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M.Sc. in Civil and Structural Engineering

Third Semester and Master Projects Ideas 2015

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Publication date:
2015

Document Version
Publisher's PDF, also known as Version of record

Link to publication from Aalborg University

Citation for published version (APA):
Clausen, J. C. (2015). *M.Sc. in Civil and Structural Engineering: Third Semester and Master Projects Ideas 2015*. Department of Civil Engineering, Aalborg University. DCE Latest News No. 48

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M.Sc. in Civil and Structural Engineering:

Third Semester and Master's Thesis Ideas 2015

Edited by Johan Clausen

ISSN 1901-7308
DCE Latest News No. 48

DEPARTMENT OF CIVIL ENGINEERING
AALBORG UNIVERSITY

Aalborg University
Department of Civil Engineering
School of Engineering and Science

DCE Latest News No. 48

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Edited by

Johan Clausen

June 2015

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Published 2015 by
Aalborg University
Department of Civil Engineering
Sohngaardsholmsvej 57,
DK-9000 Aalborg, Denmark

Printed in Denmark at Aalborg University

ISSN 1901-7308
DCE Latest News No. 48

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 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 a homepage on which they state that they would like to collaborate with students on a master 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
- Rambøll, http://www.student.ramboll.dk/be-part-of-ramboll

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 third semester project the reccomended 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 your study secretary 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/studienaevn/byggeri/studieordninger/. 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/til-studerende-ansatte/blanketter-regler/projekter-specialer/ (Danish version) and http://www.en.ses.aau.dk/students-employees/rules-and-regulations/thesis-contract/ (English version). Via the links you will also find guidelines as how to fill out the study plan. Note that the delivery date for the project report must be between January 1-10 for third semester projects and June 1-10 for Master theses. In the study plan you should state the duration of your project, i.e. the number of ECTS points.

Aalborg, May 12, 2015 Johan Clausen, *semester coordinator*

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.

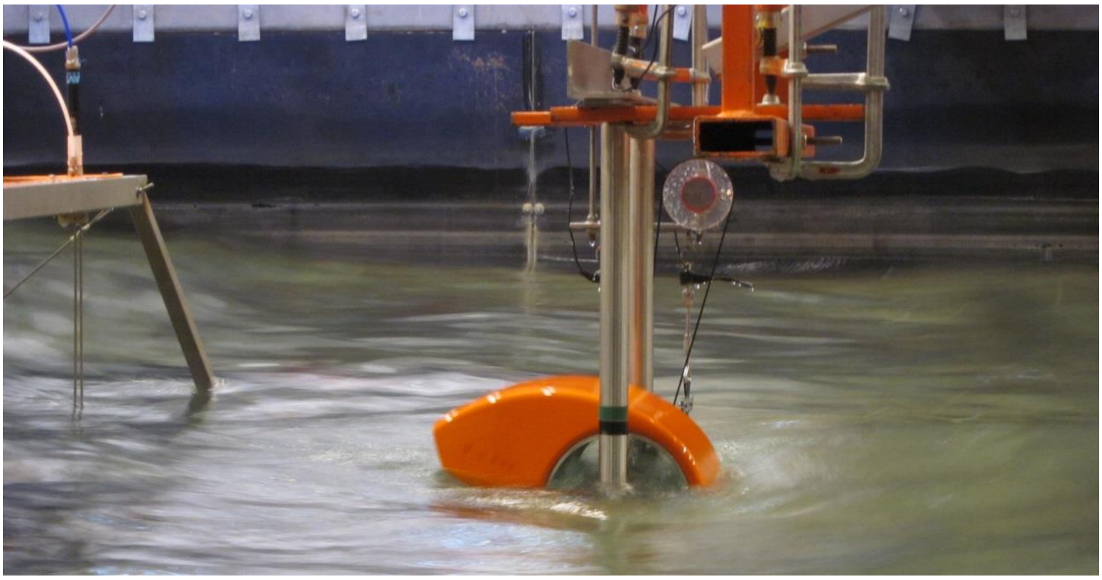


Figure 1: Picture of the rotor during experimental tests.

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.

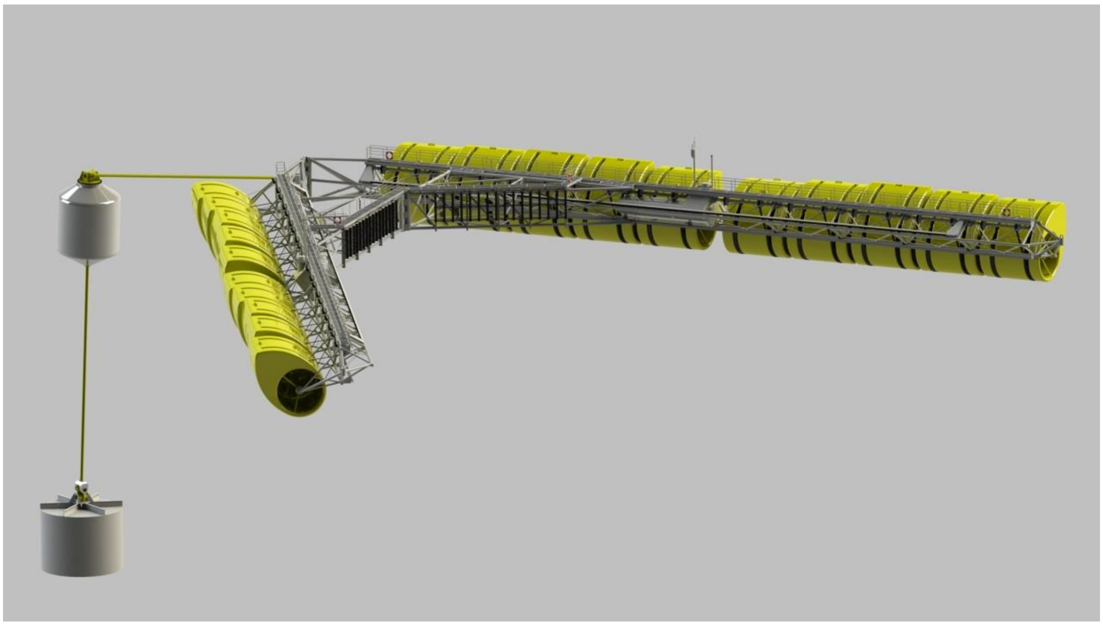


Figure 2: Artist impression of the Weptos WEC

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.

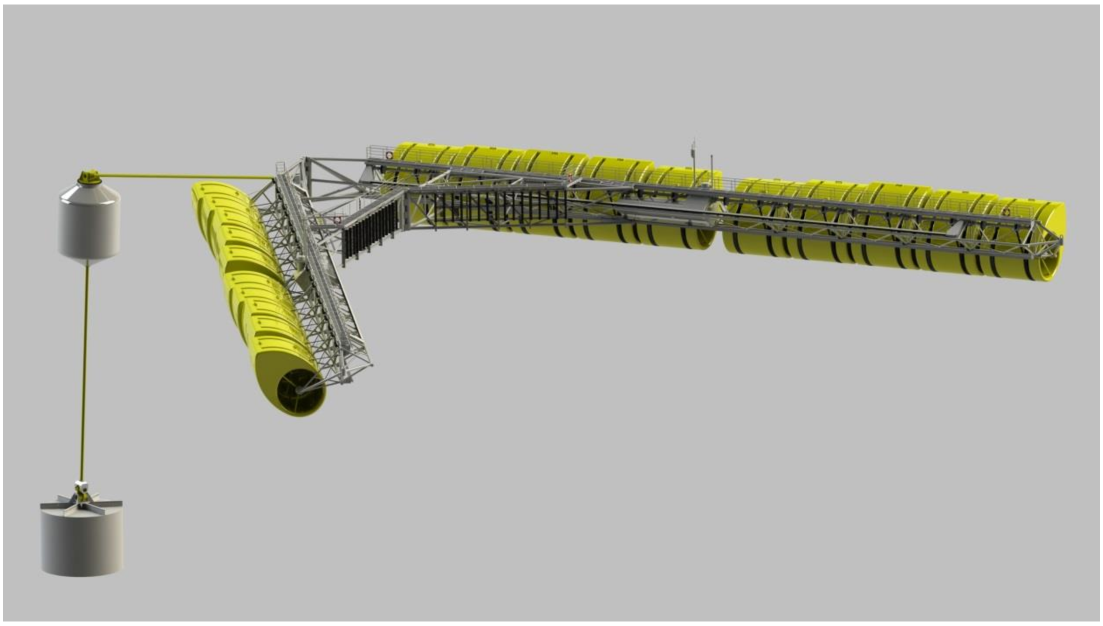


Figure 3: Artist impression of the Weptos WEC moored by a SALM system

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 attack on coastal protection structures in highly non-linear 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. The purpose of this study is to evaluate the influence of wave non-linearity and to derive modifications to existing design formulae 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 modelling of wave run-up, wave overtopping, and armour stability on rubble mound breakwaters
- Experimental modelling of dynamic wave loads on rubble mound breakwater crown walls

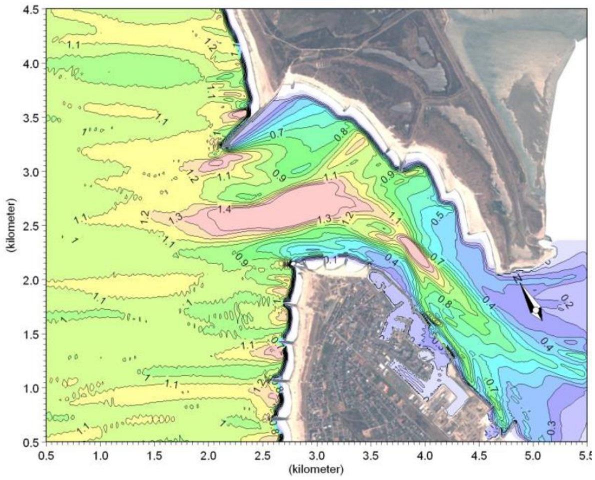
Contact persons: Jørgen Quvang Harck Nørgaard, Thomas Lykke Andersen

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

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:

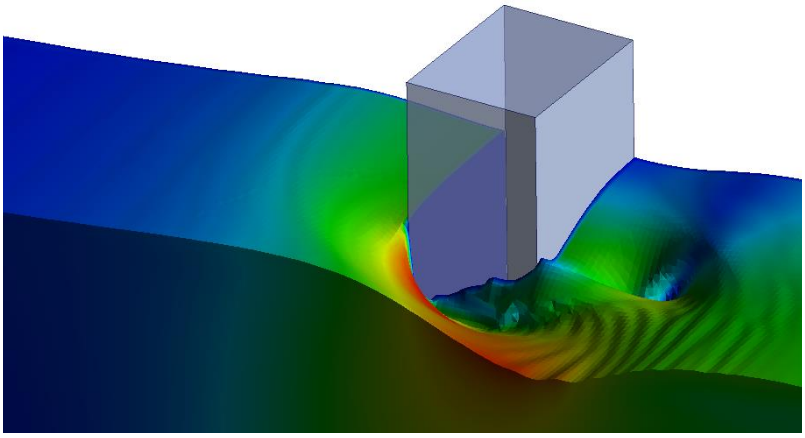
- Evaluation of the processes leading to coastal erosion near the Thyborøn channel
- Numerical modelling of the influence of closing Thyborøn channel during storm on the coastal erosion at neighbouring beaches

Contact persons: Jørgen Quvang Harck Nørgaard, Torben Larsen

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

3D Numerical Modelling of Wave Attack on Coastal Protection Structures

Purpose: The use of 3D numerical wave models for evaluating wave attack on onshore and offshore structures are gaining an increasing interest both in the research sector and in private consultancy companies. In this project, a recently developed open-source three-dimensional numerical two-phase flow solver (IHFOAM, http://ihfoam.ihcantabria.com) specially designed to simulate coastal, offshore, and hydraulic engineering processes, is used to evaluate wave loads on monolithic coastal protection structures. The purpose of this project is to validate the results from the numerical model by comparing to model tests from the wave flume in the AAU laboratory.



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

- Gain knowledge on how to simulate wave/structure interaction in a 3D numerical model
- Validation of model output by comparison with results from physical model tests

Contact persons: Jørgen Quvang Harck Nørgaard, Thomas Lykke Andersen

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

Stability of Roundheads

Purpose: The roundhead is a critical part of a rubble mound breakwater in terms of armour stability. This critical part is often tested and optimized in hydraulic model tests. These tests usually show that the stability of the armour in the rear sector of the roundhead is the most critical and that armour units on the roundhead need to be of double weight of those on the trunk section to provide sufficient stability. Based on model tests few design formulae have also been derived giving the damage in the critical rear sector.

New model tests at Aalborg University have shown that the critical sector shifts with the wave period and thus the critical sector is not always the rear one. The result is that the existing design formulae are unsafe in such cases.

The purpose of this project is to test the influence of the wave period on the stability of the roundhead and make updated formulae for damage pattern and stability of roundheads. Other main parameters can be varied also.

Main activities:

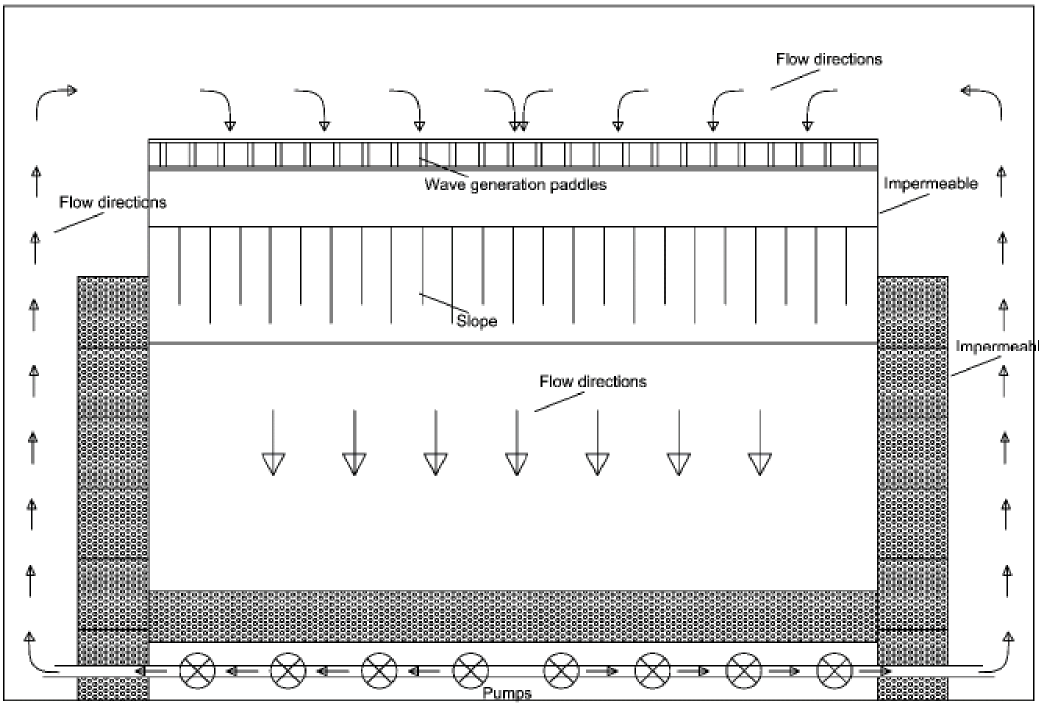
- Design the breakwater and make a model test programme based on existing knowledge.
- Perform model tests with stability of roundheads in the wave basin
- Derive new design tools for stability of round heads.

Contact person: 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 has a new building under construction in the main campus. The building includes a new wave basin 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

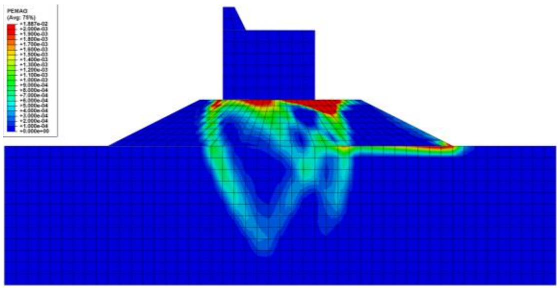
Contact persons: Thomas Lykke Andersen, Jørgen Harck Nørgaard,

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 Quvang Harck Nørgaard, Thomas Lykke Andersen

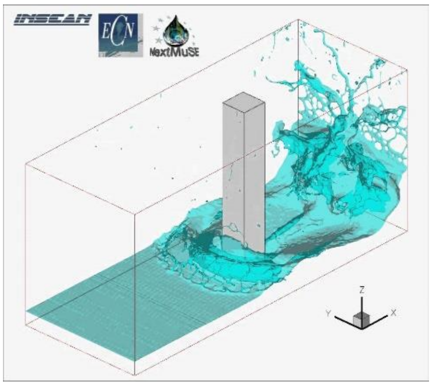
Theory: ☒☒☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☐

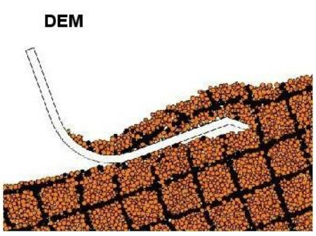
Numerical modelling of fluid–soil–structure interaction

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.

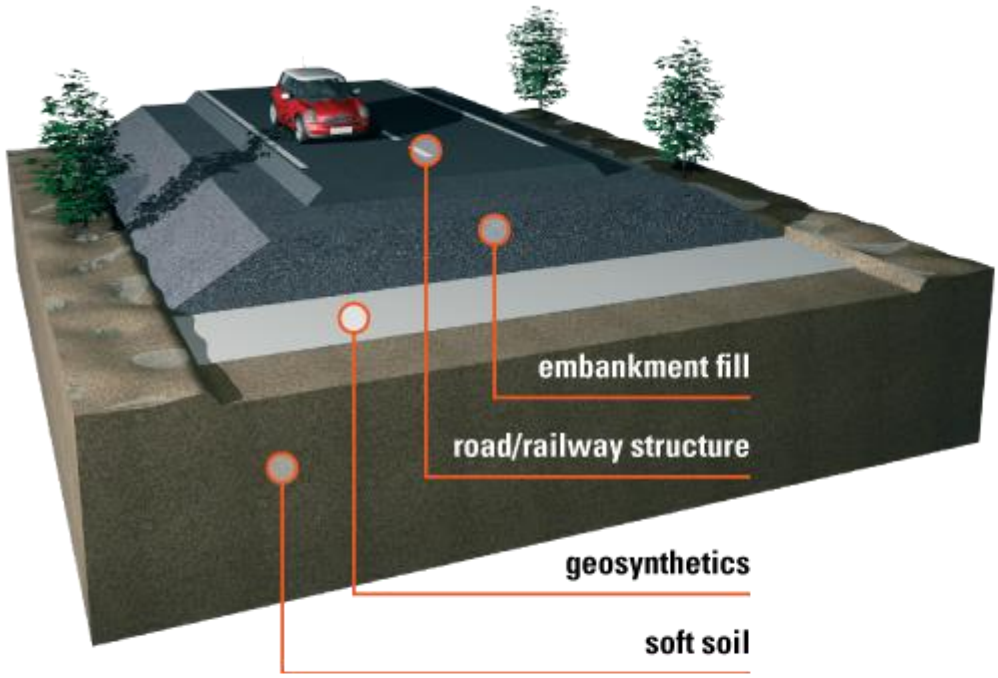
The various methods are all implemented in the commercial program Abaqus that will be used for analysis. The numerical studies and theoretical work can be combined with simple or more advanced laboratory tests to verify or falsify the various models.

Contact person: Lars V. Andersen

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

Geotechnical deformation prediction

Background: A main design driver for geotechnical structures is the deformation of the participating soil masses, which is usually analysed in the service limit state. Numerous methods exist for this purpose, ranging from simple experience-based methods, over continuum mechanics-based hand calculations to the whole palette of more or less sophisticated numerical simulations. The deformation problems are complicated due to several factors such as the time dependency, two (or three) phase materials, the stochastic nature of soils and complex constitutive behaviour, to name a few.



Main activities: An international study of two geotechnical structures is taking place in 2015/2016. Full-scale measurements will be carried out on an embankment and a shallow foundation on soft clay. The initial data will be released and geotechnicians around the world are invited to calculate their best estimates of the deformation of these structures, using methods of their own choice. This study is the inspiration for this project proposal. The goal is to use different methods for the prediction of deformation of geotechnical structures. The results of the different methods is compared, and the influence of different levels of model complexity is assessed.

Contact persons: Johan Clausen, Lars V. Andersen

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, Lars V. Andersen

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:

- Introduction to bender elements
- Gathering and analysis of current design material
- 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:** ☒☐☐

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.

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:** ☒☐☐

Soil reinforcement

Purpose: To improve the knowledge about soil reinforcement using geotextiles.

In collaboration with the company Fibertex the aim is to investigate the use of geotextiles in connection with engineered soil. New field studies show that there effect of using geotextiles in fx. Infrastructure project may be of greater interest and have a more significant effect on the bearing capacity of roads than shown in earlier studies.

Main activities: The project will contribute to the understanding of using geotextiles for soil structures.

The activities may include:

- Behaviour of geotextiles
- Use of geotextiles. Fx. roadbuilding
- Laboratory testing
- Field in situ testing
- Theoretical assessment

Contact persons: Benjaminn Nordahl Nielsen and Lars Bo Ibsen

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

Laboratory test of Aalborg Clay

Purpose: To improve the knowledge about soil parameters for late glacial clay

In connection with the "Musikhus Kvarteret" 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 late glacial clay soils.

The activities will include:

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

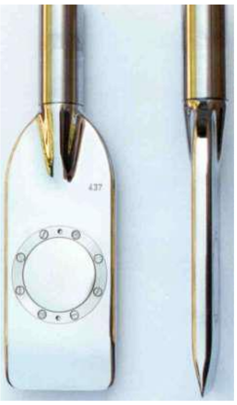
Contact persons: Benjaminn Nordahl Nielsen and Lars Bo Ibsen

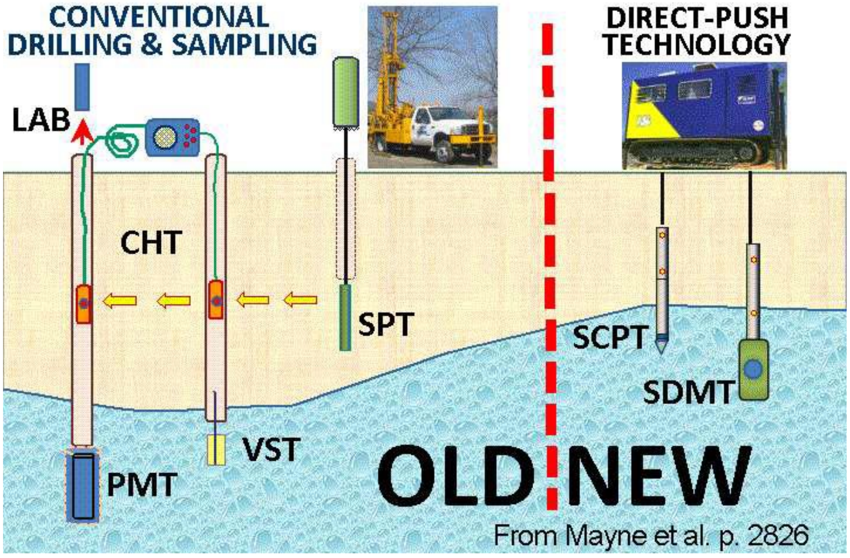
Theory: ☒☐☐ **Experimental work:** ☒☒☒ **Computer modelling:** ☐☐☐

SDMT Flat Dilatometer

Purpose: Be the first to try 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_0, 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: Benjaminn Nordahl Nielsen and Lars Bo Ibsen

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

Improved FEM-modeling 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.

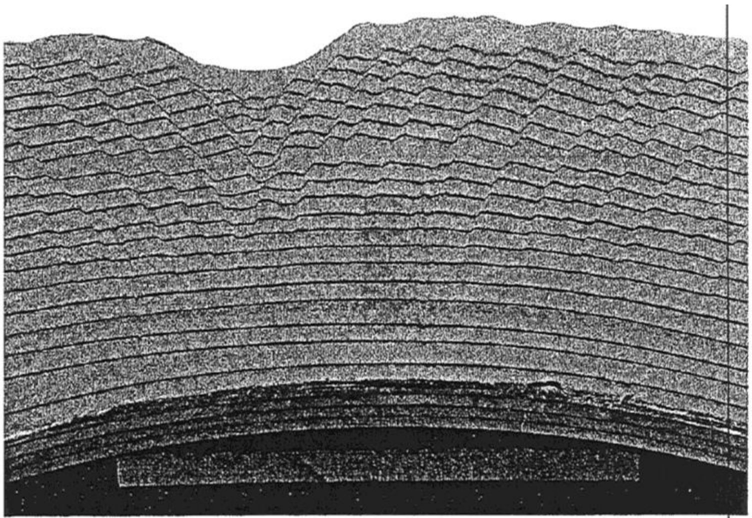


Fig. 8.2 Crestal faults over arch of uniform curvature, simulated in a sand box (Mandl, 1984).

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:

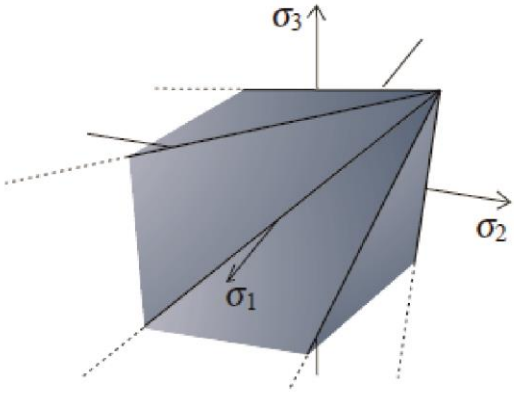
- What are the symptoms of non-associated problems? A computational and literature review.
- What do the commercial codes do (e.g. Abaqus, Plaxis, Ansys)?
- Do we have other methods of remediating the problem?
- Quantification of different results with different methods using own MatLab code

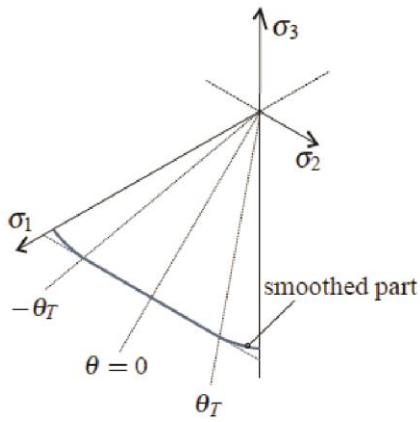
Contact person: Johan Clausen

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.

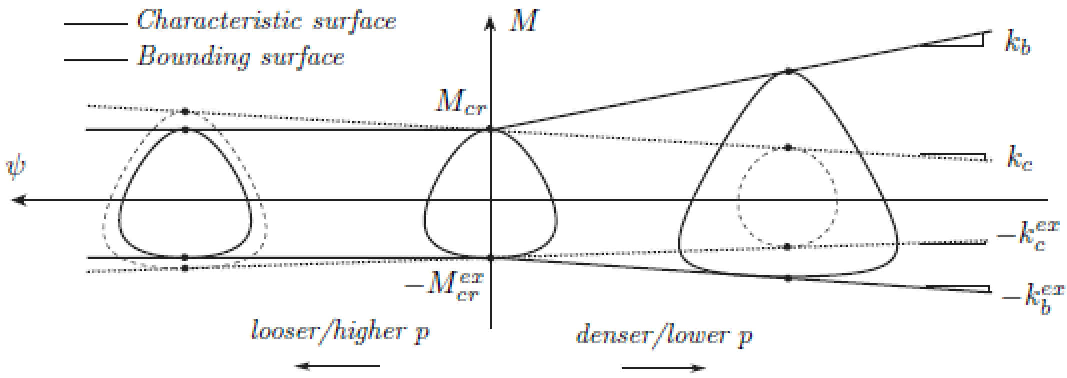
An interest in programming, e.g. MatLab, is essential.

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.

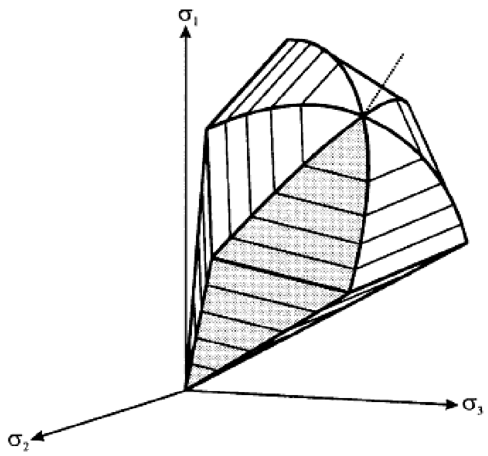


Figure 3. Representation of total yield contour of the Hardening-Soil model in principal stress space for cohesionless soil.

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.

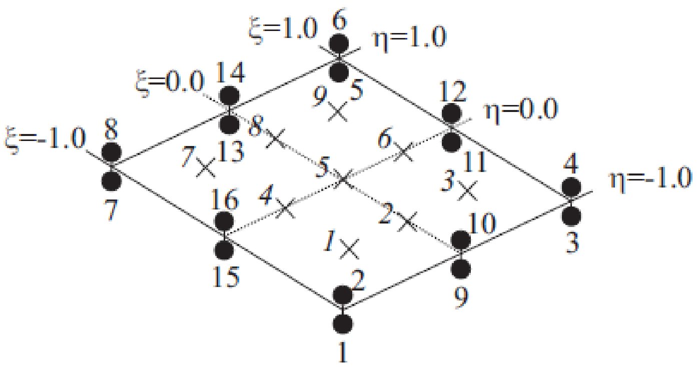
An interest in programming, e.g. MatLab, is essential.

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:** ☒☒☒

Modelling of cyclically loaded monopiles

Purpose: A common foundation type for offshore wind turbines is the monopile. In essence, it is a large steel tube driven or vibrated into the seabed. An example of the proportions is a diameter of 5 m and an embedded length of 30 m. The dominating loads are cyclic in nature, i.e. wind and wave loads. The soil supporting the pile is affected by the cyclic loading, so that the response of the pile will change as the number of load cycles builds up. Usually a degrading stiffness is observed, which must be taken into account when meeting the design criteria of the monopile. A common design criterion in the service limit state is that the accumulated rotation of the pile cap must not exceed 1°.

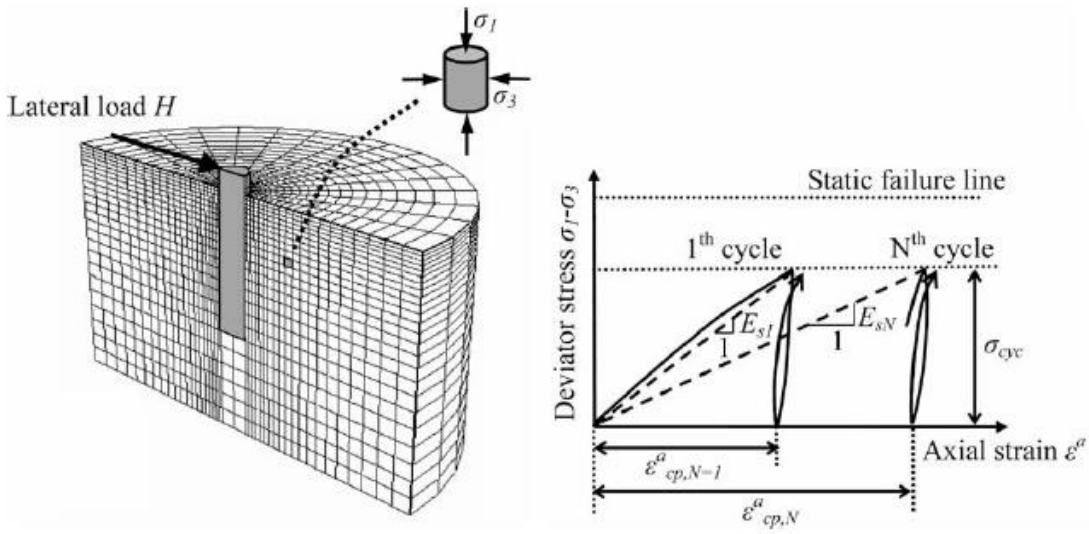


Fig. 2. Degradation of secant modulus under cyclic loading in the pile–soil model (schematic).

Main activities: The modelling of stiffness degradation can be a daunting task if carried out on a high detail level, e.g. three-dimensional geometry, advanced material models, stochastic loads etc. All in all such a detailed procedure is not well suited for design purposes. Simplified methods have been proposed in literature, with which decent estimates of the accumulated rotation should be possible. The goal of this project is to study and implement one or more of these simplified methods. Usually using the Finite Element Method or other relevant calculation tools. In this project, a co-operation with the company Universal Foundation is a possibility.

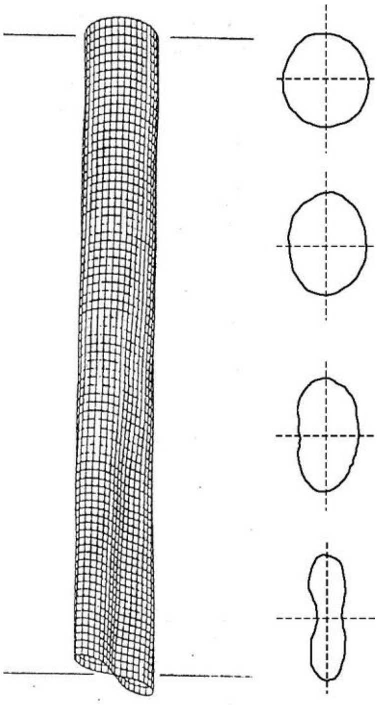
Contact person: Lars V. Andersen, Johan Clausen

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

Extrusion of initially deformed pile / Propagation of damaged pile tip

The monopile is one of the current technologies for wind turbines at water depths of up to approximately 35 metres. Axially loaded piles are currently used as the foundation for jacket substructures in the oil and gas industry. The pile-jacket foundation is also generally considered as the cutting edge foundation solution for offshore wind turbines in deeper waters.

Instability is an issue for piles during installation, where imperfections and boulder impacts during pile driving can lead to structural buckling. The failure mechanism can be an “extrusion” mechanism type, where an initial imperfection of the pile increases as the pile is penetrated through a soil of high stiffness. The Goodwyn A platform was installed on the North West Shelf of Australia in 1992. During installation of the foundation piles, it was discovered that 15 of the 20 driven primary piles were severely crushed at depths of 80 metres or more below the seabed. A crushed pile is illustrated to the right. The effect of the lateral restraint offered by the surrounding soil can be addressed both analytically and numerically. It is suggested to implement a pile-soil model in an ABAQUS finite element analyses by means of p-y springs in a Python script.



The main activities in the project are:

- Literature study on design of steel shell structures and p-y curves
- Nonlinear finite element modelling of shells
- Python scripting in ABAQUS
- Predicting damaged pile-tip propagation

Contact persons: Søren Madsen and Lars V. Andersen

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

Driveability of 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 more often than not a project deal-breaker.

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 provides valuable insight into a part of offshore wind turbine foundation design that often governs pile wall thickness and thereby influences the total amount of steel:

- Understand the basic physical and theoretical principles involved in the driving of large-diameter piles for offshore wind turbine foundations.
- Assess state-of-the-art research and methodology within the area of offshore driveability, both in regards to methods for prediction of driving resistance but also in regards to installation techniques.
- Based on available driving data from installed offshore wind farms, complete back-calculation using available methods in order to estimate the importance of various model parameters for a good driving prediction.
- Using finite element modelling, investigate the soil-structure interaction during installation and provide recommendations for driveability assessment for large-diameter piles for offshore wind turbine foundations.

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

Design framework and perspectives for offshore wind turbine foundations

A project with COWI

Purpose: The design of foundations for offshore wind turbines is still subject to development and on-going research as well as regulations defined by international certification agencies, such as e.g. DNV-GL. The design process often involves multiple parties and areas of competences, so from a designer's point of view it is important to distinguish between what's very important and what's just important. The importance of key design areas varies from project to project, and the key to an efficient design process is to pinpoint the most important areas as early in the process as possible.

The design process of foundations for offshore wind involves many parties (www.windcarrier.com).

The certifying agency DNV-GL defines requirements for designers worldwide (www.dnvgl.com).

Main activities: The project will be a journey into the world of offshore wind turbine foundation design where the current standard is the basis for all projects:

- Decipher the requirements defined in the standard and investigate the different components individually to assess the influence and/or importance to a project such as:
  - Investigate the demand for use of numerical modelling in 3D, and understand the requirements for a valid finite element model, with regards to e.g. choice of material model.
  - Examine the cyclic behavior of offshore wind turbine foundations to assess the importance of cyclic design as well as the proper method for future investigations.
  - Explore into the consequences of oblique (combined) loading on wind turbine foundations to assess the importance for various types of foundations, and the best way to investigate it.

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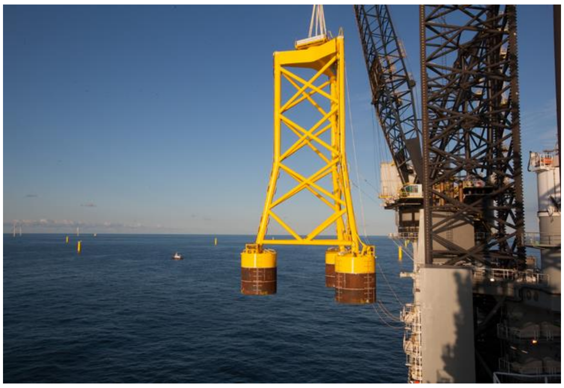
Theory: ☒☒☐ **Experimental work:**. ☒☒☐ **Computer modelling:** ☒☒☐

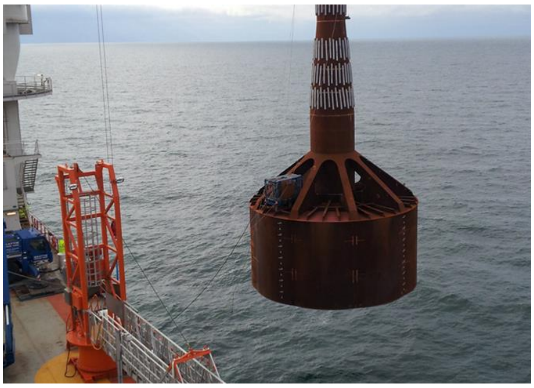
Geotechnical behaviour and design of suction caissons for offshore wind turbines

A project with COWI

Purpose: Lowering the cost of energy for offshore wind power is a joint market task, and the costs related to foundations contribute significantly to the overall cost. As a result, new and innovative types of foundations are developed and the suction caisson is one of these. The suction caisson/anchors has been used in the oil and gas-industry for years, however the concept is new in the market for offshore wind, and the framework for design of such a structure needs to be developed considering all relevant aspects.



Suction caisson used to found a jacket structure for offshore wind turbines on deep water (www.offshorewindindustry.com).



Suction caisson used a monopod foundation for a metrological weather mast (www.renews.biz).

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 behavior of the suction caisson/anchor during different loading and soil conditions.

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

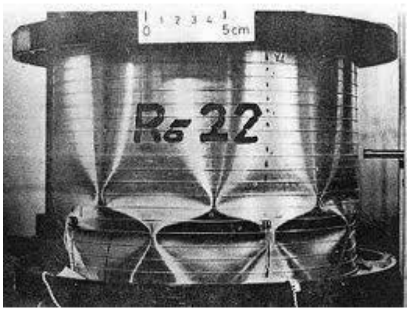
Design of steel shell structures

Shell structures are widely used in civil engineering structures e.g. chimneys, oil & gas structures, wind turbine towers, and offshore foundations. The design of these structures is often performed using the guidelines in EN 1993-1-6 which allow for at least four different design methods:

- Design using simple formulas based on membrane theory
- Linear finite element analysis
- Nonlinear (materials) finite element analysis
- Nonlinear (materials & geometry) finite element analysis

It is normally expected that the more detailed models are the most accurate. This could allow for smaller partial factors of safety if these methods are employed in design. On the other hand, some hidden safety (conservatism) can be built into the simple formulas.

There is a large difference between theoretical solutions and the load carrying of “real” shell structures. One of the primary reasons for this is the imperfection-sensitive behaviour of shell structures. Thus, different methods of modelling imperfections can be compared. The objective of the present work is to compare the different design approaches with public available test results.



The main activities in the project are:

- Literature study on design of steel shell structures
- Nonlinear finite element modelling of shells
- Investigate how to include imperfections
- Various load cases and boundary conditions can be investigated

Contact persons: Søren Madsen and Lars V. Andersen

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

Project proposals from EMD

Introduction

EMD International A/S is developing a software tool – WindPRO – for planning and projecting of wind farms. In its latest edition, the software includes modelling of wind turbine loads and the possibility to analyse wind climate parameters (site compliance analysis). The analyses are made according to IEC 61400-1 (ed 3). EMD wish to further expand the load modelling and are offering students the possibility to co-operate on specific items regarding structural (aeroelastic) load modelling of wind turbines. EMD is located in Aalborg, Denmark.

EMD Project Proposal 1:

Load Response from Wind Turbines Subjected to Extreme Turbulence Loading

Purpose:
To investigate the structural extreme load responses for wind turbines subjected to design load case 1.3 in the IEC 61400-1 (ed 3) standard.

Expected Actions:

- Available Methods: To analyse different methods to access the extreme turbulence loading – as IEC 61400-1 is not clear on how-to determine this.
- Evaluate Available Methods - Numerical Flow Simulations: Run different models to determine extreme turbulence at multiple sites (where measurements are available).
- Current Best Practices: Determine best practices to analyse DLC 1.3 based on existing knowledge from literature and other sources
- Numerical Load Simulations: Run aeroelastic simulations on selected turbines available from EMD (with the FAST aeroelastic model)
- Analysis of Measurements: To analyse data from meteorological mast (multiple sites) to determine the measured extreme turbulences and to compare with similar modelling efforts

Optional efforts:

- Include analysis of DLC 6.4 (fatigue) below cut-in and above cut-out.

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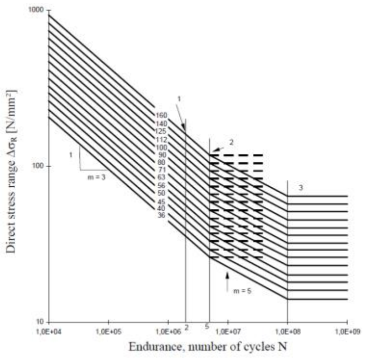
Theory: ☒☐☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☐

EMD Project Proposal 2:

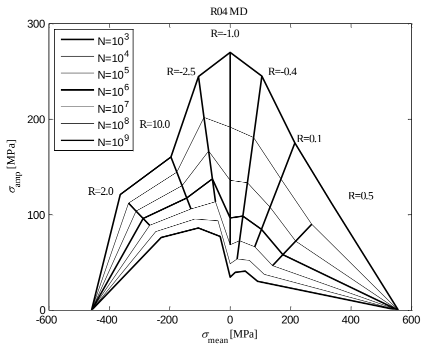
Fatigue Load Assessment by Aeroelastic Simulation of a 10 MW Wind Turbine

Purpose

In detail to evaluate the fatigue load responses for the DTU 10 MW reference turbine – and benchmark against generic EMD turbines available in WindPRO. In addition also to analyse site-specific conditions to define specific and relevant load cases for e.g. the transient conditions.



welded detail



Composite structure

Expected Actions:

- Setup fatigue load cases for main wind turbine components (welded details, cast details and composites/blades) according to 'simple' fatigue models in IEC 61400-1 ed 3
- Setup fatigue load cases for main wind turbine components (welded details, cast details and composites/blades) using detailed fatigue models based on fatigue test data
- Setup an aeroelastic model for the DTU 10 MW reference turbine - either using the HAWC2 software or in FAST.
  If using HAWC2, then the model is, ready available for download.
- Define relevant fatigue load cases (consult the IEC 61400-1 ed 3 – and consider site specific conditions also – e.g. cut-out conditions)
- Simulate a full fatigue load assessment using the aeroelastic code(s) chosen (considering all design load cases in the code and compare their relative impact on fatigue loads, such)
- Perform aeroelastic simulations suitable to generate load response surfaces (at a broad range of climate parameters)
- Simulate load-sweeps for the 10MW turbine (specific site conditions) and compare to response surface approach
- Make sensitivity analysis for most important climate parameters and turbine sensors
- Compare fatigue lives using 'simple' fatigue models in IEC 61400-1 ed 3 with fatigue lives obtained by more detailed fatigue models
- Evaluate loads at various sites with meteorological masts (multiple sites) – and benchmark against generic EMD turbines

Possible Extension:

- Comparison of FAST (modal representation) and HAWC2 (multibody) ability to captured relevant modes with the available degrees of freedom - as a function of turbine size
- For this the WindPact Ø=70m reference turbine may be compared with the DTU Ø=178m reference turbine.

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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:

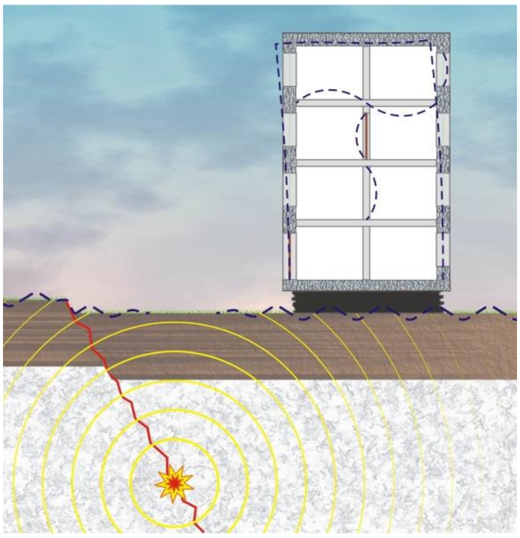
1. Dynamic Reliability Analysis and Determination of Design Criteria of Wind Turbines based on the Probability Density Evolution Method
2. Three Dimensional Turbulence Modeling for Wind Turbines based on Rapid Distortion Theory and the Evolutionary Phase Model
3. Stochastic Aeoelastic Stability of Wind 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

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.

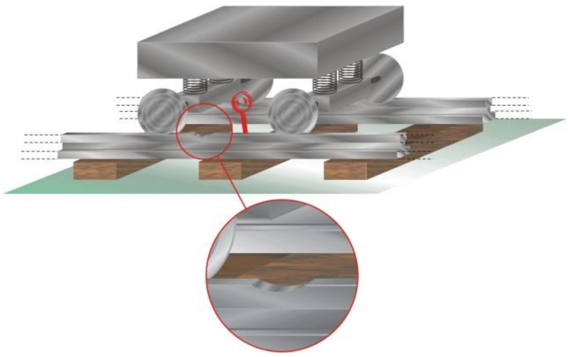
Contact person: Lars V. Andersen and Johan Clausen

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.

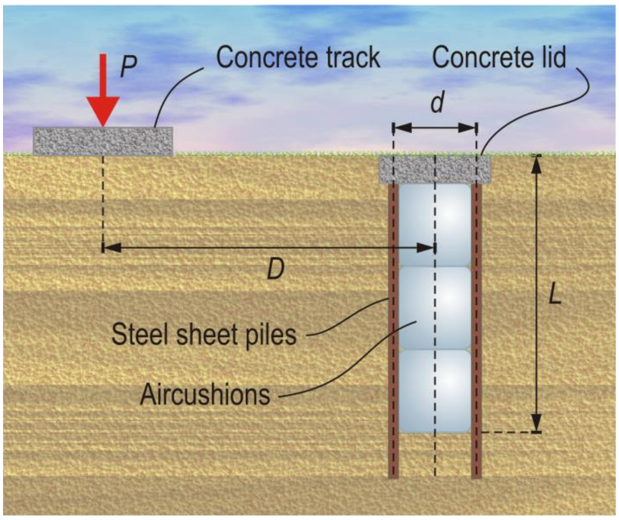
A final goal may be the development of a program for evaluation of vibration levels in building next to a heavily trafficked road or railway.

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.

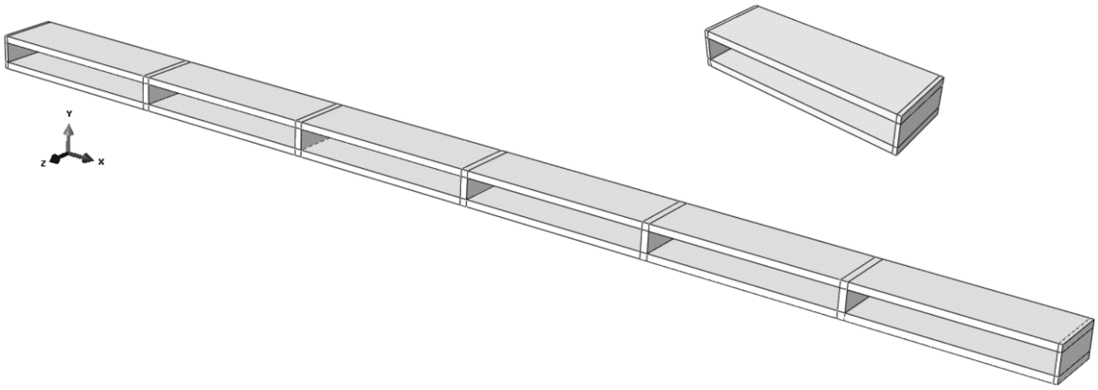
The workload related to theoretical investigations, experimental work and computer modelling may vary depending on the weight put on each item.

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:

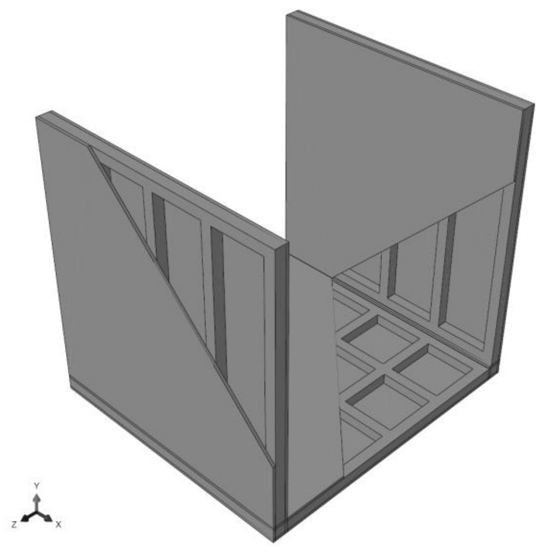
- Literature study of wave propagation in periodic structures
- Numerical modelling of a periodic structure (e.g., a tunnel, panel, or pipeline)
- Analysis of a periodic structure by means of Floquet theory
- Combination of finite-element analysis with Floquet theory
- Experimental analysis of wave propagation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

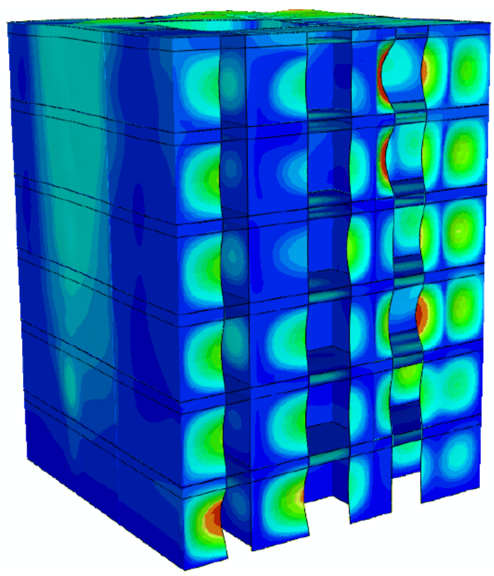
Contact person: Lars V. Andersen

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:

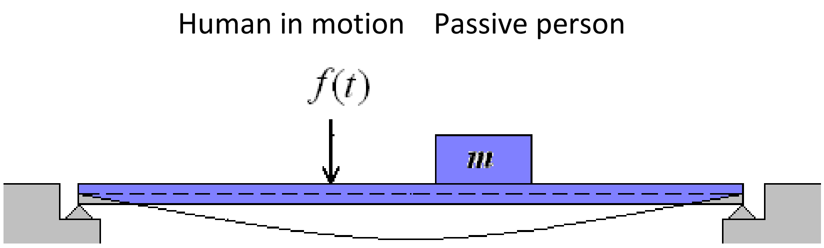
- Literature study of building acoustics
- Formulation of models for dynamic analysis of periodic structures
- Design of joints in building structures for mitigation of noise
- Parameter studies to identify the influence of geometry and material properties on sound transmission in lightweight building 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

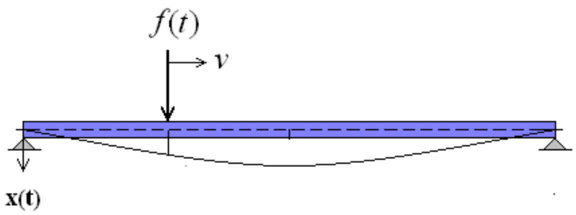
Theory: ☒☐☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☐

Dynamic human loading and stochastic models for estimating structural responses

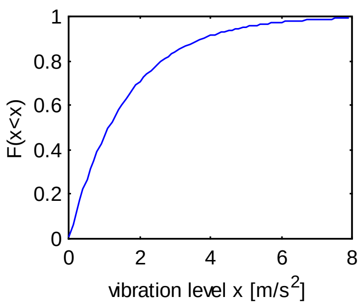
Background: Some civil structures are so slender that their modes of vibration may be excited by the basic frequency of human motion resulting in resonant structural action. The undesired resonant action may for instance occur in footbridges, stadia structures or in open-space office floors as a result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

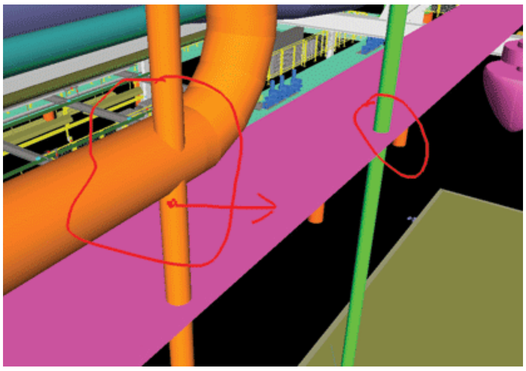
Contact persons: Lars Pedersen, Christian Frier

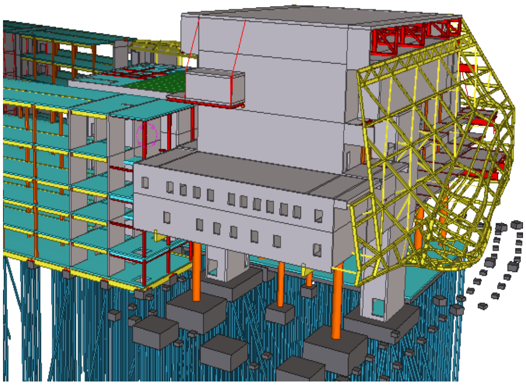
Theory: ☒☐☐ **Experimental works:** ☐☐☐ **Computer modelling:** ☒☒☒
(The amount of experimental work can be decided during the project)

Structural 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.

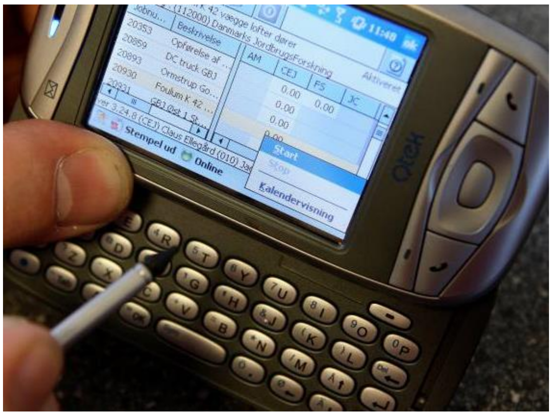
Contact persons: Kjeld Svidt

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 also be included. The project may focus on the analysis of a particular problem or structure.

Main activities:

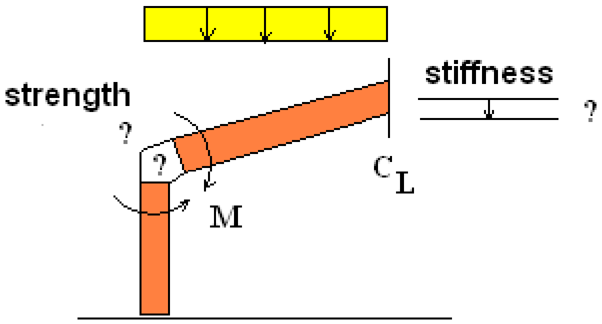
- Formulation of material models for concrete. This can be both built-in models in Abaqus and user supplied models.
- Modelling of interfaces between concrete and reinforcement
- Finite-element analysis of reinforced concrete structures
- Comparison of FE models with standard design methods.

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

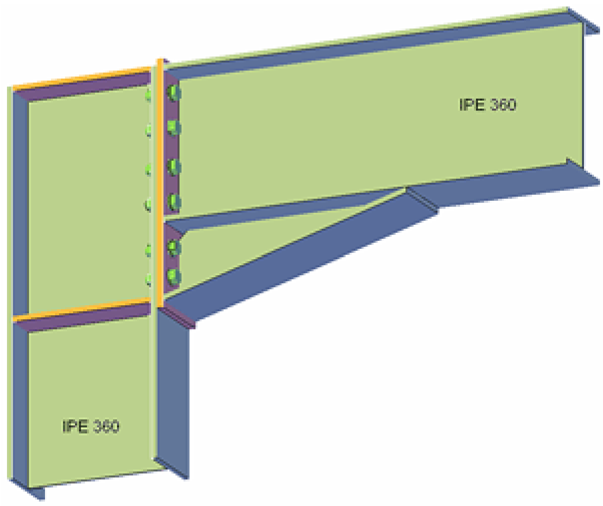
Theory: ☒☒☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☐

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 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.

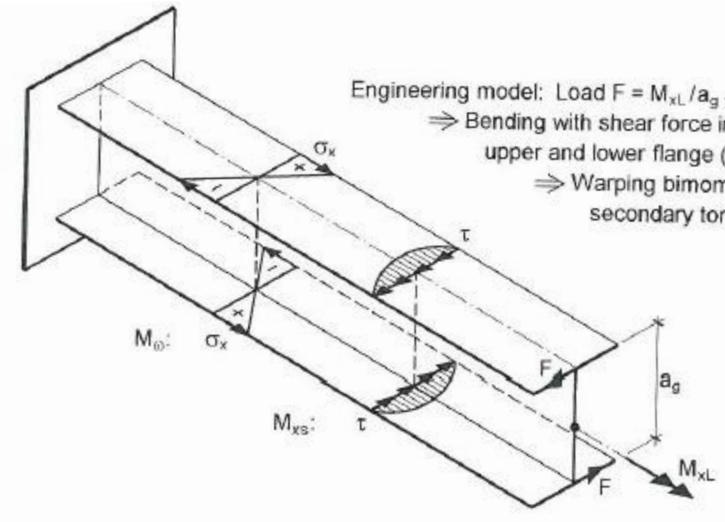
As part of the study it might be useful also to analyse one of the steel frames which recently collapsed due to heavy snow loads.

Contact persons: Lars Pedersen, Johan Clausen

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

Implementation of advanced beam finite elements

Purpose: The Eurocode for steel now makes is possible to use advanced finite element modelling to document the safety of steel structures. In the classical method interaction formulae for each steel member is used based on the linearly elastic section forces. The new method, however, allows for non-linear modelling and the documentation for larger portions of the structure at a time, i.e. not for every member. To be able to use this new method, non-linear models must be applied together with 3D elements. If possible, beam elements are preferred over shell and solid elements as the latter two result in soaring numbers of degrees of freedom. Many standard beam elements, however, do not account for the needed non-linear phenomena, or even the proper formulation for torsion.



Explanation of the warping torsion of a cantilever,

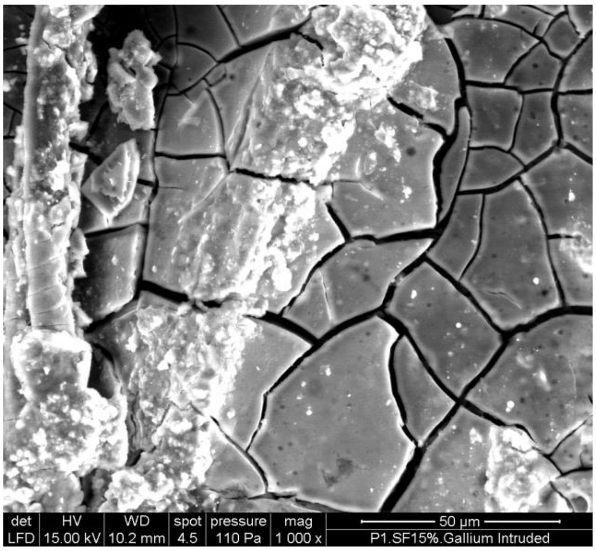
Main activities: Study, development and implementation of beam finite elements that incorporates one or more of the aspects of the advanced phenomena needed to use the new method in the steel Eurocode. These phenomena are large displacements, buckling (Euler and lateral torsional), torsional behaviour and material nonlinearities (plasticity). An interest in the finite element method and programming, for example using MatLab, is essential.

Contact person: Johan Clausen
Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☒

Modelling shrinkage and cracking of cement-based materials

It is well known that micro cracking may occur in ultra-high performance cements during their early age. While models for external restraint have been thoroughly explored, a model to predict for internal stress does simply not exist. Internal stresses in concrete can have many sources, e.g. aggregates and reinforcement bars with shrinkage behaviour different from the cement, and it becomes relevant to the service life of advanced concrete structures.

The project will focus on material modelling. The aim is to link micro cracking to stiffness, in compression as well as tension. In a first attempt, we will simulate a simply supported beam. Material design with different levels of internal restrain will be produced, so the material parameters related to the relevant service and ultimate state can be derived. The project can include non-destructive testing by use of accelerometers to determine Eigen frequencies and Eigen modes with the aim of analysing changes in stiffness and possibly the position of cracks.



The main activities in the project could possibly be:

- Literature study on concrete with focus on micro cracking
- Constitutive modelling of concrete with micro cracks
- Nonlinear finite element modelling of concrete
- Acceleration measurement on concrete beams in laboratory scale
- System identification of beams to identify cracks or damage.

Contact persons: Luis Pedro Esteves and Lars V. Andersen

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

Material design for marine environments: Fatigue life of cement grout X

Background: The ultimate state of structures located at the offshore is usually bound to the fatigue life of the structural material. It has been well known that cement grouts applied in wind turbine towers are subjected to high oscillating service stresses. This project is focused on designing and modeling grout materials to improve its fatigue service life.

Objectives: By changing certain microscopic material parameters, e.g. pore size distribution; the performance of the grout in compression fatigue will be simulated. Another parameter of interest is the environmental condition of the grout material. It has been found that the internal saturation can have a significant effect on the fatigue life of the grout material. Several experimental test results and relevant literature may be use as input. The model should be capable of evaluating the influence of stress concentration in composite cement-based materials during its service life.

Fig.1 – Off-shore platform[2]

Contact persons: Luis Pedro Esteves, (Lars Damkilde)

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

[2] European Oil and Gas, issue 9 2013

Contribution to COST action TU1404

Background: COST is a mean for European researchers, engineers and scholars to jointly develop their own ideas and new initiatives across all fields of science and technology through trans-European networking of nationally funded research activities. COST action TU1404 is focused on the study of the service state of concrete, which is closely related to limiting the crack width of structural elements. The appearance of new technologies raises a challenge to society, as it demands revision of the model codes and regulation. Furthermore the relation between service state and durability of concrete is not well established. The project will focus on these aspects in the Nordic environment.

Objectives: In particular**,** this project aims to contribute with material design and modeling in one of the workgroup objectives. Our group will focus on the material design of eco-concrete. This will include the development of a physical model for a standard concrete and for an ultra-high performance concrete. The work will focus both on the development of mix design and experiments in the Lab. The raw materials will be sent to the different European partners, and results will be used as input to model activities.

Please refer to http://www.tu1404.eu/wg2/overview, for a detailed description of the possible actions.

Contact persons: Luis Pedro Esteves, (Lars Damkilde)

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

Chemical activity of low carbon cements

Background: The models of the chemical activity of cement are gaining a new importance in the present times. One of the widely accepted models was initially proposed by Per Freiesleben Hansen, a former Professor at Aalborg University, the so called maturity model, useful to describe the hydration kinetics of Portland cement. Superabsorbent polymers are a "funny", relatively new functional material that can be used in many ways in construction building materials. One of the reasons for its development was the requirement of internal curing, which is connected with the development of early-age cracking in high performance concrete (for example CRC concrete).

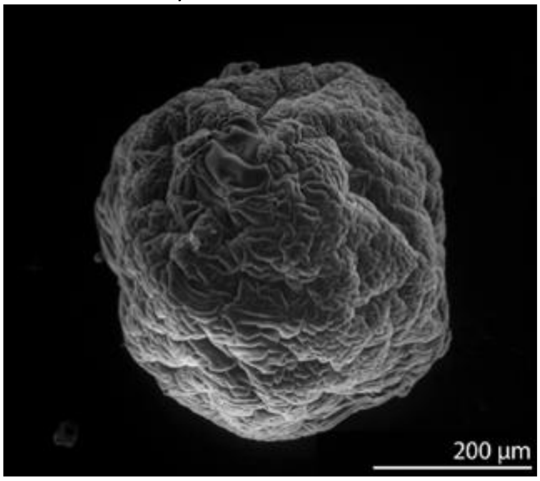


Fig.1 – Superabsorbent polymer particle useful for internal curing of cement-based materials[3]

Objectives: This project will test the applicability of the maturity model to predict the hydration kinetics of modified cement binders. The project combines experimental work in the concrete laboratory, both at AAU and Aalborg Portland, and modeling from existing data. There is a potential application of this concept to model hydration kinetics of blended cements. The experimental methodology will include isothermal and adiabatic calorimeter of blended cements, also with this new component. The chemical activity will be monitored during the initial 48 hours and compared with the strength development at different temperatures, so energy of activation can be derived.

Contact persons: Luis Pedro Esteves (AAU), Lasse Frølich (Aalborg Portland)

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

[3] Luis Pedro Esteves, Notes from a talk at Brunel University, England, 2012.

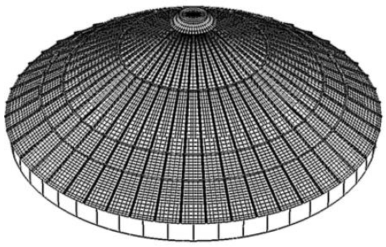
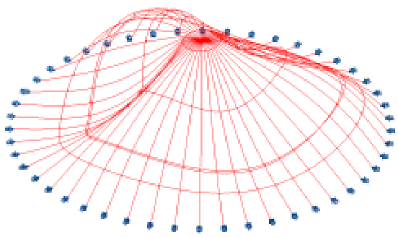
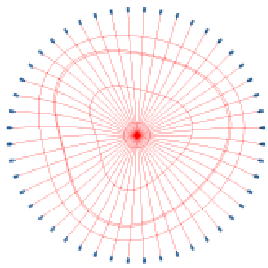
Example of company stay project

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. Also, different detail levels in the modelling were compared, as was beam and shell models.

ISSN 1901-7308
DCE Latest News No. 48