M.Sc. in Civil and Structural Engineering

3rd Semester and Master's Thesis Ideas 2008

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AALBORG UNIVERSITY
Department of Civil Engineering

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Department of Civil Engineering
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Lars Andersen

May 2008

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M.Sc. in Civil and Structural Engineering: 3rd Semester and Candidate Project 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 candidate 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. Further, other ideas for projects may be discussed with a potential supervisor.

The preferred group size is two to four students. In the interest of students as well as supervisors, single-student projects are generally not recommended.

As a final remark, a signed project plan must be handed in 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 as well as the Study Programme Guide for the M.Sc. Programme in Civil and Structural Engineering at the School of Civil Engineering, Aalborg University. A document master for the project plan is available at the homepage of the School of Civil Engineering: www.bsn.aau.dk.

Aalborg, 25 April 2008 Lars Andersen, *semester coordinator*

Vibrations from “beautiful” roads

Purpose: Over the last decades, asphalt roads in the inner cities have been replaced by concrete or natural cobblestone pavements. This is, for example, the case in Boulevarden and parts of Østerå in Aalborg. In addition to this, ramps and bumps have been established in order to reduce the speed of traffic. However, this has led to induced levels of ground and airborne noise. The uneven surface of the road implies that vibrations are generated by the passage of the wheels. Waves are then transmitted via the ground, possibly leading to nuisance for people and damage on structures in the surrounding environment. The question arises as to whether it is possible to design a pavement of high quality regarding the architecture as well as comfort and safety.

Main activities: The project concerns the analysis of vibrations from vehicles on pavements with different surfaces and subsequently the design of the road and the substructure. The following items may be part of the project work:

- Numerical modelling of vibration transmission through the road and subsoil
- Verification of the computational model by dynamic testing
- Design of a road surface with regard to a minimisation of the vibrations
- Design of the substructure in order to reduce the transmission of waves.

The work may be carried out in collaboration with a producer of pavement stones or road construction material.

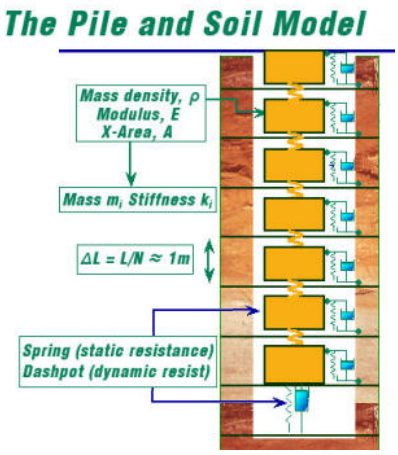
Contact person: Lars Andersen

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

Driveability of large piles

Purpose: Foundation of offshore wind turbines is primarily done using large monopiles being either drilled or driven into the soil. The driving of the pile is a critical operation and pile refusal due to hard soil might require a drive-drill-drive installation procedure to obtain required penetration depth. In addition to pile refusal problems, too many blow count will give additional fatigue and thereby reduce the total lifetime of the pile. During the installation of Barrow Offshore Wind Farm both types of problems occurred. On Barrow 30 monopiles with an OD of 4.75 m where installed on 23 m water depth.

In the design phase a driveability analysis is conducted in order to assess possibilities for driving the planned monopile as well as expected life time reduction due to driving. The driveability takes into account the actual soil characteristics, the monopile design and the planned driving equipment. Due to uncertainties and interpretations associated with the driveability analysis wrong results occur as the example on Barrow shows.



Main activities: The project will be executed partly at NIRAS and partly at Aalborg University containing the following activities:

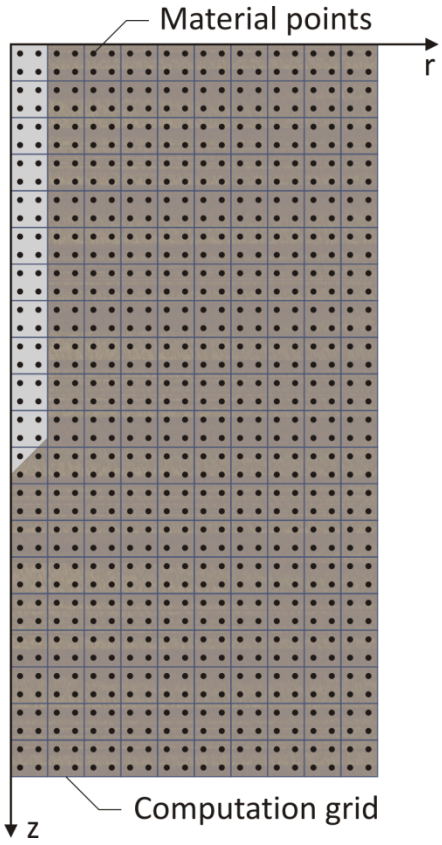
- Analysis of soil profiles and driving records from installation of MP on Barrow
- Driveability analysis using Glrweap (commercial software based on a mass-spring model) and correlation to results from Barrow
- Driveability analysis using Flac (FD software for analysis of large displacements)
- Back-calculation from actual driving record and registered resistance to driving to soil characteristics.

Contact persons: Anders Augustesen / Lars Andersen

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

Particle-based model of pile driving and CPT

Purpose: The Material-Point Method (MPM) has emerged as a computational tool for the analysis of dynamical problems related to civil engineering. Based on continuum mechanics, the method is developed from the principle of virtual work. However, in contrast to the standard finite-element method, the integration points carrying the material properties and state variables are allowed to move through the computational grid. This is ideal for the analysis of problems involving large deformations and contact between different materials and structures. Hence, the MPM is a promising tool for simulation of geotechnical problems such as pile driving and cone penetration testing (CPT).



Currently, a PhD project is being carried out at the Department of Civil Engineering, Aalborg University, regarding the analysis of landslides by utilisation of the so-called Generalised Interpolation Material Point Method (GIMP). This method is a further development of the MPM. The idea of the project is to develop a computer code based on the GIMP for the analysis of pile driving and CPT.

Main activities: The GIMP is a relatively new method, and this project is directly related to some of the ongoing research at the university. The main activities are:

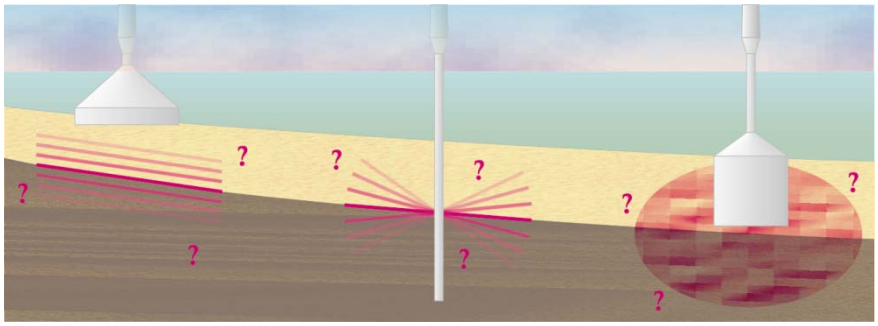
- Getting to know the MPM and the GIMP
- Formulation of the GIMP in cylindrical (axisymmetric) coordinates
- Programming the GIMP in Matlab or Fortran 95
- GIMP-analysis of CPT and/or pile driving
- Comparison of the GIMP results with experimental results.

Contact person: Lars Andersen

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

Stochastic modelling of soil

Purpose: Soil is a heterogeneous material at different levels. Thus, the ground is stratified, i.e. several soil deposits lie on top of each other, and the material within each layer is in itself heterogeneous on a local scale as seen in the figure. However, when geotechnical analysis are carried out by computational methods, soil is usually modelled as a locally homogeneous material and the position of interfaces between two different material, e.g. sand and moraine, are based on few tests. This is a huge problem because failure in the soil will always find its way through the weakest part of the material. Hence, failure figures in real heterogeneous soil may be significantly different from the ones achieved by computational analysis ... and so may the bearing capacity and deformations.



Another interesting problem is related to the dynamics of soil. Recent research indicates that even a very sophisticated model can only predict the ground vibration from metro tunnels with an accuracy of 10 to 15 dB. This means that the actual ground motion may be about four times higher than the predicted response. The main reason is believed to be the missing consideration of heterogeneity.

Main activities: The project may focus on the bearing capacity and deformations of foundations or alternatively the ground vibration from, for example, railways. In any case, the activities to be carried may include:

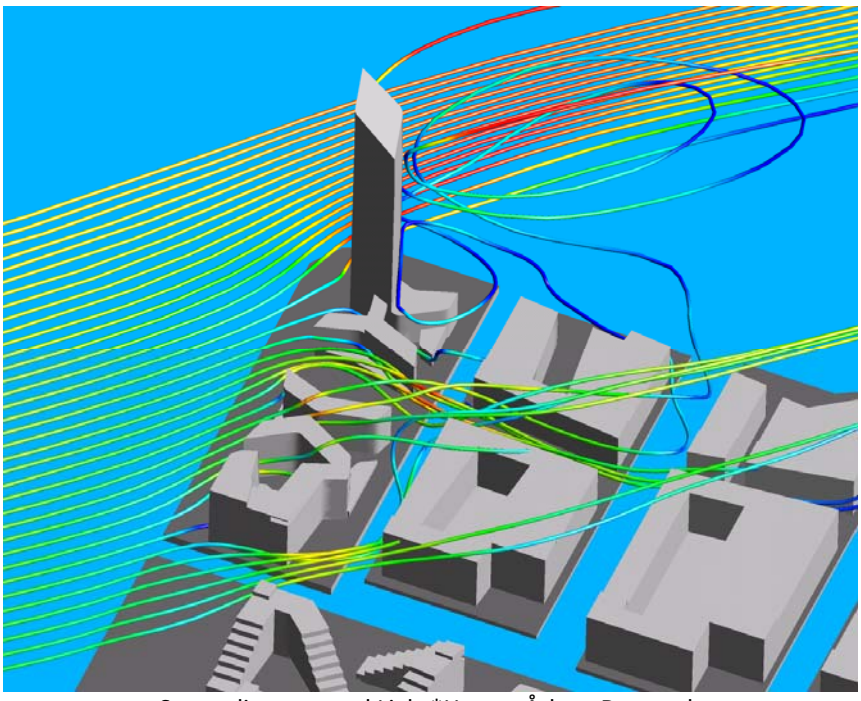
- Studying the theory of soil mechanics and/or soil dynamics
- Developing models of the spatial variation of soil properties
- Creating a finite-element model for stochastic analysis of soil
- Parameter studies of bearing capacities and deformations or vibrations
- Comparison with the results of other models or tests
- Updating the design criteria for foundations.

Contact person: Lars Andersen

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

Wind comfort modelling around tall buildings

Purpose: Tall buildings create their own local wind climate. In certain circumstances this can result in amplification of both the mean wind velocity and of the turbulence. This can generate very uncomfortable or even unsafe wind situations at ground level. The challenge is to combine the vision of the architect with methods of the civil engineer. CFD models are a strong tool for evaluating local wind climate. However, the results from a CFD model can be difficult to translate into variables which correspond to comfort levels and safety levels for pedestrians. The purpose of this project is to use CFD to study interaction between wind around tall building and operational criteria's for comfort and safety for pedestrians.



Streamlines around Light*House, Århus, Denmark

Main activities: This project will involve field, laboratory and computational methods. The main activities are:

- CFD modelling of existing tall buildings
- Comparison between CFD simulations and field measurements (local tall buildings)
- Scale experiments in water flume to generate reference data.
- Evaluate different turbulence models with respect to comfort criteria's
- Test different methods to avoid uncomfortable wind climate.

Contact person: Michael R. Rasmussen

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

Design models for soil structures with geotextiles

Purpose: Geotextiles are widely used throughout the world in four main functions: Separation, filtration, drainage and protection. Fibertex is the 4th biggest producer of nonwoven geotextiles in Europe, and is situated in Aalborg East.

The current design material available for soil structures with geotextiles is very "scattered", and the purpose of the project is, through analysis and laboratory testing, to get an overview and develop new or enhance the existing design models.

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 geotextiles
- Gathering and analysis of current design material
- Determination of focus areas
- Tests and theoretical assessment
- Computational modelling of geotextiles
- Design model creation.

Part of the project may be carried out as engineering practice, and it will be possible to perform experimental tests at the laboratory facilities of Fibertex A/S.

Contact person: Lars Andersen

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

Run-up generated slamming forces on access platforms for offshore wind turbines

Purpose: When a breaking wave hits a pile it can generate a high run-up on the front side of the pile. In case of an offshore wind turbine this can lead to very large slamming loads on the access platforms with slamming pressures up to 500 kPa. These loads are much larger than accounted for in the design of the access platforms for the Horns Reef 1 wind turbines. As a consequence of this underestimation of the loads on the platforms, strong damage has been observed and a repair project has been initiated.

Aalborg University has been involved in several model tests for this repair project and an empirical model to determine the loads have been established. However, quite some scatter is related to this model and the design loads can probably be reduced significantly if this scatter can be reduced. Tests at DHI have shown that water level gauges, as used in the AAU tests, might underestimate run-up heights by as much as 10 to 30 percent. Therefore, a main contributor to the scatter is expected to be the measurement system used to determine the run-up height. In the present project is examined the use of different methods to measure wave run-up in the laboratory. The outcome of the project should be a recalibrated load model using data from the new run-up model tests.

Main activities:

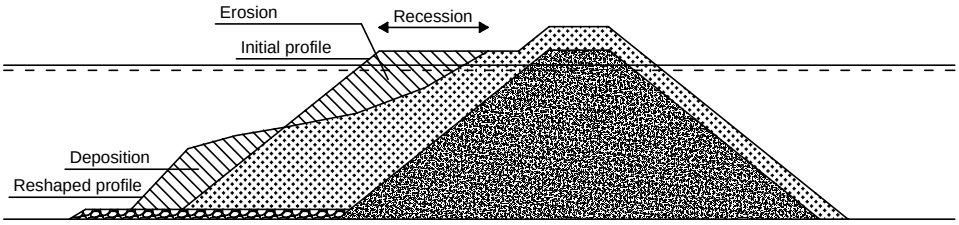
- Run-up measurements using resistance type water level gauges
- Run-up measurements using step gauges
- Run-up measurements using video camera (preferable high speed camera)
- Discussion of uncertainties related to the three measurement systems
- Calibration of run-up model
- Recalibration of slamming load model using existing and/or new data
- Alternative platform solutions.

Contact person: Thomas Lykke Andersen

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

Stability of berm breakwaters

Purpose: A berm breakwater is a rubble mound breakwater initially constructed with a large porous berm above or at still water level at the seaward side. During wave attack the berm breakwater will typically reshape into a s-shaped profile. In many cases the berm breakwater is a very good alternative to the conventional rubble mound breakwater and the concept is thus gaining more and more attention at the moment. The reshaping of a berm breakwater is often characterised by the recession of the berm as defined in the figure below.



A large number of model tests have previously been carried out at AAU to establish an empirical design formula for the recession of reshaping berm breakwaters. However, the influence of a number of important parameters was not tested and thus the formula might be somewhat uncertain in these areas. The purpose of the present project is to investigate the influence of these parameters and if necessary to update the existing recession formula.

Main activities:

- Initial test to compare with previous tests
- Tests to cover the influence of front slope angle, berm elevation, stone gradation and other parameters
- Update recession formula if needed.

Contact person: Thomas Lykke Andersen

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

Cost reduction and stochastic modelling of uncertainties for wind turbine design

The price per kWh electricity produced by wind turbines is approaching a level which is comparable with other types of energy production. However, there is still a need for cost reductions and to investigate up-scaling to large wind turbines (up to 15-20 MW). A rational approach for cost modelling is to use a life-cycle approach including all costs related to planning; fabrication, installation, operation, maintenance and demolition should be included. The optimal design is the one minimizing the total expected costs in the design lifetime. An important part of this framework is to model the uncertainties related to wind energy, to wind and wave loads for extreme and fatigue, and to operation and maintenance.

The purpose of this project is based on a literature review and available information to formulate a cost model for a typical wind turbine design and an uncertainty model. Next using up-scaling laws are established to investigate the optimal wind turbine size (up to 20 MW wind turbines).

Main activities:

- Establish a cost model for a typical wind turbine design including models for up-scaling
- Formulate stochastic models for
  - Wind profiles, turbulence models and wake effects
- Wave loads
- Formulate models for main failure modes (extreme load and fatigue)
- Reliability analysis by FORM and simulation
- Implementation in a computer program using existing algorithms
- Illustrative optimization studies – what is the optimal wind turbine size?

The project can be made in cooperation with an external partner and the UpWind project.

Contact person: John Dalsgaard Sørensen

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

Risk analysis of wind turbines

Wind turbines are a building/machine with many structural (tower, blades, foundation, …), mechanical (gearbox, bearings, …) and electrical (generator, …) components. The complete wind turbine is a complicated system where failure of some of the components can have serious consequences. Failure of a component can not only be critical for the wind turbine itself but also for the environment. The consequences for the environment can be loss of electricity supply which is serious if the supply from a complete offshore wind farm is lost. Another consequence in case of full or partial failure of e.g. a wind turbine blade is that people, buildings, etc. can be hit by a part from the wind turbine thrown several hundred meters away. In case of wind turbine icing also the risk of ice-fragments thrown away from the blades can be important.

The purpose of this project is to establish an overview of risks associated with wind turbine failures and icing. This includes description of failure modes, failure rates and consequences. Further to describe a methodology to assess these risks quantitatively and how to establish acceptable risks.

Main activities:

- Literature survey to give an overview of risks associated with wind turbine failures and icing:
  - failure modes
  - failure rates
  - consequences
- Use principles from risk analysis to describe a methodology to assess
  - Risks related to the wind turbine itself
  - Risks related to the environment
  - What are the acceptable risks?
- Selection of representative part of the whole wind turbine system and implementation in a computer program using existing algorithms
- Illustrative example studies.

The project can be made in cooperation with an external partner.

Contact person: John Dalsgaard Sørensen

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

Optimal, risk based operation and maintenance planning for offshore wind turbines

For offshore wind turbines costs to operation and maintenance are substantial and is one of the main focus points for development of offshore wind energy. One of the main problems is that operation and maintenance activities can only be performed in a cheap way (by bout) if wind speeds and wave heights are not too large. The purpose of the project is to develop a risk-based life-cycle approach for optimal planning of operation and maintenance. The approach should be based on pre-posterior Bayesian decision theory. Deterioration mechanisms such as fatigue, corrosion, wear and erosion are associated with significant uncertainty. Observations of the degree of damage can increase the reliability of predictions, especially in connection with condition-based maintenance.

Main activities:

- Identification of main problems associated with operation and maintenance of offshore wind turbines
- Establishment of a representative cost model for operation and maintenance during the lifetime – for one or more of the main components in a wind turbine
- Modelling of failure rates, weather windows (wind and wave dependent) and other uncertainties
- Formulation of risk-based framework for optimal planning of operation and maintenance
- Implementation in a computer program
- Illustrative examples – e.g. by application to gearboxes, cracks, corrosion, scour, etc.

The project can be in cooperation with an external partner.

Contact person: John Dalsgaard Sørensen

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

Robustness of structures

In the new Eurocodes it is required to document robustness of structures in high consequence class. Methods to assess robustness are only developed for a few types of structures. Development of guidelines to assess and quantification of robustness are ongoing internationally. The overall purpose of the project is to compare existing methods to assess robustness on a probabilistic / risk-based basis.

Main activities:

- Collect and compare different definitions of robustness of structures
- Stochastic modelling of load bearing capacities and loads for typical structures including use of existing information on materials and loads
- Comparison of different methods to assess system reliability of structures
- Formulation of method(s) to assessment of the robustness of a structures on a probabilistic / risk-based basis
- Application on e.g. timber structures – for example calculations on real structures (high-rise building in massive timber, glued laminated timber sports centre in Norway or a timber bridge in Austria)

The project is in cooperation with:

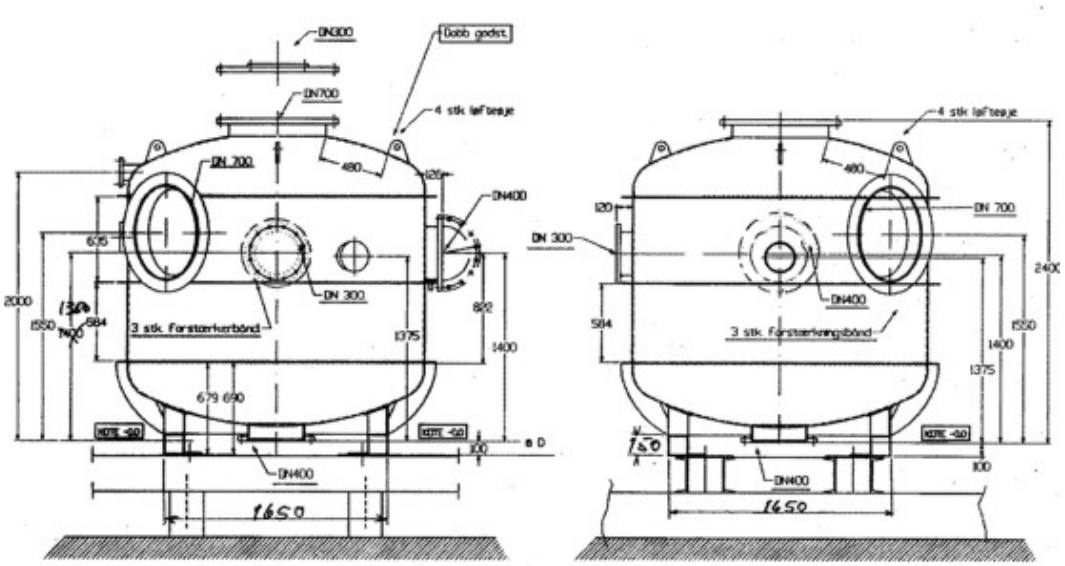
- JCSS 'Task-Group on Robustness' – http://www.cost-e55.ethz.ch/
- COST E55: 'Modelling of the performance of timber structures' - WG3: Robustness of systems. 2006-2010. http://www.cost-e55.ethz.ch/
- COST TU601: 'Robustness of structures'. 2007-2011. http://www.cost-tu0601.ethz.ch

Contact person: Poul Henning Kirkegaard / John Dalsgaard Sørensen

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:

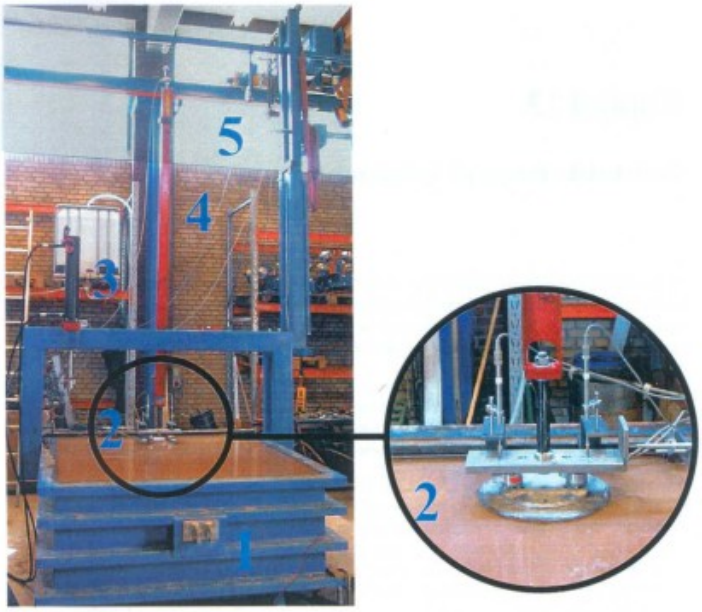
Resultaterne af disse forsøg sammenholdes med resultaterne fra de statiske forsøg. Herved kan det evalueres, om den varierende belastning har indflydelse på fundamentets bæreevne, stivhed samt plastiske deformationer.
Den elastiske opførsel under cyklisk belastning er vigtig for interaktionen med tårnet, 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.

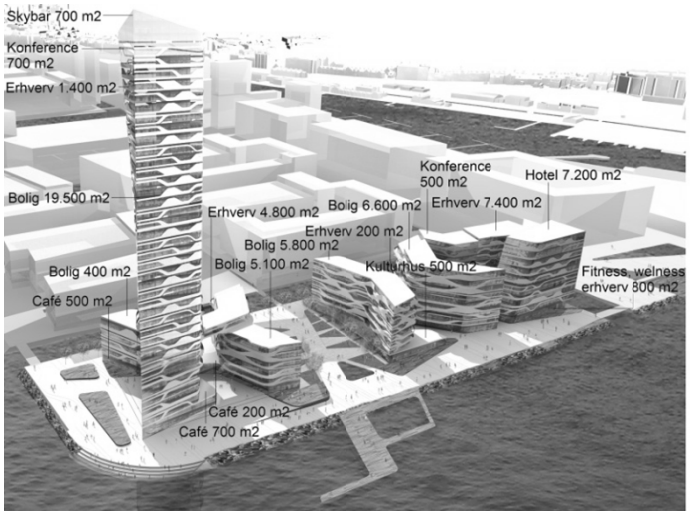
De simulerede bøttefundamentforsøg er de ovenfor beskrevne modelforsøg og de forsøg. Disse inkluderer udrænede forsøg, i hvilke bøtterne er påvirket af moment, horisontale og vertikale kræfter. De numeriske analyser er i stand til at simulere ændringen i størrelse og form af brudfladen i H-M/D planet,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

Contact person: Lars Bo Ibsen

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

Fundering af Light*house på Århus Nordhavn

Purpose: Light*house er et bolig- og erhvervsområde, der skal opføres som led i et større byggeprojekt, hvor den nuværende containerterminal på Nordhavnen i Århus skal omdannes fra industriområde til byområde. De eksisterende pier på havnen skal omdannes til en række kunstige øer, og på den yderste ø ud mod Århus Bugt skal bebyggelserne, der under ét kaldes Light*house, opføres. Områdets varetegn skal være et Danmarks højeste hus, 142 meter, placeret yderst på den anlagte ø ud mod Århus Bugt. Under hele området skal der anlægges et underjordisk parkerings-anlæg. En af de geotekniske udfordringer i forbindelse med byggeprojektet bliver at undersøge, hvordan højhuset kan funderes under hensyn-tagen til anlæggelsen af parkeringskælderen samt påvirkninger fra de omkring-liggende bygninger. Projektet gennemføres i samarbejde med Grontmij | Carl Bro



Main activities: Dette projekt tager udgangspunkt i højhus-byggeriet Light*house på Århus Nordhavn Hovedfokus er hvor-dan styrke og deformationsegen-skaber for den tertiære ler, der på lokaliteten findes til 70 - 90m dybde, kan bestemmes ud fra geotekniske forsøg og hvordan disse resultater kan anvendes i 3D finit element modellering.

- Jordens egenskaber analyseres ud fra boreprøver samt CPT-boringer foretaget på projektlokaliteten. I forbindelse med boringerne er der foretaget vingeforsøg, og der er optaget en række prøver hvorudfra vandindhold, kalkindhold, pH-værdi samt konsistensgrænser er bestemt.
- Intakte prøver fra boringerne analyseres vha. konsolideringsforsøg , **c**onstant **r**ate of **s**train-forsøg (CRS-forsøg) og triaxialforsøg.
- Alle de foretagne undersøgelser anvendes til at bestemme, hvordan jordens egenskaber varierer med dybden. Forsøgsresultaterne anvendes til at kalibrere de numeriske beregningsmodeller.
- Der gennemføres 3D Plaxis beregninger af sammenspil mellem funderingen af højhuset og parkeringskælderen.

Contact person: 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

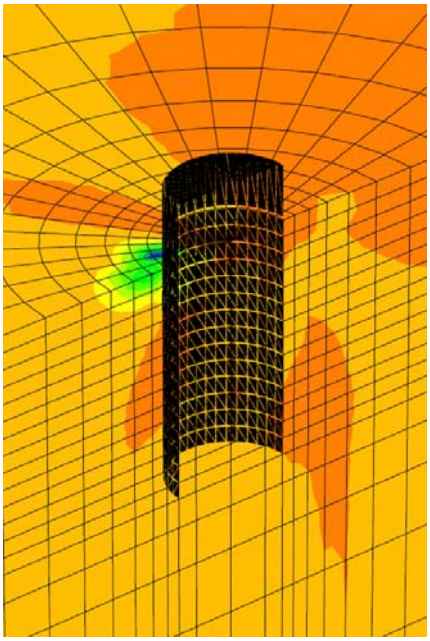
Theory: ☒☒☐ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☐

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

A project in cooperation with

DONG energy

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 person: Lars Bo Ibsen / Anders Augustesen

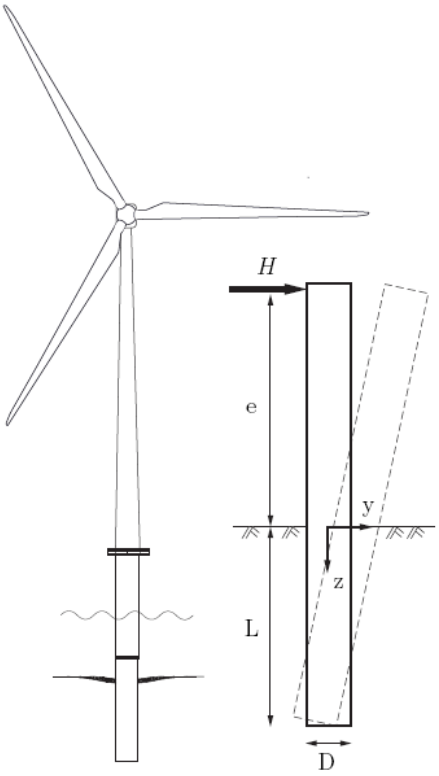
Theory: ☒☒☐ **Experimental work:** ☐☐☐ **Computer modelling:** ☒☒☒

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

A project in cooperation with

DONG energy

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:

- Series of laboratory tests shall be conducted on stiff piles in the pressure tank at AAU.
- Results shall 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 person: Lars Bo Ibsen

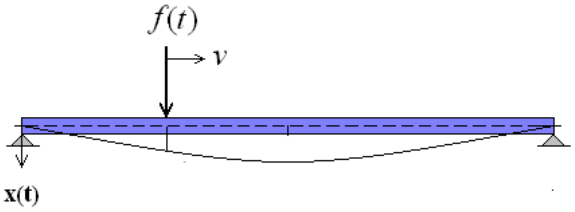
Theory: ☒☒☐ **Experimental work:** ☒☒☒ **Computer modelling:** ☐☐☐

Dynamisk personlast og stokastiske modeller for estimering af konstruktionsrespons

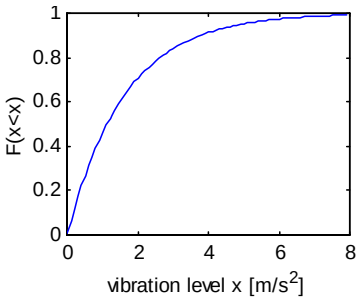
Purpose: Mange konstruktioner i dag er af forskellige årsager meget slanke, og deres laveste egenfrekvens så lav, at den frekvens mennesker bevæger sig ved (f.eks. gang- eller hoppefrekvensen) kan forårsage resonanssvinger (af gangbroer, tribuner, kontorarealer).

Gældende normer og standarder håndterer problemstillingen lettere semi-empirisk og typisk deterministisk selv om lasten fra mennesker i bevægelse grundlæggende er stokastisk, og selv om den dynamiske last fra mennesker udgør et stadigt stigende problem.

Projektets formål er vha. forskellige stokastiske modeller for belastningen at estimere den statistiske fordeling af konstruktionens dynamiske respons. Dette giver indblik i risikoen for overskridelse af uacceptable vibrationsniveauer, hvilket er vigtig information, når man vurderer konstruktionens anvendelighed og/eller sikkerhed.



Ganglast når v > 0 m/s, "hoppelast" når v = 0 m/s



Statistisk fordeling af respons

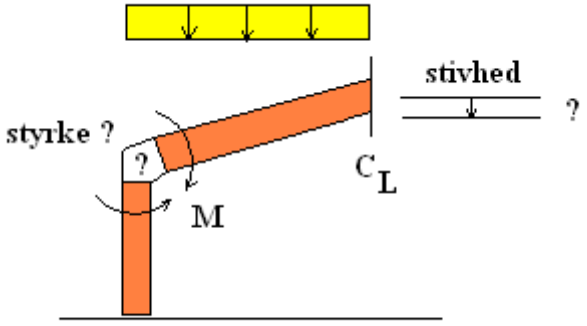
Main activities: Parameter-studier og numeriske simuleringer gennemføres for at belyse implikationerne af en stokastisk modellering (forskellige stokastiske modeller) af mekanismerne. Projektet kan tage udgangspunkt i en konkret konstruktion eller vibrationsfølsomme konstruktioner i almindelighed. Hvis ønsket eller fundet relevant på baggrund af dine undersøgelser forventes mulighed for at søge at kalibrere eller verificere centrale modeller knyttet til problemstillingen eksperimentelt (dette dog kun hvis der er tale om et langt afgangsprojekt, og projektet kan gennemføres uden en eksperimentel del).

Contact Person: Lars Pedersen / Christian Frier

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

Rammehjørner i limtræskonstruktioner

Purpose: Limtræsrammer er f.eks. ønskelige i konstruktioner, hvor der ligges stor vægt på konstruktionens æstetiske fremtoning. Et svagt punkt i en limtræsramme er imidlertid dens styrke og stivhed i rammehjørner. Men i selve rammehjørnet behøver man måske ikke anvende limtræ?



Kunne man ikke anvende (indskyde) en jernbeton-konstruktion i rammehjørnet eller en stålkonstruktion og derved afhjælpe de svagheder, som der umiddelbart er med anvendelse af limtræsrammer?... og samtidigt bevare limtræ i den øvrige del af rammen?

Projektets formål er at undersøge rammestivhed og -styrke af limtræs-rammer med forskellige løsninger i rammehjørnet (stål og/eller jernbeton og med løsningen med en fuld limtræsramme som reference).

Main activities: Der opstilles numeriske og analytiske modeller for rammeløsningerne, og disse søges verificeret eksperimentelt ved fuldskalaforsøg i laboratoriet. Måtte undersøgelserne vise, at løsninger med stål eller jernbeton i rammehjørner er anvendelige i relation til styrke og stivhed, kan det indikere at der er et potentiale for en ny type af ramme-konstruktioner.

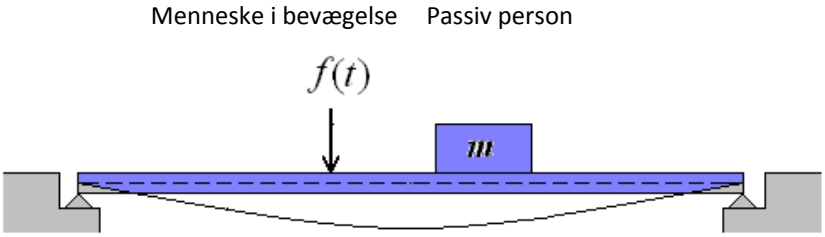
Projektet vil involvere samarbejde med eksterne parter (i særdeleshed limtræsproducenter), der har en interesse i at afdække mulighederne for alternative løsninger for limtræsrammer.

Contact Person: Lars Pedersen / Christian Frier

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

Dynamisk interaktion mellem mennesker og struktur

Purpose: I statikken modellerer man passive (siddende/stående) mennesker som en tillægsmasse på konstruktionen. I dynamikken modellerer man mennesker i bevægelse (f.eks. personer der går eller hopper) som en ren dynamisk last, der kan sætte konstruktionen i svingninger.



I vurderinger af vibrationsniveauer af konstruktioner, der bærer mennesker (f.eks. gangbroer, tribuner, kontorarealer) anvendes disse modeller for passive mennesker hhv. mennesker i bevægelse. Men hvor rimelige er disse modeller? Og hvor er der behov for forbedringer af modellerne?

Projektets formål er at studere mekanismer knyttet til dynamisk interaktion mellem mennesker og konstruktion med fokus på de mekanismer, hvor modellerne anført ovenfor har mangler, men hvor alternative modeller først kan bringes i spil i normsæt, når de er grundigt belyste og verificerede.

Main activities: Et udvalgt element indenfor dynamisk interaktion mellem mennesker og struktur gøres til genstand for undersøgelse. Dette kunne eksempelvis (og for at nævne blot en mulighed) være hvordan menneskers tilstedeværelse på konstruktioner ændrer dynamiske egenskaber for konstruktionen herunder dæmpningsegenskaberne, der er væsentlige ved en vurdering af konstruktioners adfærd ved resonans.

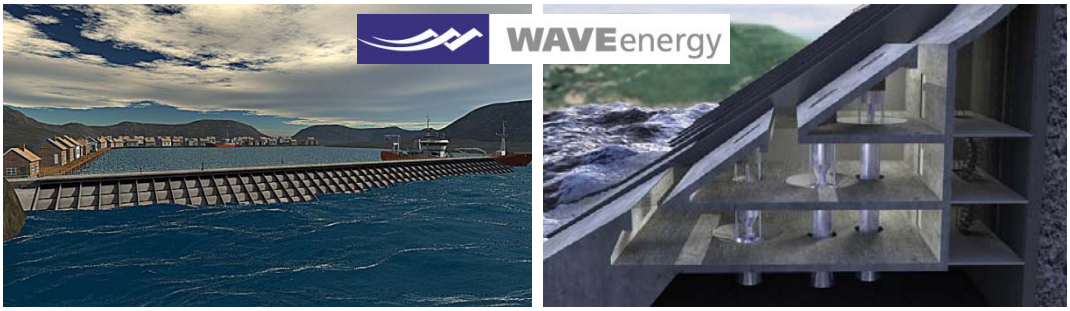
Mekanismerne knyttet til den valgte problemstilling undersøges gennem kontrollere forsøg i laboratoriet, hvilket skaber mulighed for at opstille og/eller kalibrere alternative dynamiske modeller for menneske-struktur interaktion ved at sammenholde testresultater med resultater af dine numeriske beregninger. De alternative modellers pålidelighed vil indgå som et centralt element i dine undersøgelser.

Contact Person: Lars Pedersen

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

SSG Breakwater Wave Energy Device

Purpose: The Sea-wave Slot-cone Generator (SSG) is a wave energy converter of the overtopping type initially designed to be installed near shore and on breakwaters for coastal and harbour protection, as illustrated below. The device is being developed by the Norwegian company WaveEnergy AS, in cooperation with Aalborg University. The device accumulates the overtopping water in a number of reservoirs at a higher level than average sea water level, for efficient capture of the energy in incoming waves. The potential energy in the stored water is, on its way back to the sea, converted into electricity, as it passes through specially designed low head turbines. The project will focus on one or more of the following key performance aspects of the geometrical design of the SSG – energy capture, structural loadings, overtopping over the whole structure, wave reflections from the structure. The goal is to provide design tools based on laboratory tests, supported by theoretical and numerical calculations for each of the investigated aspects.



Main activities: The work involved in this project can be divided into the following items:

- Planning of experimental setup – wave conditions, scaling, instrumentation.
- Carrying out the laboratory testing in the wave tank.
- Data analysis.
- Generalize results and compare to existing information from literature on related issues.
- Apply obtained results in a case study.

During the project, a close contact to the developer WaveEnergy AS is possible.

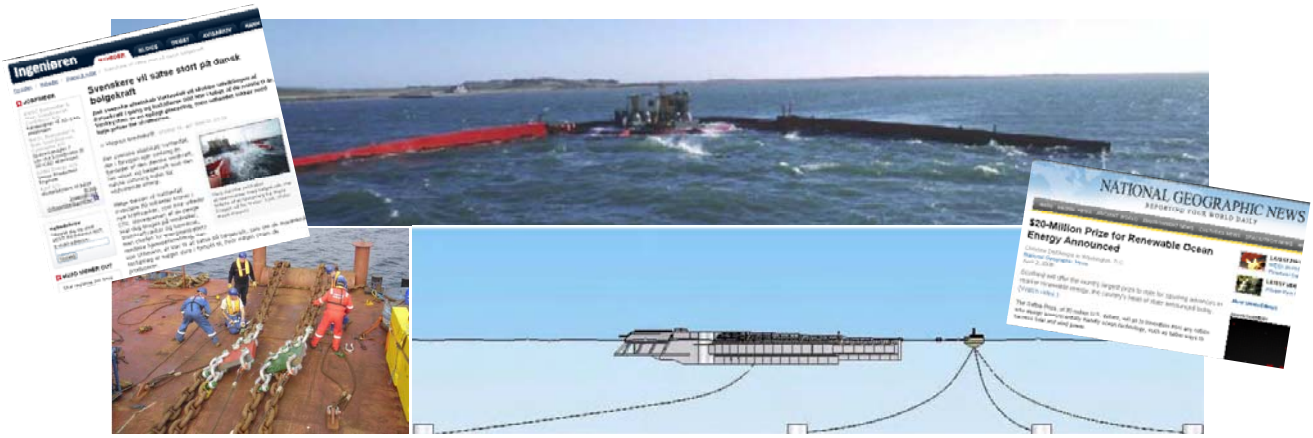
Contact person: Jens Peter Kofoed

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

This is one among a large space of options to work within the field of wave energy utilization – if you are interested in participating in the development of the renewable energy industry of the future, please drop by and we will formulate the project that fits your specific interests!

Mooring of floating Wave Energy Converters

Purpose: Currently, the race towards developing the most cost efficient wave energy converters is dramatically picking up in speed. One important element of this development is the design of cost efficient mooring systems. In the proposed project focus will be on generic design and comparison of different mooring layouts for a slack moored floating wave energy device. This could be an overtopping based device, such as the Wave Dragon, or other device types, e.g. LEANCON, DEXA, Pelamis, etc. Traditionally, this type of mooring systems is of the catenary type, using heavy steel chains attached to anchor blocks at the sea bed. However, other options exist, e.g. using weights and floaters on lighter moorings lines. This option should also be explored and compared in terms of cost efficiency.



Main activities: The work involved in this project can be divided into the following items:

- Design basis – device, location, environmental conditions (wave, wind, current), soil conditions, etc.
- Design criteria – loadings on mooring system, performance requirements, etc.
- Design of mooring systems – different alternatives. This involves analytical/numerical calculations and/or laboratory tests.
- Design of anchor points – different alternatives gravitation/piling/suction buckets. Involves analytical/numerical calculations and/or laboratory tests.
- Estimation of economics of the various alternatives.
- Conclusions – pros and cons of the alternatives.

Contact person: Jens Peter Kofoed

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

This is one among a large space of options to work within the field of wave energy utilization – if you are interested in participating in the development of the renewable energy industry of the future, please drop by and we will formulate the project that fits your specific interests!

New services in intelligent and responsive buildings - IB

Purpose: The latest progresses within Information and Communication Technology (ICT) have provided designers and building owners/users with possibilities to formulate and test new services in buildings. The project will focus on needs and requirements formulation as well as service integration in connection with design and evaluation of new services for offices, hospitals etc. with special regard to building users wishes and needs (end-users, operation and maintenance, facility management, and administration).

Main activities: The project will map the latest progress within ICT supported services, state-of-the-art implementations and future IB systems installations, and propose methodologies for creative Intelligent Building design and innovation. Some of the main activities focus on:

- State-of-the art and historic background
- Service descriptions (and Ontologies) on application (business) and technological levels
- Design considerations and changed methodologies in connection with building and IB systems innovative design.
- Proposals on a mixed reality virtual platform to support building users and service providers in creative Intelligent Building design and innovation.
- Future scenarios on user services in Intelligent and Responsive buildings.

Contact person: Per Christiansson / Kjeld Svidt

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

User participation in innovative building design

Purpose: During the late years there has been an ever-increasing focus on the possibilities to change the building process to raise quality on the final building products as well as the activities of actors involved in the building process. One reason for this interest is the new opportunities evolving due to introduction of advanced ICT. The project will focus on creative changes of the building process powered by user driven innovation activities.

Special attention will be given to innovative methods used in Virtual Worlds settings where building end-users can collaborate in asynchronous or synchronous modes on building models in different representations from symbolic to very realistic models. Important contributions to innovative user driven innovations methods are expected in terms of technical support strengths, weaknesses, opportunities and threats (SWOT).

Main activities: The project will map and describe the latest progress within ICT supported virtual worlds access and implement a Virtual Reality supported test case for user driven innovative design. Some of the activities are:

- State-of-the art and historic background on ICT supported Virtual Worlds.
- User driven innovation methods overview and analyses, partly based on discussion with Danish companies on experiences within the area.
- Design and implementation (including user needs and requirements capture) in Virtual Reality Panorama and CAVE of an innovative user-driven design methodology (in collaboration with VRMediaLab AAU).
- Realization of a test case in the Virtual Reality environment.
- SWOT analysis on own implementation supported by collected international experiences.
- Suggestions for improvement of innovative design methodologies and arguments for these improvements.

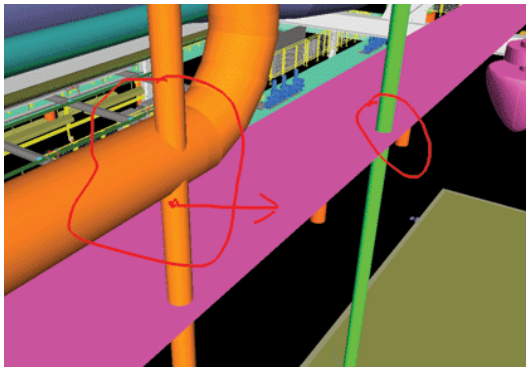
Contact person: Per Christiansson / Kristian Birch Sørensen

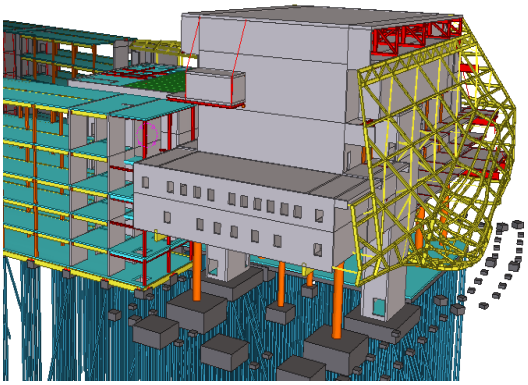
Theory: ☒☒☒ **Experimental work:** ☒☒☐ **Computer modelling:** ☒☒☐

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 person: Kjeld Svidt / Per Christiansson

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 person: Kjeld Svidt / Per Christiansson

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 armouring must be accounted for as well.



The idea in this project is to develop an ABAQUS model that can be applied to the finite-element analysis of reinforced concrete structures with a complex geometry, e.g. curved shells. The goal is to construct of a model that facilitates both a genuine model of the respective materials and, not least, a realistic description of the interfaces between concrete and steel. The project may focus on the analysis of a particular problem or structure.

Main activities:

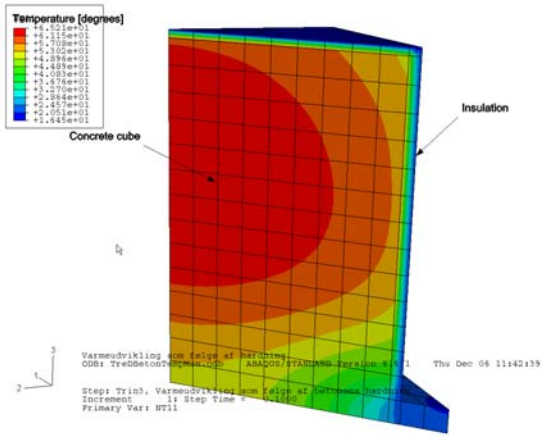
- Formulation of material models for concrete
- Modelling of composite shells in ABAQUS
- Modelling of interfaces between concrete and reinforcement
- Finite-element analysis of reinforced concrete structures
- Comparison of FE models with standard design methods.

Contact person: Lars Andersen / Eigil V. Sørensen / Christian Frier

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

Numerical simulation of stress development during concrete curing

Purpose: In order to secure an adequate quality of a concrete structure, it is essential to design a curing procedure which avoids excessive temperature differences within the concrete. Large temperature differences result in internal stresses which may cause crack development in the concrete. The purpose of the project is to model the temperature and stress development during curing of concrete with numerical tools, e.g. ABAQUS.



Hand calculation methods are only sufficient for calculating the temperature development for the simplest geometries. Complicated geometries and varying boundary conditions (degree of insulation, ambient temperature and wind speed) calls for numerical modelling of the phenomena.

Depending on the interest of the student(s), varying thermal and mechanical material behaviours can be included, such as time and temperature dependent parameters and concrete creep. Experiments can also be included, either in the laboratory or measurements on real concrete structures during curing.

Main activities: The project can include (but is not restricted to):

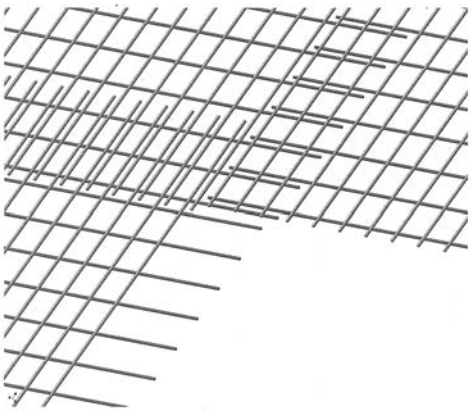
- Simulation of the temperature development in curing concrete
- Quantifying the effects of different types of insulation and their activation time
- Using different material models (elastic, plastic) to determine internal stresses
- Modelling the creep behaviour of concrete during curing

Contact person: Eigil V. Sørensen / Johan Clausen

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

Reinforced Densiphalt®

Purpose: Densiphalt® is used for industrial floors and pavements. The material is a composite combining asphalt and Ultra High Strength Concrete, thus creating a product with higher strength and modulus of elasticity than asphalt, but still flexible enough to be laid without joints. Densiphalt® can be reinforced in special cases, in order to increase rutting resistance or to reduce the risk of reflective cracking.
The purpose of the project is to evaluate the effect of steel reinforcement in Densiphalt®, with special attention to the zone around adjoining meshes.



Adjoining steel meshes with end- and right side overlaps.

Main activities: The project concerns the analysis of strains and stresses in reinforced Densiphalt® from thermal and traffic loads. Special attention must be given to the risk of crack formation in the zone around adjoining meshes. The following items may be part of the project work:

- Numerical modelling of the state of stresses and the risk of crack formation in reinforced Densiphalt®
- Validation of the numerical model by testing
- Determination of best practice for joining reinforcement meshes, considering the importance of a simple and secure laying process.

The work may be carried out in collaboration with Densit ApS.

Contact person: Eigil V. Sørensen

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

Clay stabilized Self Compacting Concrete

Purpose: Self compacting concrete (SCC) is a relatively new concrete type characterized by a very high degree of fluidity which makes it possible for the concrete to completely fill the form and encase the reinforcement without any need of vibration. In order to attain this flow behaviour it is of major importance that the paste phase of the concrete is sufficiently cohesive to avoid segregation of the coarser particles in the concrete. To this end, various types of organic additives have been employed to modify the rheology of the paste.

The purpose of the present project is to investigate stabilization of self compacting concrete using clay minerals.

Various forms of clay minerals are known to have a significant effect on the rheologic properties of concrete. This project will focus on a special type of clay which is produced in connection with the processing of coarse aggregate for concrete.

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

- Survey of the main relevant types of clay
- Use of existing/new models for the flow behaviour of SCC
- Experimental work in the concrete laboratory
- Development of mix designs for stable SCC using clay minerals.

The work may be carried out in collaboration with Kroghs A/S and Spæncom A/S.

Contact person: Eigil V. Sørensen

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

Pre-stressing using "smart materials"

Purpose: The purpose of the project is to develop a composite with an inherent pre-stressed state in order to increase the overall tensile performance of the composite.

Compared to metallic materials cement based materials suffer from their poor tensile strength. In pre-stressed concrete strained steel wires are embedded into structural concrete members in order to increase the overall tensile capacity of the member. This solution works well for relatively big structural members.

The idea of the present project is to employ a new class of materials, the so called smart materials or materials with "memory". They are special metallic alloys which can be bent, stretched and plastically deformed, and after heating to a certain temperature (say 50°C) they will return to their original shape by themselves. If fibres made of such alloy (say 5 – 10 mm long) were pre-strained and cast into an ultra-high-strength-cement based material (like a Densit® binder) and after hardening the composite was heated to the recovery temperature of the alloy, the component would be supposed to become internally pre-stressed. If the fibres were randomly oriented the component would be pre-stressed in all directions!

Main activities:

- Investigate alloys with memory in order to be able to select one or two that will work in this context
- Find a way to make pre-strained fibres
- Based on the amount of pre-strain, E-modulus and strength, consider the effect of fibre size and amount of fibres (theory and FEM)
- Cast samples and test the effect.

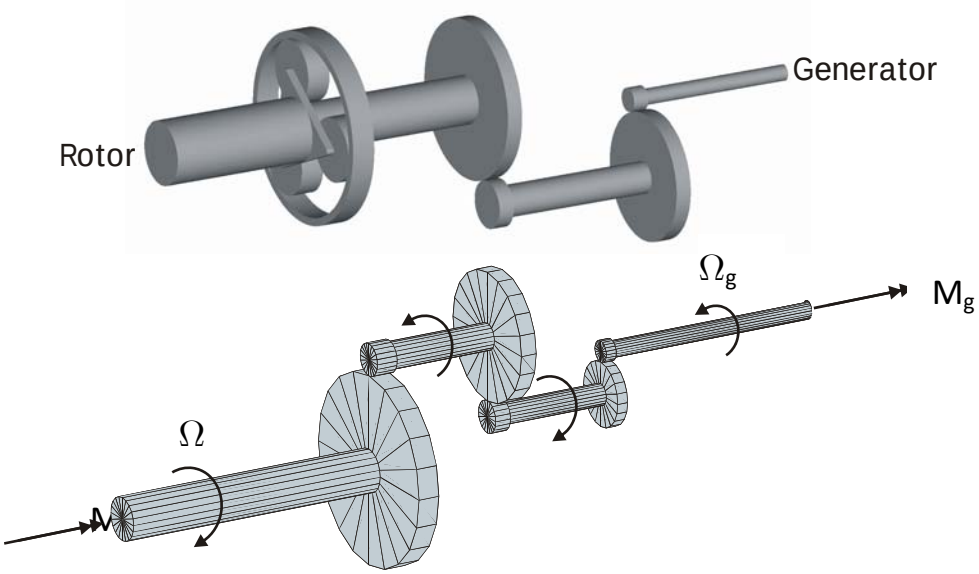
The work may be carried out in collaboration with Densit ApS.

Contact person: Eigil V. Sørensen

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

Modelling of drive-train and generator in wind turbines

Purpose: The rotor with the rotational frequency Ω provides a torque M on the rotor axis and hence a power $M\Omega$ to the drive train. The generator delivers a reactive moment Mg on the generator rotor, which must be in the opposite direction of the rotational frequency Ωg in case energy is extracted from the drive train. At stationary operation we have $M\Omega=Mg\Omega g$.



Main activities: The idea of the project is to make a computer model based on the multi-body principle (advanced substructure based finite element modelling).

- A standard multi-body program (ADAM) will be available. Resonance vibrations in gear and rotor axis are studied based on random variations of M(t).
- The possibility of using the generator torque for vibration control is investigated.
- Next, Mg(t) can be prescribed within a certain range by means of modern power electronics.

Contact person: Søren R.K. Nielsen

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

Optimal design of semi-active dampers in building structures

Purpose: Tall buildings are sensible to vibrations caused by turbulent wind and earthquake. These vibrations may be counteracted by the installation of dampers at optimal placed positions and with optimal direction of action. In the project especially so-called MR-dampers (Magnetic-Resonance) are investigated. The damping properties of these can be changed actively by charging a magnetic field in a way that is optimal for the present vibrations of the structure.

Contact person: Søren R.K. Nielsen

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

Multi-modal semi-active vibration control of wind turbine blades by means of tuned mass damper

Purpose: The project aims at the design of a semi-active damping system for multi-modal control of wind turbine blades. The principle is based on a point mass m on a pre-stressed wire with the pre-stressing force F0, and connected to the blade via a linearly viscous damper with the damping constant c. The mass is acting as a tuned mass damper, where the spring stiffness is provided via the geometrical stiffness of the wire. By active change of the pre-stressing force F0 several modes of vibration can be controlled simultaneously.

Contact person: Søren R.K. Nielsen

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

System identification and stability analysis of wind turbines with large periodic loading

Main activities:

- Aeroelastisk modellering af vindmølle med få betydende frihedsgrader
- Anvendelse af teknikker for stabilitets analyse af systemer med periodiske koefficienter, Floquet, Fourier udvikling, perturbation, (time-lifting?)
- Sammenligning af analytiske modeller med tidsdomæne simulering, for udvalgt respons, samt stabilitet.

Contact person: Søren R.K. Nielsen

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

Power output maximization of wind turbine parks

Main activities:

- Modellering af vind-flow i park, herunder modellering af enkelt wakes, samt overlejring af wakes
- Udvikling af pitch kontrol algoritme til styring af pitch på samtlige møller i parken for maksimering af park produktionen
- Sammenlign konvergenshastigheder for traditionel gradientbaseret optimering af pitch settings med genetisk algoritme baseret optimering for en stor park.

Contact person: Søren R.K. Nielsen

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

Flutter analysis of wind turbine wings

Main activities:

- Aeroelastisk modellering af en enkelt roterende vinge (2-3 flap modal frihedsgrader, samt en enkelt torsions frihedsgrad. Stationær og transient aerodynamisk last)
- Undersøg betydningen af strukturel modal kobling mellem flap og torsion for flutterstabilitet
- Undersøg betydningen af masse, shear og aerodynamisk center placering for flutterstabiliteten
- Undersøg betydningen af forudbøjning af vingetip i kantvis retning, mod vingebagkant (blade sweep) for flutterstabiliteten.

Contact person: Søren R.K. Nielsen

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

Development of stability tools using Flex5

Main activities:

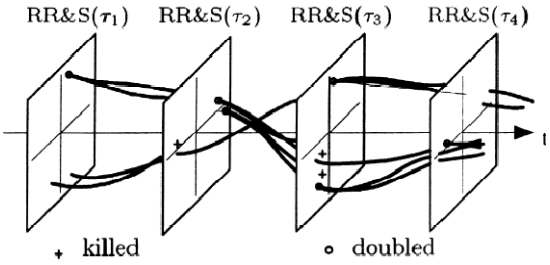
- Numerisk linearisering af Flex5 for fordefineret arbejdspunkt, herunder specielt udvikling af metode for numerisk bestemmelse af aero-elastisk modaldæmpning
- Plotning af Campbell diagrammer
- Visualisering af komplekse modalformer
- Bestemmelse af frekvensresponsfunktion matrix, (FRM)
- Tilpasning/ændring af FRM mhp. dynamisk tuning for reduktion af udmattelseslaster
- Programmering af passende GUI.

Contact person: Søren R.K. Nielsen

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

Estimation of extreme response and failure probabilities of wind turbines in normal operation using controlled Monte Carlo simulation

Vindmøller øges stadig i størrelse uden at stivheden af konstruktionen øges proportionalt, hvorved følsomheden over for dynamisk respons bliver stadig mere udtalt. Dynamikken i responset opstår primært som følge af turbulens i det indkommende vindfelt. På grund af indflydelsen af kontrolsystemer og strukturelle ikke-lineariteter bestemmes møllens dynamiske respons sædvanligvis ved, at et simuleret turbulensfelt påføres en numerisk strukturmodel af møllen, hvorefter ekstremværdier af flytninger og spændinger i kritiske tværsnit af vinger, tårn og transmissionssystem i en belastningsperiode af typisk 10 minutters varighed bestemmes.



Russian Roulette and Splitting (RRS) – line sampling

De registrerede ekstremværdier varierer fra simulering til simulering, og en sådan standard eller crude Monte Carlo simulering bestemmer blot et enkelt udfald af ekstremværdierne. Dimensioneringen af strukturen skal baseres på fordelingen af ekstremresponserne i hele konstruktionens stipulerede levetid. Fordelingen af disse bestemmes normalt ifølge standarden IEC 61400-1 ved ekstrapolation af de tilsvarende ekstremfordelinger i reference belastningsperioden. En sådan ekstrapolation er dermed kun muligt, hvis ekstremfordelingen i referenceintervallet er kendt tilstrækkelig nøjagtig, hvilket igen nødvendiggør, at mange uafhængige Monte Carlo simuleringer tilvejebringes.

Som alternativ har projektet til formål at udvikle såkaldte controlled Monte Carlo simuleringsalgoritmer til vindmølledimensionering, hvor et mere nøjagtigt estimat af fordelinger af ekstremværdier og svigtsandsynligheder i referenceintervallet opnås for det samme antal numeriske simuleringer. Nøjagtigheden opnås, fordi metoden udelukkende opererer med realisationer, der bevæger sig i et 'væsentligt' område med høj svigtsandsynlighed, bl.a. ved såkaldte line-search simuleringsteknikker.

Contact persons: Søren R.K. Nielsen / John Dalsgaard Sørensen

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

Dynamic stability of wind turbines

Purpose: From a dynamic point of view, a wind turbine experiences a rather complex behaviour. Especially, when the wind turbine is in operation, the aerodynamic loading on the rotor is significant and interacts dynamically with the elastic deformations of the structure and the turbine controller which continuously adjust the blade pitch (turning the blades) to maintain electrical power and optionally seek to reduce fatigue loads. This mutual dependency between aerodynamic, elastic/inertial and control forces are denoted *aero-servo-elasticity* and the net effect is a non-linear response characteristic which may only be solved by numerical time-domain methods. In order explicitly to judge the aero-elastic stability of the wind turbine, i.e. to check if the turbine acts stable or unstable, a linearization of the dynamics is required. For the structural dynamics this is done by numerically finding partial derivatives and for the aerodynamics, especially the aerodynamic damping this is done by integration of aerodynamic forces through one full natural mode. However, the natural aero-elastic modes originating from aerodynamic and elastic/inertial forces are not known a-priori and an iterative scheme to make the numerical linearization method converge must be developed.

When the linearization scheme is established the project will focus on exploring how aero-elastic stability depends on the size of the wind turbine. Since stability is expected to decrease with size and since the size of wind turbines in industry will keep growing it will be interesting to reveal the design conditions for wind turbines of the future. For this purpose, 2-4 wind turbines with different size will be roughly designed and modelled using the program LAC_{flex} provided by LAC engineering – a wind energy consultancy, which will participate in the project.

Main activities: This project will explore the design conditions, in respect of aero-elastic stability, for wind turbines of the future.

- Development of a numerical linearization scheme for a non-linear aero-elastic wind turbine model using the program LAC_{flex} provided by LAC engineering
- Rough design and modelling of 2-4 different in size wind turbines using standard design methodologies
- Determine relation between the size of wind turbines and the aero-elastic stability
- Conclusions on design conditions of future large wind turbines.

Contact person: Søren R. K. Nielsen (AAU), Bo Juul Pedersen (LAC engineering)

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

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