature.



Main activities: Different models for smoothing the Mohr-Coulomb model should be implemented, and maybe also as a user programmable material in Abaqus. Then the implications of using these approximate models should be quantified and compared to the exact Mohr-Coulomb material model. Both with respect to accuracy, computation time and number of iterations. The approximate models may perform better than the exact model in some parameters and poorer in others.

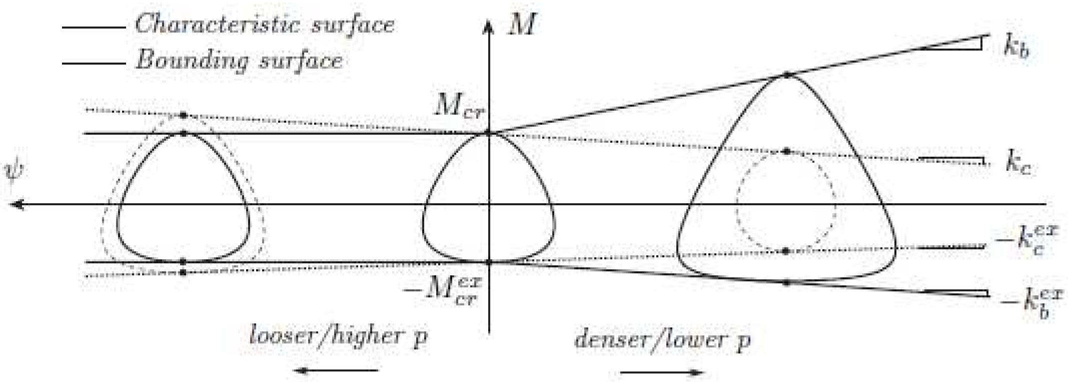
An interest in programming, e.g. MatLab, is essential.

Contact person: Johan Clausen

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

Implementation of a plasticity model into the finite element method 2: A two-surface model for cyclic loading on sand

Purpose: For strength calculations the Mohr-Coulomb criterion is often a sufficient material model for soils. If a more precise calculation of the deformation is needed then the simple linearly elastic – perfectly plastic Mohr-Coulomb model is not adequate. This is especially true if the loading is not monotonic or even cyclic. Offshore structures are subjected to time varying loads from wind and waves which means that their foundation will experience cyclic loading. At the same time the allowable deformation is small which means that it is often this criterion rather than the soil strength that governs the foundation design. For these reasons many advanced material models for soils have been developed. If such an advanced model is to be used in practical calculations it must be implemented in a numerical method, e.g. the finite element method. Different types of stress update schemes can be examined.



Main activities: The main activity of the project would be to implement a specific material model into a finite element program, which would make it possible to simulate soil structures with cyclic loading.

An interest in programming, e.g. MatLab, is essential.

Contact person: Johan Clausen, Lars Bo Ibsen

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

Implementation of a plasticity model into the finite element method 3: The Plaxis Hardening Soil model

Purpose: For strength calculations the Mohr-Coulomb criterion is often a sufficient material model for soils. If a more precise calculation of the deformation is needed then the simple linearly elastic – perfectly plastic Mohr-Coulomb model is not adequate. For this reason various advanced constitutive models for soils have been developed over time, with the aim of correctly modelling the total stress-strain path of the soil, in order to be able to accurately predict the displacement of geotechnical structures in the service limit state. Probably the most popular advanced soil model for practical use is the so-called Hardening Soil model. Its popularity is probably due to two reasons: 1) It is available in the popular geotechnical software Plaxis 2) the model parameters include the Mohr-Coulomb parameters together with some stiffness parameters which are fairly easy to obtain from laboratory testing. As of yet the model is not available in other software codes. Therefore the goal of this project is to implement the hardening soil model in an in-house finite element code and possibly export it as a user material into Abaqus.

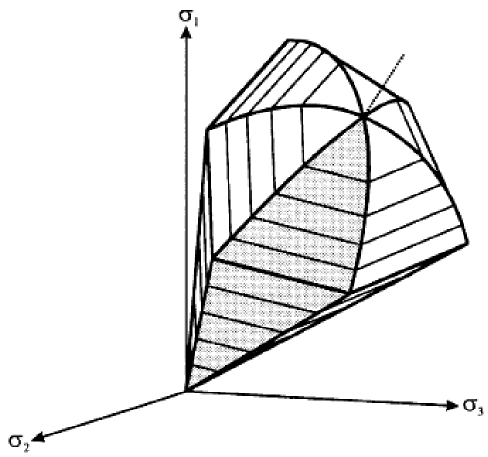


Figure 3. Representation of total yield contour of the Hardening-Soil model in principal stress space for cohesionless soil.

Main activities: The main activity of the project would be to study and implement the Hardening Soil model into a finite element program, and compare results with e.g. results from Plaxis.

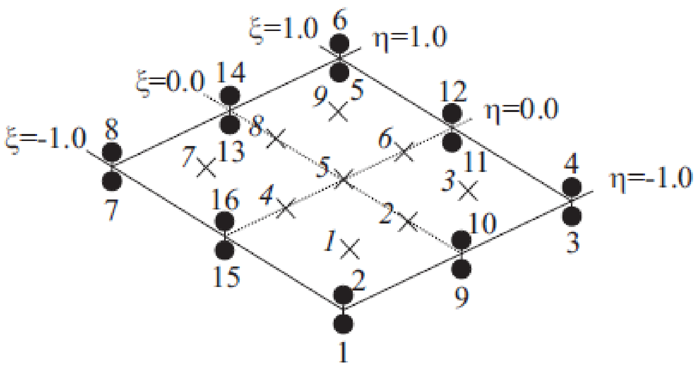
An interest in programming, e.g. MatLab, is essential.

Contact person: Johan Clausen

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

Implementation of interface friction finite elements

Purpose: When designing geotechnical structures the interaction between the soil and the structures, e.g. footings or walls can have a significant impact on the displacement and strength on the overall structure. The interaction can consist of both adhesion and friction. In finite element analyses the interaction can be modelled with so-called interface elements, as it is seen in e.g. the commercial code Plaxis, from the manual of which, the figure below is taken. Several methods of implementing interaction elements exist. The goal of this project is to implement interaction elements in a finite element code in MatLab.



Local numbering and positioning of nodes (•) and integration points (x) of a 16-node interface element

Main activities: Firstly a litterature study on interface finite elements should be carried out. Then one or more types of interface elements should be implemented into a finite element code. The performance of the elements should be compared to existing solutions, e.g. strip footing bearing capacities, where exact solutions are known for different degrees of footing roughness. Other case studies can be carried out, e.g. quantifying the effect of the degree of roughness of sheet pile walls.

If time permits the work can be extended to three-dimensional finite elements.

Contact person: Johan Clausen

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

Comparison of Finite Element calculations for geotechnical cases

Purpose: Many finite element software packages that are used for geotechnically related computations exist. Some are specialized for geotechnical problems and others are general purpose programs. Even though the initial problem is well defined, e.g. a surface footing on a Mohr-Coulomb soil, different programs can arrive at different solutions for the sought after results, be they stresses, displacements or bearing capacity. This can be due to, for example, variations in the numerical implementation, or different formulations of the material models.

If these variations in the results are significant, it poses a problem for the design engineer who relies on the solutions of the chosen software: What is the correct solution?

The idea of this project is to examine the variations between different tools for solving geotechnical problems, both qualitatively and quantitatively.

Main activities: One or more geotechnical calculation cases should be chosen. Ideally one of them with a known solution to which numerical results can be compared. Then the problems are modelled using different numerical tools, of which some relevant examples can be seen in the above figure. Inhouse codes, e.g. written in MatLab, can also be used. The calculation cases should range from a simple bearing capacity calculation to some problems with higher complexity according to the interest of the student and capabilities of the chosen software packages. Examples are: Advanced constitutive models, seepage, consolidation, interface elements, staged construction, slope stability.

Contact person: Johan Clausen

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

Structural design of buried pipelines

Purpose: The purpose is to study the design procedure for buried pipelines in pumping systems for water transport (potable water and waste water). The loads include both internal pressure variations because of internal water transients (see figure 3) and external water and soil pressure. The hypothesis is that the design in this area is much more conservative than necessarily because of the complexity of the issue. Significant cost reduction can be expected if the design criteria are changed to build on the basic properties of the materials in combination with modern computer simulations in order to leave the present “rule of thumbs design”. Actually, a large number of pipelines are under planning and design in Denmark and Europe.

Figure 1 .Failure because of high pressure

Figure 2. Collapse because of low internal pressure and soil pres.

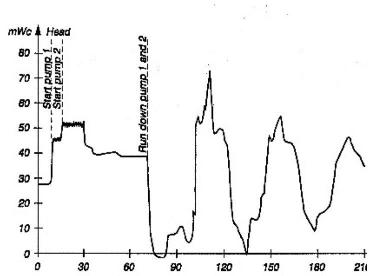


Figure 3. Example of internal pressure variations during pump run-up and pump run-down

Main activities: The project will take inspiration from the actual design of number pumping mains for the transport of wastewater in Mariagerfjord Municipality where the largest pipeline is 16 km long and has a diameter of 800 mm**.**

Examples of planed activities:

- Study of the design criteria for plastic pipelines
- Experimental and numerical modelling of fatigue caused by long term cyclic loads from water hammer in plastic pipelines (e.g. PE polyethylene pipes as seen on figure 2)
- FEM-modelling of plastic pipelines with loads of soil and water pressure
- More to come.

Contact persons: Johan Clausen, Torben Larsen

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

Reliability assessment of existing and temporary structures

Generally reliability requirements and partial safety factors are related to permanent structures, e.g. with a design lifetime equal to 50 years. This is for example the case in the Eurocodes. For existing structures and for temporary structures, e.g. structures during execution and structures only used for a short time interval, no design requirements can generally be found in the codes, but are highly demanded by industry.

Both for existing and temporary structures it is sometimes argued, that the reliability level could be chosen lower than for permanent structures. But is that reasonable - e.g. for structures where people can be in danger in case of failure? And if the reliability level in some cases can de lowered, how much can the partial safety factors be decreased?

For existing structures, e.g. concrete bridges, information will often be available, e.g. in the form of measured concrete compression strengths of test samples, measured traffic loads, ... How can such information be used to assess the reliability of the structure, and eventually decrease the partial safety factors?

Main activities:

- Collect information from literature on assessment of reliability of temporary and existing structures
- Assess and describe methods to obtain the minimum reliability level using risk and reliability-based principles:
    - cost-benefit analyses: minimize lifecycle total expected costs
    - LQI (Life Quality Index) principles: requirements by society
- Transformation of reliability level to 'reduced' partial safety factors and/or reduced characteristic loads.
- Select one or more illustrative structures (an existing structure and/or a temporary structure), and for the selected structure(s):
    - Stochastic modelling of loads and strengths
    - Assessment of minimum reliability level to be required
    - Estimation of evt. reduced partial safety factors

Contact persons: John Dalsgaard Sørensen

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

Reliability and Risk analysis of Wind Turbines – Planning of Operation & Maintenance

Costs to operation and maintenance (O&M) of offshore wind turbines are large, typically more than 25% of the cost of energy. Recent experiences from offshore wind farms indicate even larger costs. The costs consist of planned maintenance and corrective maintenance due to failure of components such as gearboxes, electrical components, blades, corrosion 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.

The purpose of this project is to apply risk based techniques and Bayesian statistical methods for planning of O&M activities in practical applications (in cooperation with a wind farm operator, see below) incl. modelling of costs and risks in connection with O&M for offshore wind turbines. Further, the aim is to compare different O&M strategies considering a typical wind farm for a limited, but representative application area for O&M.

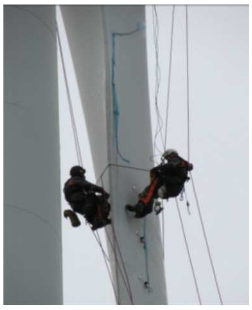
Main activities:

- Literature survey to give an overview of different methods for O&M planning
- Based on examples from other industrial areas (oil&gas) develop / describe how a Bayesian, risk-based approach can be used for O&M planning
- Illustrative example studies considering O&M for a limited number of components for a typical wind farm

The project will be connected to ongoing research projects.
Industrial cooperation: Vattenfall.

Contact person: John Dalsgaard Sørensen

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



Project Proposals in Wind Turbine Mechanics and Optimal Vibration Control

A number of project proposals are available in this area:

1. Dynamic Reliability Analysis and Determination of Design Criteria of Wind Turbines based on the Probability Density Evolution Method
2. Three Dimensional Turbulence Modeling for Wind Turbines based on Rapid Distortion Theory and the Evolutionary Phase Model
3. Stochastic Aeoelastic Stability of Wind Turbines based on the Top Lyapunov Exponent
4. Influence of the Geometric Non-linearities and Non-conservative loads (follower forces) on the Aerodynamic stability of Wind Turbines
5. Semi-active Pitch Control of Wind Turbines against Dynamic Stall based on Partial State Observation
6. Semi-active and Active Vibration Control of Edge-wise Vibrations of Wind Turbine Blades
7. Optimal Non-linear Stochastic Control of a Cluster of Wave Energy Point Absorbers in Irregular Sea-states

A part of the projects may be carried out abroad as secondment to universities in China (Tongji University, Shanghai), Norway (NTNU) or Ireland (Trinity College Dublin).

Contact person: Søren R.K. Nielsen

Design and control of a vertical-axis wind converter

Purpose: The most common type of wind turbines today is the three-bladed horizontal-axis wind converter (HAWC). This type of converter is typically twice as efficient in converting wind power into electricity as its counterpart, the vertical-axis wind converter (VAWC). However, the VAWC has the advantage that it may be a simpler and more economic design than the HAWC. Further, by using a double airfoil combined with pitch regulation of the blades on a VAWC, the efficiency may be improved. The double airfoil introduced at jet stream of air though the blade that controls the airflow such that the blade does not stall easily. Combined with the pitch regulation this can be used to increase the lift coefficient and thereby the power production. The aim of the project is to design a control system for an existing VAWC to optimise power output.

Main activities: Some of the activities within this project may be:

- Literature study of aeroelasticity, especially regarding VAWCs
- Literature study of control algorithms
- Determination of parameters for the VAWC
- Analysis of the dynamics of the VAWC, possibly using a finite-element model
- Design of control algorithm for pitch regulation
- Implementation of control algorithm in Simulink.

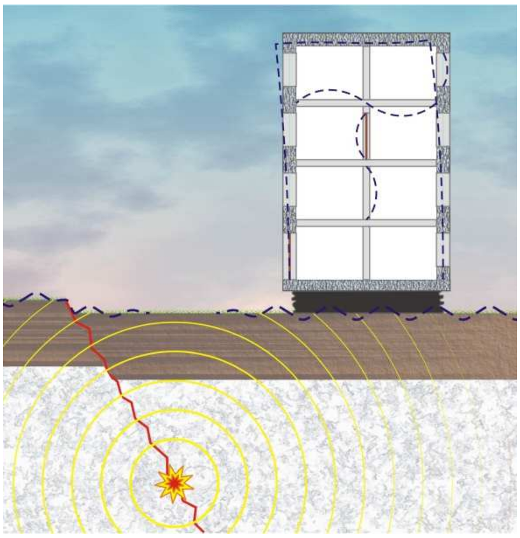
The final goal may be to prove that the control system works for a real VAWC.

Contact person: Lars V. Andersen and Søren R.K. Nielsen

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

Nonlinear analysis of earthquake-induced vibrations

Purpose: Earthquakes are a source to vibrations of large magnitude, each year causing damage to building structures in many regions of the world, often resulting in human casualties. Earthquakes cannot be prevented, but a proper design of a structure may reduce the risk of fatal damage significantly.



Usually, building design is accomplished based on codes of practice and static (or quasi-static) analysis. However, vibration in a building is dynamic by nature, and to fully describe the structural behaviour, time-domain analysis of the building response is necessary. The idea of the present project is to use a finite element model for analysis of a building in order to investigate the occurrence and possible accumulation of damage in a steel or concrete structure during an earthquake. For this purpose, a nonlinear dynamic finite element analysis is carried out.

Main activities: The analysis may be carried out by means of a complex three-dimensional model, utilising a commercial finite-element code such as Abaqus. Alternatively, a simpler two or three-dimensional building may be analysed by a Matlab code developed as part of the project. The main activities may include:

- Literature study of earthquake engineering
- Literature study of nonlinear dynamic finite-element analysis
- Literature study of material behaviour in cyclic response
- Finite-element modelling of a building, possibly including the subsoil
- Formulation of a constitutive model for damage in concrete or steel
- Coding of a nonlinear dynamic solution algorithm in a finite element code
- Parameter studies regarding structural design and material properties
- Design of a building to mitigate damage
- Comparison of finite-element based building design with code-based design.

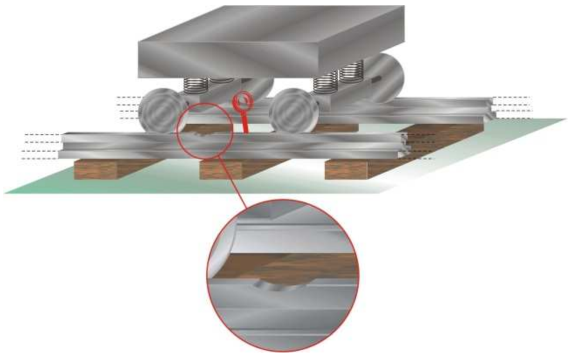
Contact person: Lars V. Andersen and Johan Clausen

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

Traffic induced vibrations

Purpose: Traffic on roads and railways is a source to vibrations that may be a nuisance to people in the built environment. Current design regulations provide limited information about design criteria, and valid models for prediction of vibration levels are generally not available. Usually, vibration levels are measured on “similar” roads or railway tracks, and in similar building structures, and an empirical model is employed for prediction of vibrations in a new building project.

Hence, there is a general need for better prediction tools, and in this project the idea is to develop a method based on computer modelling. The model should include the vehicle, the track or road structure, the subsoil and the building. Focus of the project will be to determine the significance of different parameters, e.g., soil properties, vehicle type, building material or road irregularity, on the vibration levels observed by people in a building.



Main activities: The coupled model consisting of vehicle, track, subsoil and building can be made in a commercial finite-element analysis program (e.g., Abaqus) or, preferably, a Matlab code may be developed for the purpose. In either case, the following items will be part of the project work:

- Literature study of vehicle dynamics
- Literature study of wave propagation in tracks, soil and building structures
- Numerical modelling of vibration transmission through the rails and subsoil
- Modelling of a lorry, bus or train as a multi-degree-of-freedom system
- Modelling of road or track surface irregularities
- Parameter studies for various vehicles, tracks, soils and/or buildings.

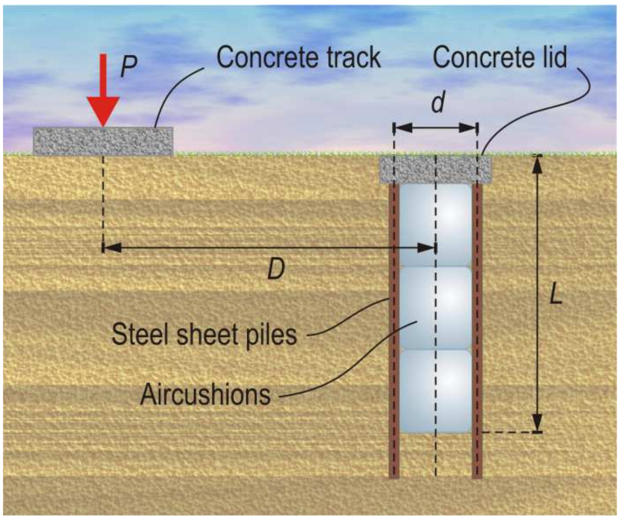
A final goal may be the development of a program for evaluation of vibration levels in building next to a heavily trafficked road or railway.

Contact person: Lars V. Andersen

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

Vibration mitigation in civil engineering problems

Purpose: Sources to vibration cannot be avoided in the built environment. For example, traffic and heavy machinery may cause vibrations that can be transported over long distances through the soil. This is a nuisance to people in residential buildings as well as people working in offices or production facilities. A special problem concerns laboratory, hospitals and concert halls, where only a very small vibration level can be tolerated. To mitigate vibrations caused by external sources, a wave barrier may be introduced. A classical solution is to put an open trench between the source and receiver, but more sophisticated solutions have been proposed. As illustrated on the right, this includes aircushions that maintain the high efficiency of an open trench but keep the soil from collapsing and people, rain and objects from falling into the trench.



Several other possibilities exist, such as soil improvement by grouting or pile installation. Even "intelligent landscaping" has been suggested as a means of reducing vibration levels in the new MAX4 test centre near Lund in Sweden. The idea of the project is to investigate and optimize one or more methods of vibration mitigation and suggest materials, techniques or structures that can be used for dynamic isolation of buildings.

Main activities: Focus of the project may be development of a particular kind of wave barrier, or the problems related to vibration mitigation can be approached in a more general way. The activities of the project may include:

- Literature study of soil dynamics and wave propagation theory
- Numerical analysis of wave propagation in soil
- Optimal design of a wave barrier or wave impeding material
- Mitigation of wave propagation by intelligent landscaping or soil improvement
- Experimental analysis of a wave barrier.

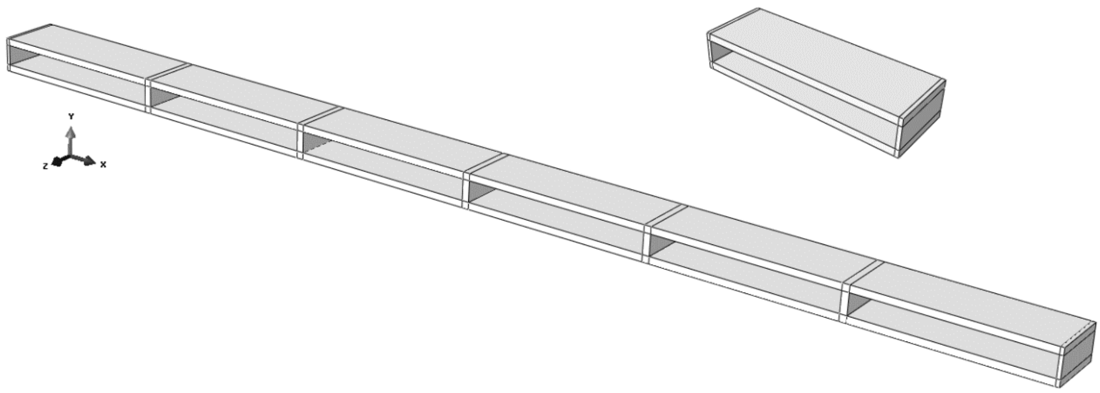
The workload related to theoretical investigations, experimental work and computer modelling may vary depending on the weight put on each item.

Contact person: Lars V. Andersen

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

Modelling and dynamic analysis of periodic structures

Purpose: In a periodic structure, the same geometry is repeated a number of times as illustrated below, where six identical cells are connected to form a beam. Such structures occur in many civil and structural engineering problems. For example, joists and studs are usually placed in a periodic manner in a wooden floor or wall panels, and tunnels may consist of a number of identical segments connected by gaskets at the joints. However, periodicity may also be introduced into structures that are usually not periodic, e.g., by placing additional masses or springs in a periodic manner. This may be beneficial, since periodicity within a structure has a documented effect on vibration transmission. Thus, so-called stop bands will form, in which wave propagation is attenuated dramatically. In a building structure, this can be utilized to avoid transmission of vibrations in frequency ranges where, for example, washing machines or elevator motors are known to induce vibrations. Theoretically, the reference cell may be repeated infinitely many times. Analysis of such structures can be carried out by means of Floquet theory which is a generalisation of Fourier theory. This can be combined with the finite-element method to establish models of railway tunnels, long wall panels, pipelined etc.



Main activities: The following items may be part of the project work:

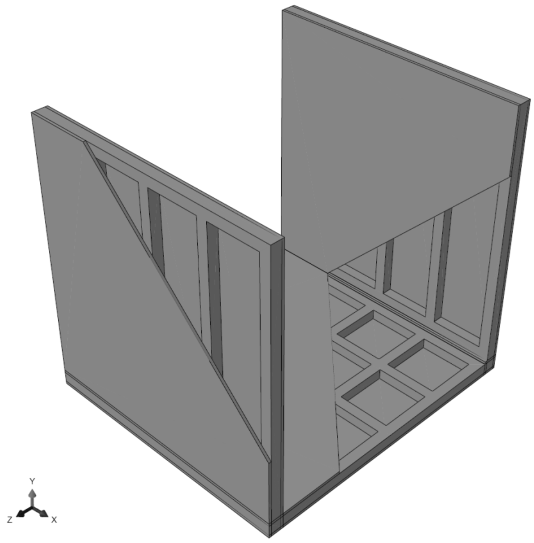
- Literature study of wave propagation in periodic structures
- Numerical modelling of a periodic structure (e.g., a tunnel, panel, or pipeline)
- Analysis of a periodic structure by means of Floquet theory
- Combination of finite-element analysis with Floquet theory
- Experimental analysis of wave propagation in a periodic structure
- Optimization of a periodic structure to minimize vibration transmission in a predefined range of frequencies.

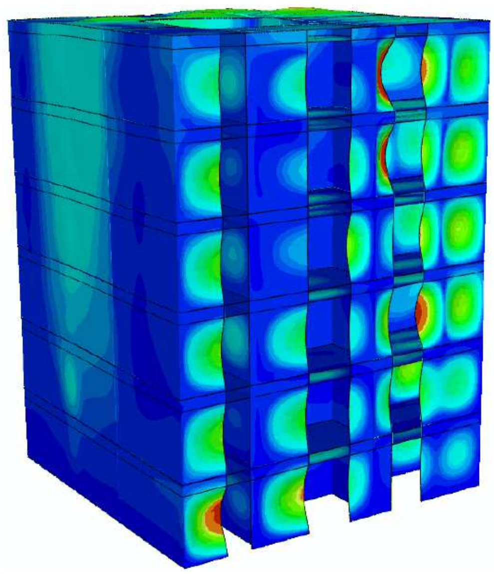
Contact person: Lars V. Andersen

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

Noise and vibrations in lightweight building structures

Purpose: Walls and floors in lightweight timber structures are usually constructed as wooden panels. Depending on the geometry, material properties and boundary conditions, such panels may resonate at different frequencies within the audible range, leading to emission of noise. Furthermore, the panels may serve as waveguides, transmitting noise from one room to another or between floors. The project may concentrate on a global model for a building—or transmission paths may be studied at a local level, e.g. at a junction between a wall and a floor. Alternatively, the project may focus on an optimized design of wall or floor panels where the studs or joists are placed periodically to minimize noise transmission in the audible range.





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

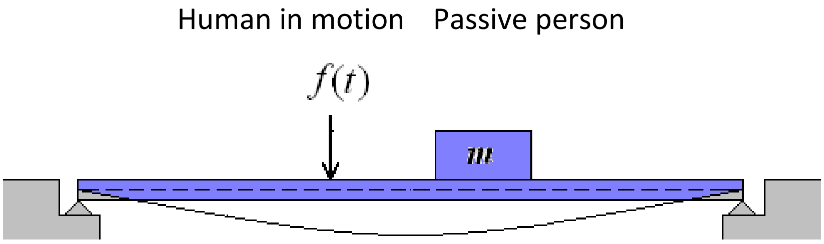
- Literature study of building acoustics
- Formulation of models for dynamic analysis of periodic structures
- Design of joints in building structures for mitigation of noise
- Parameter studies to identify the influence of geometry and material properties on sound transmission in lightweight building structures
- Finite-element modelling of coupled acoustics and structural vibration
- Experimental testing of structural dynamics and acoustics.

Contact person: Lars V. Andersen

Theory: ☒☒☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☐
(The relative weight of experimental work and computer modelling is not fixed)

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.



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

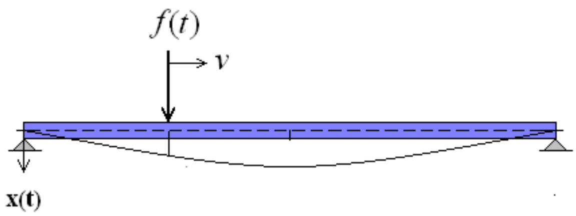
Theory: ☒☐☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☐

Dynamic human loading and stochastic models for estimating structural responses

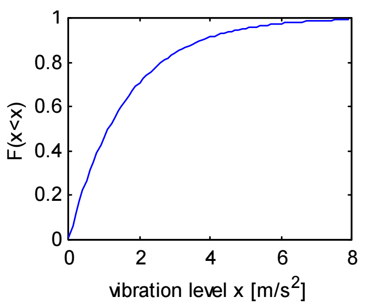
Background: Some civil structures are so slender that their modes of vibration may be excited by the basic frequency of human motion resulting in resonant structural action. The undesired resonant action may for instance occur in footbridges, stadia structures or in open-space office floors as a result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

Structural Health Monitoring of Civil Engineering Structures

Purpose: Structural health monitoring (SHM) is the name of a process of continuously monitoring the states of a structural system, with the aim to *detect*, *localize*, *classify, quantify* and *predict* damages in the structure. Presence of the damage in the structure is directly related to structural performance so it is one the major issues with respect of optimal, cost-efficient and safety operation in a wide range of applications (for example, in the case of bridges, wind turbines, offshore structures, buildings, airplanes and many others). Online monitoring of dynamic responses and loads on a structure can be used for extraction of system parameters that can indicate the presence of faults in the system. Early fault detection allows implementation of predictive operation and maintenance strategies and prevention of complete structural failure.

Main activities: The content and application of the project can be shaped by interests of the candidate. For example, load estimation for monitoring of wind turbine gearbox, fault detection and identification of oil and gas offshore structures/ turbine blades/ grout connections, etc. The main activities that project may/will include are:

- Learning about structural health monitoring methods for the selected application
- Classification of different fault scenarios and recognition of their features
- Data pre-processing and indirect measuring of parameters/ signals for fault detection
- Development of a damage detection algorithm

Part of the project can be carried out together with Ramboll Oil&Gas (http://www.ramboll.com/Oil-Gas) on experimental data measured on offshore platforms.

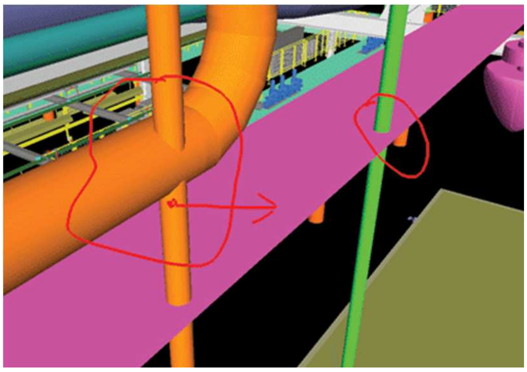
Contact persons: Lars Damkilde

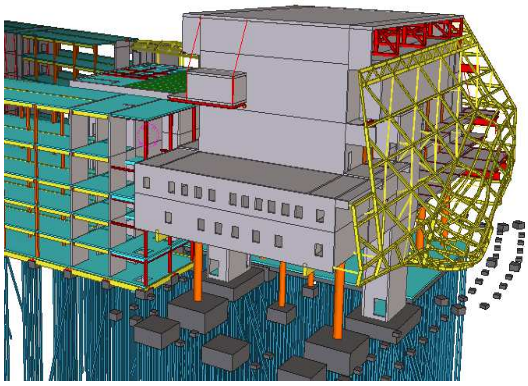
Theory: ☒☒☐ **Experimental work:** ☒☐☐ **Computer modelling:** ☒☒☐

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:** ☒☒☐

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:** ☒☒☐

Finite-element modelling of reinforced concrete

Purpose: Reinforced concrete is widely applied as a construction material in civil engineering. Concrete is a complex material, both chemically and mechanically, and the formulation of material models demands a deep knowledge of the behaviour during casting, curing, utilization and, eventually, degradation. The introduction of reinforcement results in a composite material. In this case, the interaction between the concrete matrix and the steel reinforcement must be accounted for as well.



The idea in this project is to use advanced finite element calculations, e.g. via ABAQUS, to model reinforced concrete. Different methods should be compared, and a comparison with analytical methods should be included. The project may focus on the analysis of a particular problem or structure.

Main activities:

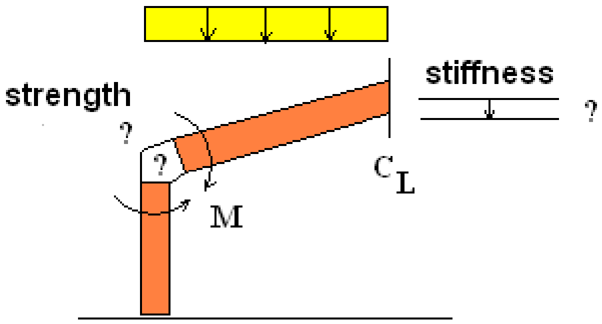
- Formulation of material models for concrete. This can be both built-in models in Abaqus and user-supplied models.
- Modelling of interfaces between concrete and reinforcement
- Finite-element analysis of reinforced concrete structures
- Comparison of FE models with standard design methods.

Contact person: Johan Clausen

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

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

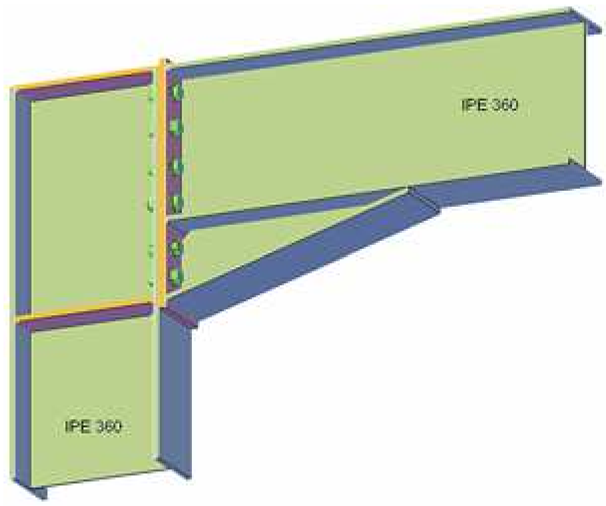
Theory: ☒☒☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☐

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:** ☒☒☐

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 other, 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: In addition to 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.

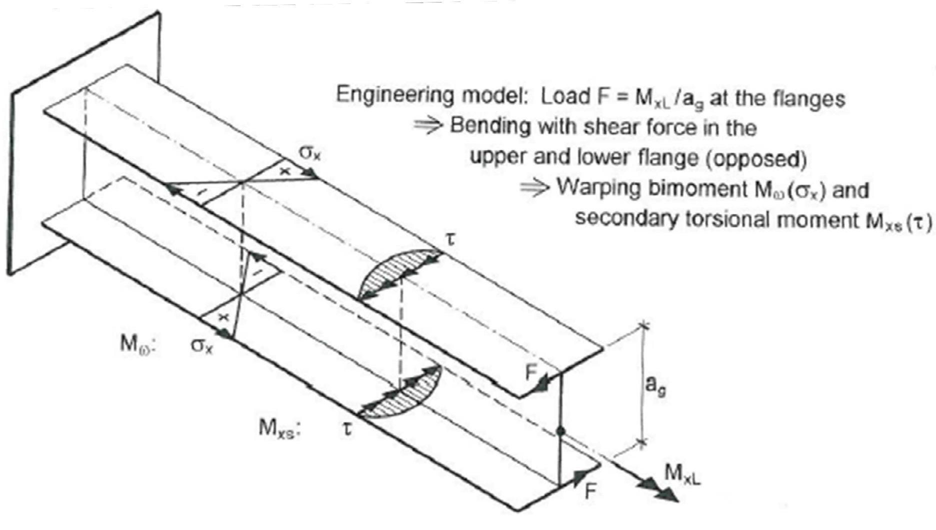
As part of the study it might be useful also to analyse one of the steel frames which recently collapsed due to heavy snow loads.

Contact persons: Lars Pedersen, Johan Clausen

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

Implementation of 3D beam finite elements including warping torsion

Purpose: Many standard implementation of three dimensional beam finite elements only account for the simplest form of torsion, which is called St. Venant's torsion. The part of the torsion that stems from warping of the cross section is then ignored. This approximation can be justified for closed cross sections which present a large warping stiffness, but for open profiles, as the one shown in the figure, the neglection of the warping will result in a gross underestimation of the torsional displacement. The goal of the project is to implement a beam finite element that includes warping torsion.



Explanation of the warping torsion of a cantilever,

Main activities: The initial part of the project would be a study of the concept and equations of torsional displacements in beams. As part of this study it could be examined how commercial finite element codes have implemented 3D beam elements.

The next part of the project is then to program a beam finite element that includes warping torsion. This can be done in MatLab or another language of the students' preference. A simulation of a simple frame structure can then be used as a verification example. An added challenge is then to couple the elements at the frame corners. The results of this analysis can then be compared to the results from commercial codes, and/or more elaborate simulations using shell or solid elements.

If time permits the composed beam element can be extended to solve bifurcation problems e.g. lateral torsional instability (Danish: kipning).

Contact person: Johan Clausen

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

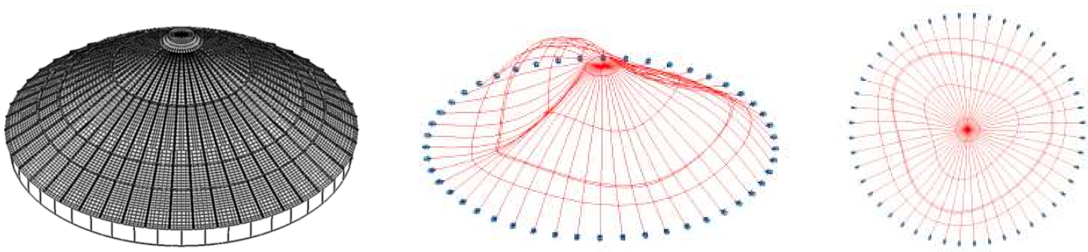
Example of company stay project

Analysis of snow-load-induced damage on conical silo roof

Company: Cowi, Aalborg Office
Company type: Consulting engineering company
Webpage: www.cowi.dk, www.cowi.com
Location: Aalborg

In the winter of 2009/2010 heavy snowfalls occured in Northern Jutland in Denmark. The ensuing large snowloads caused several roof collapses throughout the region. Among these were the several roofs of silos for crop storage. Crop silo structures are typically composed of corrugated steel sheets stiffened by steel profiles.

The company wanted to perform a detailed analysis of these collapses to assess the cause(s), and this was chosen as a project for the student doing the company stay.



The structure was studied by means of finite element analysis, including non-linear effects such as bifurcation buckling, large displacements and plasticity. In addition, different detail levels in the modelling were compared, as was beam and shell models.

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