DTU Civil Engineering
Department of Civil Engineering

BSc-Project (20ECTS):

Distortional Mechanics of Thin-Walled Structural Beam Elements

The project focuses on a novel generalized beam theory in the context of distortion of the cross section. The new theory is a considerable theoretical improvement which can provide fast analysis of complex dynamic problems and stability related issues. Thus making it a good alternative to classical and time consuming finite element calculations.

Keywords: Thin-walled beams; Generalized Beam theory; Distortion; Stability; Buckling; Warping; Semi-discretization.

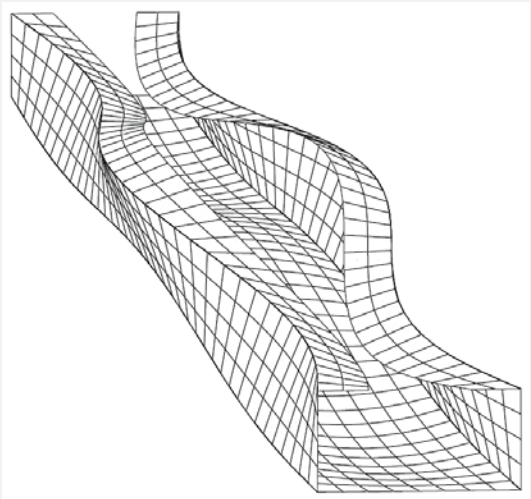
Thin-walled members are often used in the civil, mechanical and aerospace industry due to the effective use of the materials.

Because of an increased use there has been increased focus on optimization and more detailed calculations. The present project deals with a novel theory concerning more detailed calculations in the context of distortion of the cross section.

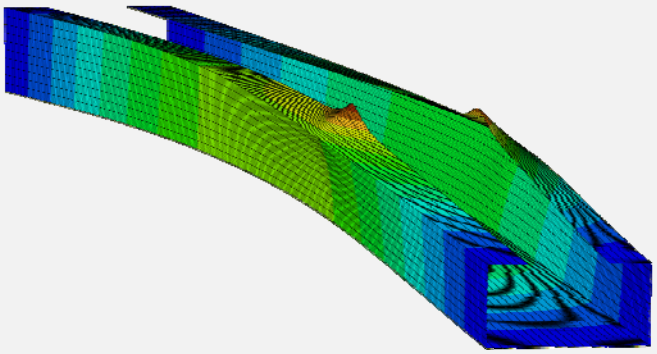
The new theory is a considerable theoretical improvement which can provide fast analysis of complex dynamic problems and stability related issues. Thus making it a good alternative to classical and time consuming finite element calculations.

Due to this mode based approach the mechanics of the problems at hand are very well described and understood.

Thin-walled building steel structure. These structures are generally optimised to save material which increases the need and focus on optimization and more detailed calculations.



GBT column buckling mode shape of a lipped channel column in pure compression.



Typical time consuming and CPU expensive shell finite element model using 92106 degrees of freedom. By using a generalized beam theory (GBT) model the number of degrees of freedom can be reduced to only 264 dofs.

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DTU Civil Engineering
Department of Civil Engineering

MSc-Project (30ECTS):

Distortional Mechanics of Thin-Walled Structural Beam Elements

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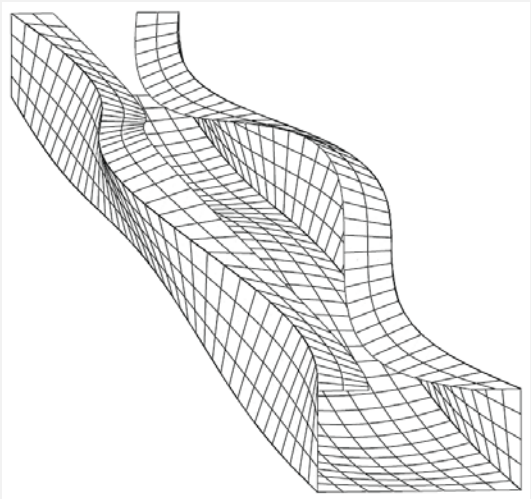

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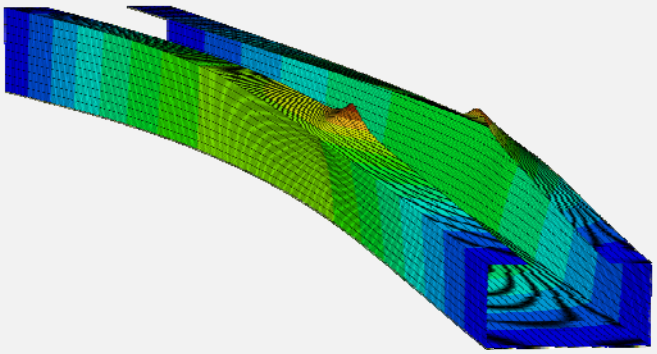

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Diplom/civilbachelor-projekt (15-20 ECTS) eller Kandidat-projekt (30ECTS):

Nye samlinger i betonelementbyggeri

Elementbyggeri er dominerende i Danmark. Den store udfordring i byggeri med præfabrikerede enheder er altid samlingerne og dette projekt fokuserer derfor på testning og dokumentation af den nye wirebox samling.

Nøgleord: præfab, beton, samlinger, testning

Baggrund

Elementbyggeri er særdeles meget anvendt i Danmark og en række andre lande, men med den moderne arkitektur vokser mængden af specielle elementer. Dette giver voksende udfordringer til samlingerne i det komplekse byggeri.

Der er derfor et klart behov for nytænkning i hvordan elementer kan samles nemt og sikkert og samtidig sikre en god performance af samlingen.

Et smukt eksempel på elementbyggeri

Projektet

Projektet fokuserer primært på testning af forskellige typer samlinger med hovedvægt på wireboxsamlingerne, samt en kritisk vurdering af disse samlingers kvalitet igennem sammenligninger med andre samlingstyper.

Projektet kan for kandidatstuderende udvides til at omfatte en mere teoretisk vinkel i form af beregninger på brudformerne i stål, beton og mørtel.

Testelement i testopstillingen[1]

Projektet gennemføres i 2 mands grupper i samarbejde med producenten EXPAN.

[1]Fra projekt af Rikke Sejer og Rikke Nordkvist, 2013.

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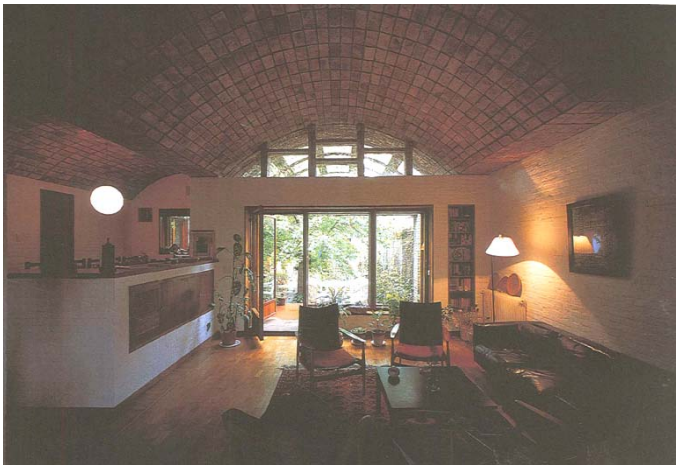
BSc-Project (20ECTS):

Konstruer et DOGMEHUS:
Konstruer et passivhus i et og kun et materiale

Projektet undersøger mulighederne for at bygge et passivhus ved at anvende et og kun et materiale til alle konstruktioner bortset fra fundamentet, det vil sige til gulve, vægge og lofter. Huset kan være et enfamiliehus, et rækkehus eller et sommerhus.

Eksempel på konstruktion i krydslimet massivtræ.



Eksempel på konstruktion i teglsten.

Nøgleord: passivhus, materialekendskab, konceptuelt design, konstruktive systemer, innovation, byggeteknik.

Baggrund
Parcelhusets arkitektur og byggeteknik er stærkt præget af en funktionstankegang og en gradvis udvikling af kravene til de enkelte bygningsdele, der betyder at for eksempel en væg er opbygget af mange forskellige lag i hvert deres materiale og med hver deres funktion. Dette giver en række ulemper, fx samles de forskellige materialer med forskellige samlingsmetoder og der opstår meget komplicerede geometrier langs kanter og i hjørner der tilsammen giver stor risiko for fejl under opførelsen og ved ombygning. Forskellige levetider for de forskellige materialer betyder at intervallet mellem renoveringer bestemmes af materialet med den korteste levetid og fører til en dårlig ressourceudnyttelse.

Projektet
Arkitektur og planløsning kan tage udgangspunkt i et eksisterende hus eller indgå i projektet.
Den store begrænsning i materialevalg lægger op til at der tages kontakt med en virksomhed og udvikles nye innovative løsninger i projektet.

Projektet vil typisk indeholde følgende faser:
- Fastlæggelse af forudsætninger
- Undersøgelse af materiale
- Undersøgelse og afklaring af mulige statiske systemer
- Undersøgelse og afklaring af opbygning af tværsnit i væg, loft og gulv
- Overslagsdimensionering af konstruktion
- Undersøgelse og afklaring af samlingsmetoder
- Fremstilling af samling eller model
- Afprøvning af samling eller model
- Endelig beregning og dimensionering
- Dokumentation med tegninger og rapport

Eksempler på konstruktionsmateriale:
- savskåret træ
- krydslimet massivtræ
- betonelementer
- in-situ støbt armeret beton
- porebetonblokke eller letklinkerbetonblokke
- teglsten og kalkmørtel
- tyndplade i stål

Projektet gennemføres i grupper af to studerende.

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BSc-Project (20ECTS):

Skaller i krydsfiner
Koncept, analyse, design og konstruktion

Dette projektforslag dækker egentlig en helt række projekter under en samlet overskrift. Baggrunden er konstruktionen af en kuppel i krydsfiner til Roskilde Festivalen 2011, 2012 og 2013. Tidsplanen var stram, så det var ikke muligt at undersøge alle aspekter i opgaven.

Baggrund
En skalkonstruktion er en usædvanlig konstruktion. Generelt er en skalkonstruktion en materialeøkonomisk konstruktion, men en del af materialeøkonomien kan hurtigt sættes til, fordi geometrien er vanskelig og de sædvanlige beregningsmetoder ikke umiddelbart kan anvendes.

Eksempler på projekter
Geometrisk analyse
Hvordan udnytter man bedst muligt krydsfinerplader i standardmål til at dække en - i princippet - krum flade. Skal elementerne fx være plane eller krumme?

Vindtunnelforsøg
Dimensioneringen er meget afhængig af vindlast og snelast. Hvis ikke kuplen er helt glat, kan vindlasten reduceres. Hvor meget den kan reduceres må fastlægges ved forsøg i vindtunnel.

Sikkerhed mod buckling
Buckling har i mange tilfælde vist sig at være kritisk for skalkonstruktioner. Sikkerhed mod buckling kan opnås med simple betragtninger, matematisk analyse eller 2. ordens numeriske beregninger.

Projektering
Beregning og dimensionering kan foretages ved hjælp af normerne og anvendelse af sædvanlige analysemetoder og beregningsprogrammer. Blot skal man sikre sig hele tiden at være på den sikre side.

Konstruktionsdesign
Skallens æstetiske virkning og konstruktive effektivitet er i høj grad afhængig af den konkrete og praktiske udformning af elementer og samlinger. Bygning og test af elementer indgår i dette projekt.

Fundering
At fundere en midlertidig konstruktion er en anden opgave end at fundere en permanent konstruktion. Forslag til udførelse, analyse og dimensionering samt afprøvning vil indgå i dette projekt.

Et projekt vil typisk indeholde følgende faser:
- Teoretisk afklaring
- Numerisk analyse
- Designoplæg
- Modelbygning
- Afprøvning

Projekterne gennemføres i grupper af to studerende.

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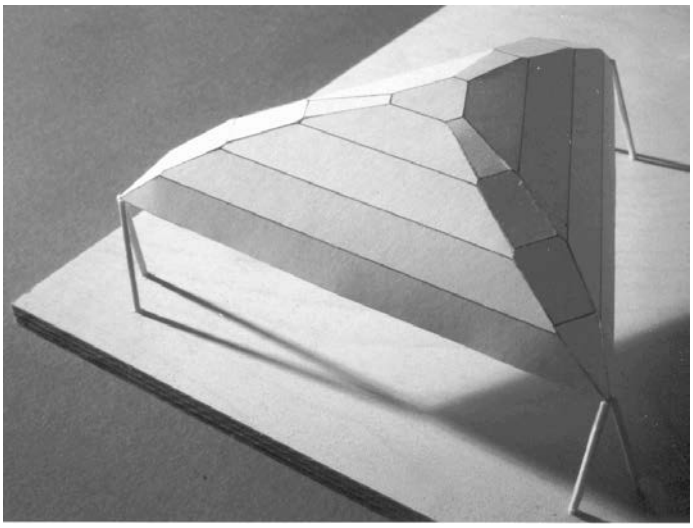
MSc-Project (30ECTS):

Polygonal shells - design and analysis

Heinz Isler designed and built a large number of quadratic and rectangular shells in reinforced concrete for factories and warehouses. Many years later it was found that such polygonal shells had a very interesting and contra intuitive property: If they had elliptical curvature, they just have to be supported in the vertices.

Factory building covered by rectangular shells. Designed and build by Heinz Isler 1954.



Simple faceted paper model of triangular shell. (Henrik Almegaard 1989)

Background

A polygonal shell is a curved shell structure with a planar polygonal edge. Heinz Isler designed and build a large number of quadratic and rectangular shells in reinforced concrete for factories and warehouses. Many years later it was found that such polygonal shells had a very interesting and contra intuitive property: If they had elliptical curvature, they just had to be supported in the vertices.

Model studies show that this type of shell is extremely stiff which indicate that it is structurally very efficient. But how do they work structurally? How can we determine proper geometrical forms? And how could we design such shells from a practical point of view?

Project outline

1) An investigation into geometrical methods for determining a smooth surface with positive Gaussian curvature and planar polygonal edge.
2) An investigation into geometrical methods for determining such faceted surfaces.
3) A number of structural analyses of polygonal shells using an appropriate Finite Element program.
4) A qualitative description of the structural behavior of these shells.
5) Design proposals for polygonal shells build as smooth, grid and/or plate shell structures, taking aesthetical, structural and practical issues into consideration.

The ultimate goal for this project is to introduce the concept of polygonal shells for architects and structural engineers and produce a guideline for design of this type of shell.

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MSc-Project

Structural design and behaviour of ECC modular composite floor panels

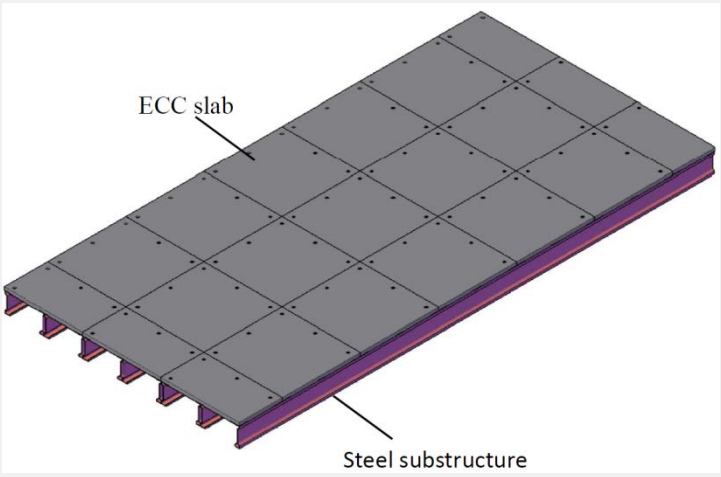
The project focuses on optimal design of modular composite floor panel consisting of ECC slab (~50mm thick) and lightweight steel beams.

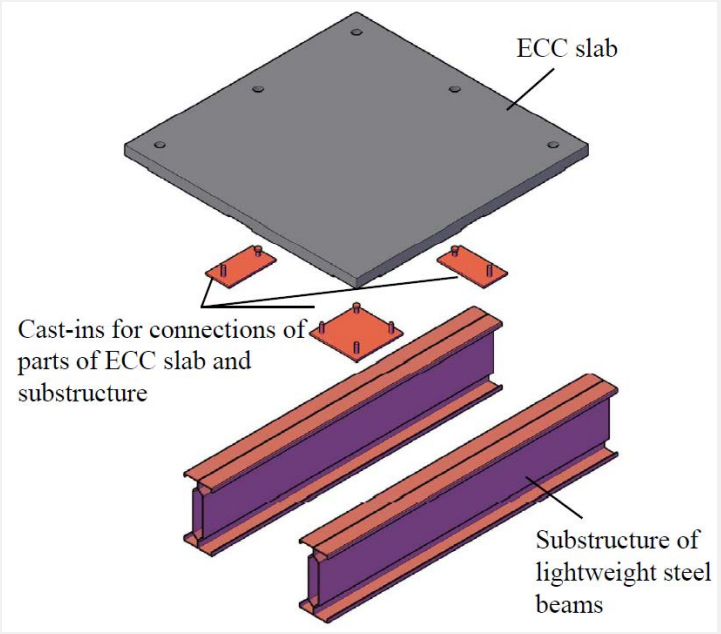
The globally increasing need for economic, durable, attractive and high quality housing requires innovative technologies to meet demands, while considering environmental impact, sustainability, and life-cycle performance. Current construction practices typically involve prefabricated modular structures and intrinsically reinforced structural elements that can be automatically manufactured in a factory setting with mass-customized design and a multitude of assembly configurations.

Recent innovative advances in fibre reinforcement technology and the introduction of ECC have provided the prerequisites to achieve a high performance and economically viable alternative to traditional reinforced concrete materials. The unique feature of ECC is its ability to increase its tensile loading capacity in the cracked stage, showing a so-called tensile strain hardening behavior, leading to a ductile deformation response similar to that of metals and steel reinforced concrete. As a result of these unique material properties, ECC can to be used economically in particular structural applications, such as thin-walled precast concrete elements. One of these applications can be to use ECC in the prefabricated modular type composite floor panels.

The project focuses on the design and testing of modular composite floor panel of 8 m span. That involves:

- develop and design the shear connection between lightweight steel substructure and cast-ins (using HILTI X-ENP-19 or similar);
- to design and test the optimal thickness of ECC slab;
- to design shear connection between ECC slab and cast-ins based on previous testing;





Light-weight composite panel with ECC deck

- full scale composite floor panel (span 8m) test under 4 point bending (involves material testing too – compressive, tensile strength and E modulus).

MSc-Project

Structural design and behaviour of ECC modular composite floor panels

The project focuses on optimal design of modular composite floor panel consisting of ECC slab (~50mm thick) and post-tensioned concrete substructure

The globally increasing need for economic, durable, attractive and high quality housing requires innovative technologies to meet demands, while considering environmental impact, sustainability, and life-cycle performance. Current construction practices typically involve prefabricated modular structures and intrinsically reinforced structural elements that can be automatically manufactured in a factory setting with mass-customized design and a multitude of assembly configurations.

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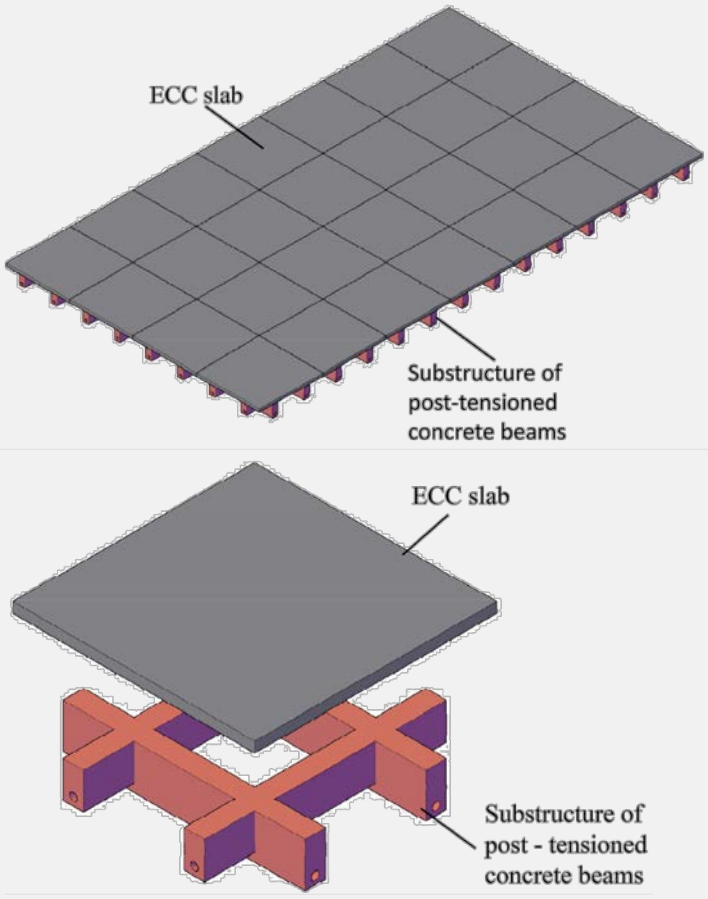
The project focuses on the design and testing of modular composite floor panel of 8 m span. The panel consists of ECC slab with reduced shrinkage and post-tensioned concrete substructure. That involves:

- Investigate techniques to reduce/midigate drying shrinkage in ECC (for example: Yang et al, Shrinkage reducing measures for engineering cementitious composites, Journal of Wuhan University of Technology, 2008, Volume 23, Issue 6, pp. 907-911; Zhang et al, Engineered cementitious composite with characteristic of low drying shrinkage, Cement and Concrete Research — 2009, Volume 39, Issue 4, pp. 303-312)



Light-weight composite panel with ECC deck

- to design optimal dimensions of post tensioned concrete substructure;
- to design shear connection between ECC slab and concrete substructure;
- to design connection between modular panels – to provide vertical and horizontal “shear” connection;
- full scale composite floor panel (span 8m) test under 4 point bending (involves material testing too – compressive, tensile strength and E modulus).

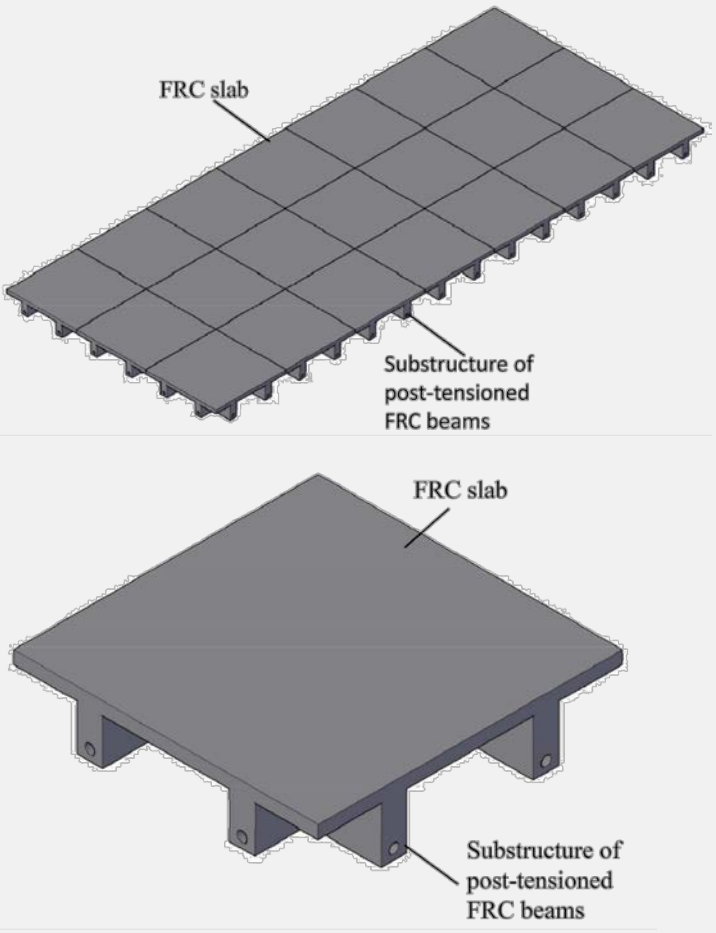
MSc-Project

Structural design and behaviour of ECC modular composite floor panels

The project focuses on optimal design of modular composite floor panel consisting of SFRC slab and post-tensioned SFRC substructure

The project focuses on the design and testing of modular composite floor panel of 8 m span. The material used for panels is steel fiber reinforced concrete (SFRC) with reduced shrinkage. The project involves:

- design optimal dimensions of post tensioned concrete substructure and slab;
- design connection between modular panels – provide vertical and horizontal "shear" connection;
- do standard flexural round panel tests of SFRC, ECC and SFRC with reduced shrinkage according ASTM 1550;
- full scale composite floor panel (span 8m) test under 4 point bending (involves material testing too – compressive, tensile strength and E modulus);
- to compare ECC to SFRC behaviour of slab structure



Light-weight composite panel of FRC

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MSc-Project (30ECTS):

The constructability and capacity of shear connectors for ECC modular composite floor panels

The project focuses on the investigation of the local transfer of shear forces at the interface between a thin-walled Engineered Cementitious Composite (ECC) slab and steel girders. The task is to study the constructability and capacity of various types of shear connectors.

Keywords: ECC; modular panels; shear connectors; composites

The globally increasing need for economic, durable, attractive and high quality housing requires innovative technologies to meet demands, while considering environmental impact, sustainability, and life-cycle performance. Current construction practices typically involve prefabricated modular structures and intrinsically reinforced structural elements that can be automatically manufactured in a factory setting with mass-customized design and a multitude of assembly configurations.

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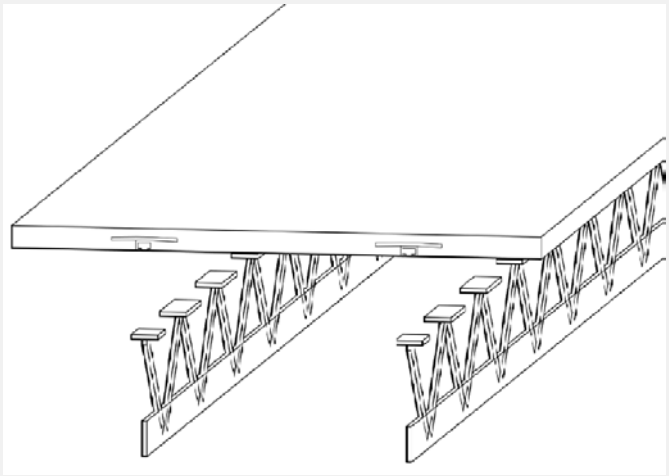
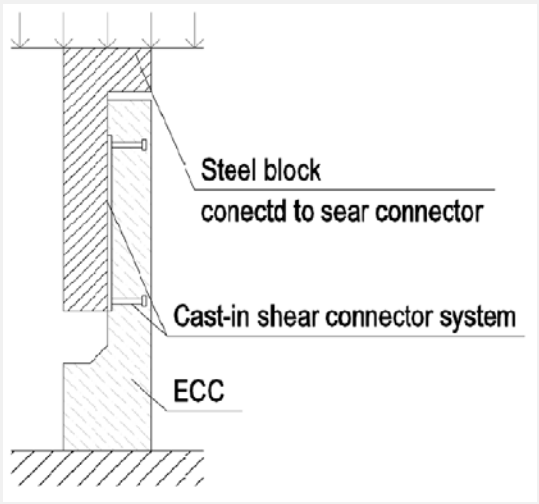
Shear connection design plays a very important part in all composite type structures due to traditionally brittle failure. To design cheap, light and easy constructible modular panel, the shear connection should be simple, but capable of carrying adequate load. The project involves the design and testing of shear connection system.



Light-weight composite panel with ECC deck



Test setup for experimental investigation of shear connector behaviour

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MSc-Project (30ECTS):

Comparison of simulated response prediction to wind loading to full-scale observations on a high-rise building

The project focuses on the dynamic response of a high-rise building, the east tower of the European Court of Justice in Luxembourg, to wind loading. Particular aspect is the comparison of response prediction in the design phase and real-life observations on the completed structure in full-scale.

Keywords: *wind load; high-rise building; structural dynamics; full-scale testing & monitoring; dampers*

The response prediction is based on experimental studies performed in 2001/2002 in the boundary-layer wind tunnel at FORCE Technology and the full-scale observations have been conducted in the period 2007 to 2009.

The building is equipped with tuned liquid dampers, which have been tested for performance efficiency in a separate study. In this connection, the dynamic properties of the full-scale structure could be established with high accuracy. The study should give answer to the question of how close are the observed responses to the predicted responses, both with and without damper – depending on how much measurement data are available. Second special aspect is the analysis of the response process characteristic with respect to human comfort to horizontal acceleration.

Wind data measured on the nearby international airport in Luxembourg are available and need to be transferred to the actual construction site on the Kirchberg Plateau.

The completed twin-towers of the European Court of Justice on the Kirchberg Plateau in Luxembourg.

Main focus points of the study are:

- Accuracy evaluation of the predicted response based on the full-scale measurements under ambient excitation (both with and without damper).
- Identification of the main contributors regarding inaccuracy.
- Analysis of the response process characteristic with respect to human comfort to horizontal acceleration.

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Department of Civil Engineering

MSc-Project (30ECTS):

Feasibility Study of using Rotational Friction Damper for Wind-induced Vibrations in Tall Buildings

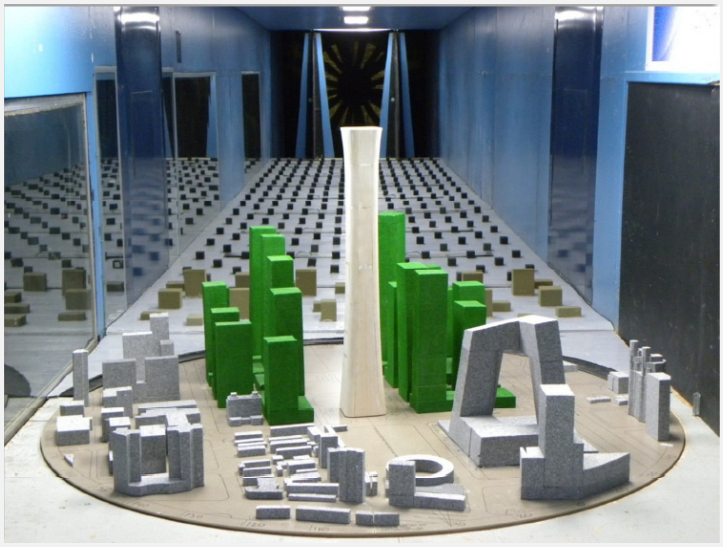
The project focuses on studying a novel approach of using rotational friction dampers (RFD) in tall buildings to mitigate wind-induced vibrations. RFDs have so far been used to safeguard tall structures under earthquake loading. This project shall research whether this concept can be transferred to wind-induced motion.

Keywords: wind load; high-rise building; damping; dynamic response; time domain analysis; Finite-Element model;

Project: Tall buildings are subjected to wind-induced vibration. Modern design concepts cope with the magnitude of wind loading with respect to structural safety but the actual motion of building can affect the human comfort significantly. For this reason, tall buildings are equipped with active or passive damping system, increasing the inherent structural damping to a level that the motion of the building executed under wind action is not felt uncomfortable by people staying, working or living in the building. Typical concepts are tuned liquid or mass dampers engaged by the natural motion of the building. Controlled damper systems can increase the efficiency but are expensive in implementation and operation. Many tall buildings are erected in earthquake-prone regions and are equipped with high-capacity dampers to minimise the impact of seismic loading on the bearing structure. One damper type is the Rotational Friction Damper (RFD). This project shall look into the possibility to use the same concept to reduce wind-induced vibrations, which are of significantly lower magnitude compared to earthquake response.

Collaboration: DAMPTECH A/S, Dr. Eng. Imad Mualla, CTO, head of R&D, project co-supervisor

Recommended skills: This project is based on numerical analysis of the dynamic response of a high-rise building to wind loading. You should be trained in the usage of suitable Finite-Element software (Robot) and/or in using Matlab on an advanced level to program the analysis. You should have a study background in dynamic and wind engineering. If you have some questions please contact us!



Wind tunnel test setup to determine the wind load process on the tall building. The measured time series of the loading is available to study the applicability of RFD.

Basis for calculating the response of the tall building are wind load data (time series) measured in a wind tunnel study for a real building project in China. Load and structural information will be provided to conduct the project.

Rotational Friction Damper (RFD) developed for energy dissipation in building structures under earthquake loading. (source: http://www.damptech.com).

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MSc-Project (30ECTS):

Capacity Methods for Steel Connections - Gusset Plate Connections

Investigation and development of capacity methods for analysis and design of gusset plate connections in steel structures.

Keywords: Bolted connections, gusset plates, bolt forces, fasteners, block tearing, plasticity theory, bolt "hole" capacity, design methods.

The design of gusset plate connections such as the one shown in Figure 1 involves consideration of several possible failure modes. The structural elements being connected or the elements of the connection may fail in several ways. The overall design procedure is thus quite complex and the designer needs to be systematic in his approach. Figure 2 shows elements to be connected (A and B), section forces considered, bolts (+), bolt groups (a and b), gusset plates and connection plate (web stiffener plate) mounted on element (A).

Fig. 1. A bolted gusset plate connection.
(Et dobbelt laskepladestød)

The design and capacity of the individual bolt depends on the bolt category (A, B or C), i.e. on whether the bolt is preloaded and to what degree (in ultimate or just in service state). The bearing resistance of the individual bolt also depends on gusset plate thickness, the distances between bolts, the distances between bolts and plate edges and thus on the loading direction. This dependency is not well documented and should be analysed. Furthermore different block tearing failures such as those shown in Figure 3 have to be considered.

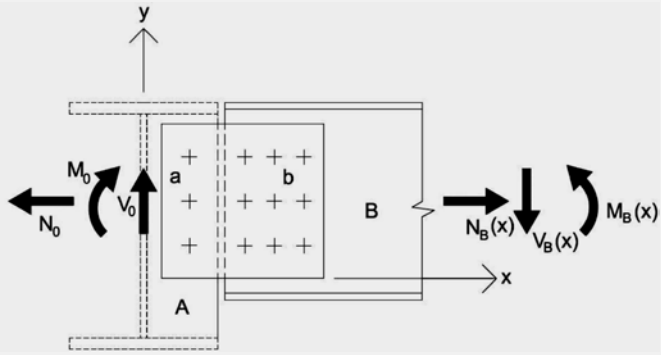

Fig. 2. Gusset plate connection and section forces.

The calculation and equilibrium related to block tearing is not well described and will have to be developed.

In this project it is the aim to investigate and further develop a systematic approach to the design and calculation of these gusset plate connections as well as to further develop the approaches outlined in Eurocode and other standards.

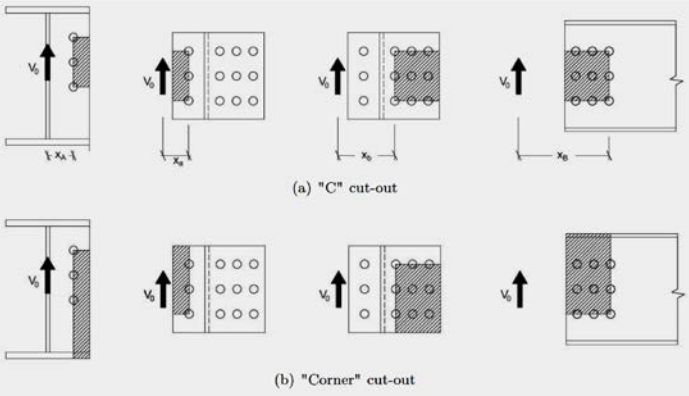

Fig. 3. Block tearing failures to be considered.

The preferred applicant has a strong record in structural analysis, has taken the steel course, the advanced steel course and has programming skills enabling development of Matlab routines. Knowledge of the theorems of plasticity and static understanding is an advantage.

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MSc-Project (30ECTS), B.Sc project (15-20ECTS) – Cluster Project

Capacity Methods for Structural Steel Joints

Investigation and development of capacity methods for analysis and design of structural steel joints. May involve laboratory testing, FE-analysis and/or theoretical analysis. (Several student projects are possible)

Keywords: Bolted connections, end plates, gusset plates, bolt forces, fasteners, block tearing, yield patterns, plasticity theory, bolt "hole" capacity, design methods.

The design of structural steel joints such as those shown in the illustrations to the right involves consideration of several possible failure modes. The structural elements being connected or the elements of the connection may fail in several ways. The overall design procedure is thus quite complex and the designer needs to be systematic in his approach. There are many parts of a connection and each individual part has to be designed, analysed and checked.

The design and capacity of the individual bolt depends on the bolt category (A, B or C), i.e. on whether the bolt is preloaded and to what degree (in ultimate or just in service state). The bearing resistance of the individual bolt also depends on plate thickness, the distances between bolts, the distances between bolts and plate edges and thus on the loading direction, etc. These dependencies are not well documented and should be analysed. Different yield patterns may arise in end plates and prying action increase bolt tension. Furthermore different block tearing failures modes complicate gusset plate connections.

CAPACITY METHOD DEVELOPMENT:
A joint transfers "section forces" (normal force, shear forces, moments and torsion) from one element to other elements of the joint. In the design of standard I-beams capacity methods have been developed involving capacity checks on the individual section forces and interaction checks through general interaction formula. It is the hypothesis that it is also possible to develop such formula involving individual checks and interaction checs for (element ends entering into) different types of connections.

Fig. Bolted structural steel joints

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MSc-Project (30ECTS):

Formulation and development of advanced beam elements with distorting cross sections

Formulate and develop a small finite element program based on advanced thin-walled beam elements, which include distortional modes of deformation, i.e. include cross section deformation.

Keywords: cross section analysis, flexure, torsion, distortion, deforming cross sections, advanced beam elements, stability, thin-walled beams, Generalized Beam Theory (GBT).

Thin-walled members are often used in the civil, mechanical and aerospace industry because of the high strength and the effective use of material. Due to the increased consumption of thin-walled structural elements there has been increasing focus and need for more detailed calculations. Thus, it has been necessary to extend the classic beam theory to include distortion of the cross section. Such an extension of beam theory is considered in this project in a finite element context.

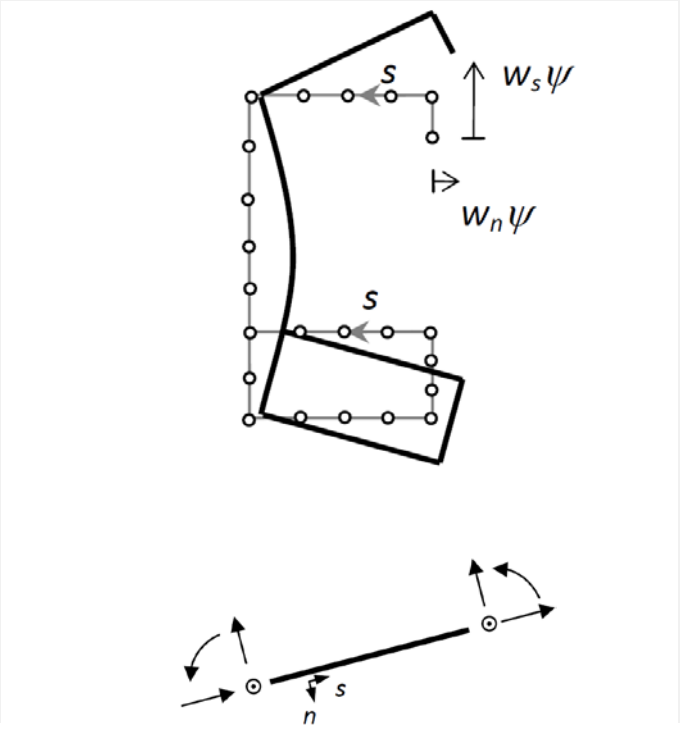

Fig. 1. Identification of semi-orthogonal modes.

The plan is to use a first step to perform a cross section analysis which defines a set of deformation modes. This is to be done by discretizing the thin-walled cross section into straight wall elements just like the modelling of a frame with beam elements as shown in Figure 1. The axial, transverse and shear strain energies are formulated and used to find deformation modes, through related eigenvalue problems.

Having defined adequate deformation modes we move on to the second step in which we will rely on a virtual work formulation. A subset of deformation modes is chosen and the variation of the modes along the beam is assumed to be cubic. On this basis a simple distorting beam element is to be formulated allowing relatively simple distortional deformation modes as shown in Figure 2.

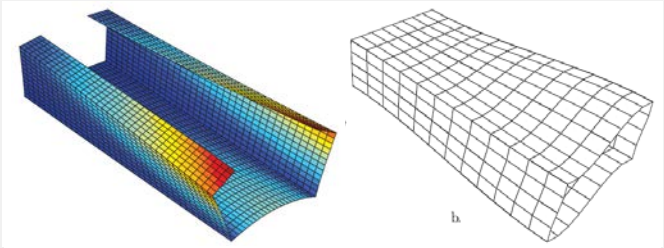

Fig. 2. Distortional deformation shape included.

The third step in the project will be to identify transformations and constraining methods, which allow the element to be attached to or used in an ordinary finite element context with plate element. Thus if possible the project will also include the formulation of a very simple plate element. The constraint equations may be based on assumption allowing only the beam displacement modes at the common finite element nodes at the end of a beam.

The preferred applicant has a strong record in structural analysis and knowledge of the application of finite element analysis to plated structures. Experience with programming and ABAQUS is necessary. Those applicants who are looking towards a PhD study may view this as a potential starting point.

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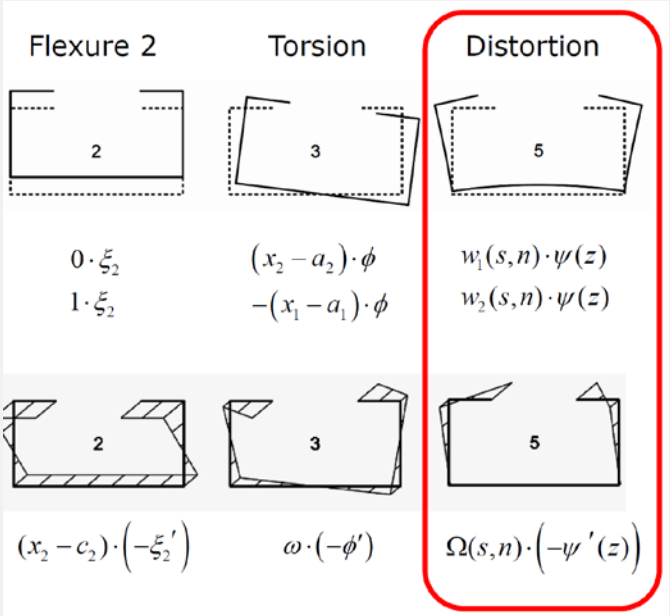
MSc-Project (30ECTS), B.Sc project (15-20ECTS) – Cluster Project

Generalization of Beam Theory
- Investigation into further generalizations

Investigation of possible further generalizations of beam theory in order to include shear, torsion, cross section distortion, orthotropic material, tapering and/or possible pre-twist. (Several student projects are possible)

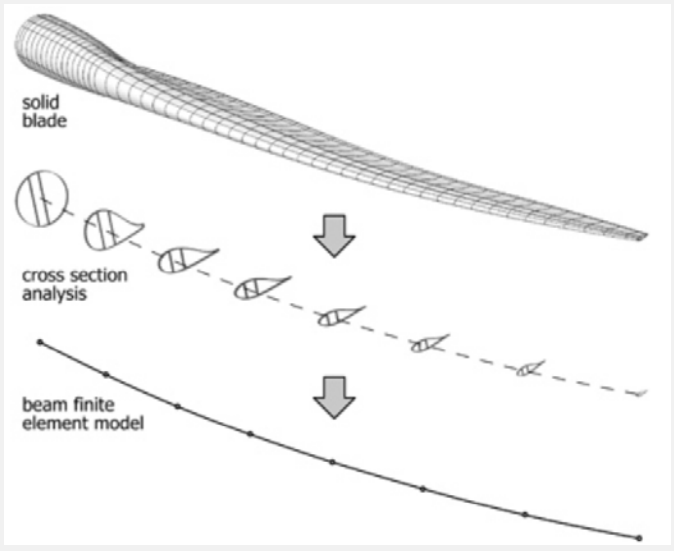
Keywords: Bernoulli Beam Theory, Timoshenko Beam Theory, torsional analysis, distortion, GBT, pre-twist, tapering.



The GBT format of distortional modes

Several generalizations of classic beam theories are possible and through several decades a number of different generalizations have been proposed in order to include different behaviours and aspects. In this project it is the quest to investigate possibilities of including one or some of these in a modern (Generalized Beam Theory) GBT formulation, which already includes of distortion of the cross section.

It will be necessary to study a number of papers and previous student B.Sc. and M.Sc. projects in order to understand and learn the current formulations of GBT. Furthermore it will be necessary to perform a literature study with respect to specifics theories related to one or several topics such as shear, torsion, distortion, orthotropic materials, tapering and pre-twist.



The reason for the interest in pre-twist as well as tapering is that wind turbine blades are always tapered and have a pre-twist. The typical blade materials are orthotropic fibre composites. The current state of the art for turbine blades is that they are analysed as a row of assembled beam elements that are gradually tapered and twisted, or they are analysed using layered shell elements.

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DTU Civil Engineering
Department of Civil Engineering

MSc-Project (30ECTS):

Prediction of Human Wind Comfort through Digital Erosion Imaging in Wind Tunnel Tests on Urban Areas

Urban life quality is closely related to the city micro climate. Wind is in this connection the most relevant climatic parameter and is generally investigated for new city developments. This project aims on the development of an advanced method with which wind tunnel erosion tests on city models can be used to map human wind comfort in urban areas.

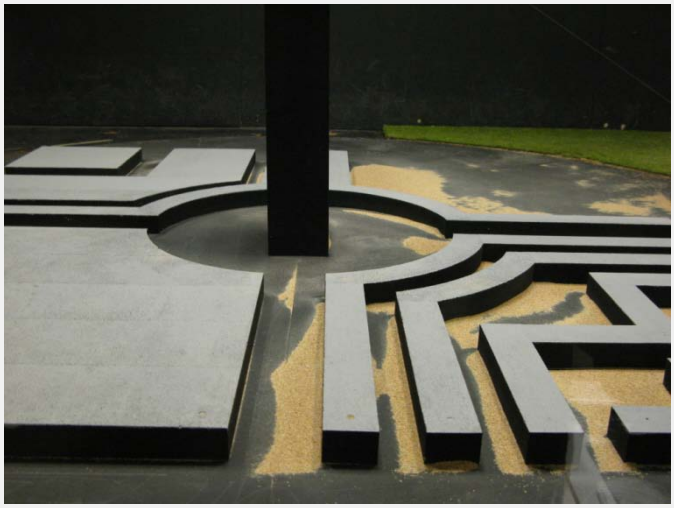
Keywords: *human wind comfort; erosion tests; wind tunnel testing; digital image computer analysis; wind climate statistic*

Wind in cities is a key parameter for urban climate and is consequently a core element of urban planning since the first formation of settlements.

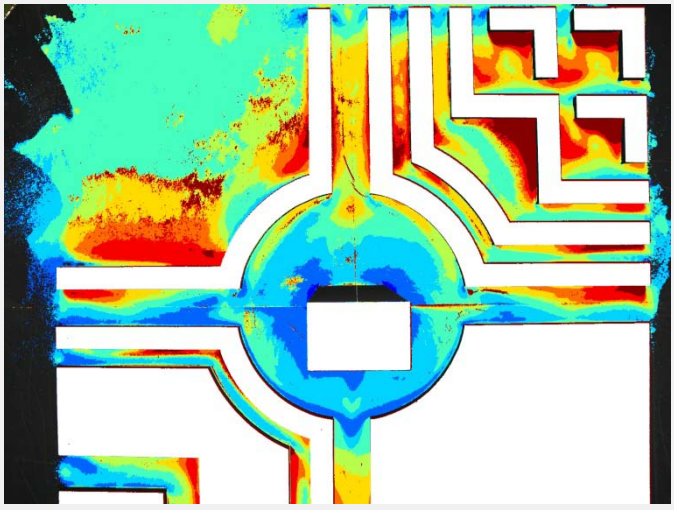
A proven method to investigate pedestrian wind conditions in urban areas is the erosion or scour method in wind tunnel testing. On a scaled physical model granular material is applied on the surfaces to be investigated. When increasing the airspeed in the wind tunnel the material erodes and reveals exposed and sheltered zones.

The method is relatively simply to apply and does not require a profound background in wind tunnel testing or fluid dynamics. Observing the erosion process provides detailed information of the airflow and modifying the model allows direct interaction with the aerodynamic of the city. This is an enormous advantage in parametric studies and conceptual research.

Using digital photographs the information on ground-near wind speeds can be processed numerically and be combined with wind climate data. The aim of the project is the development of a Matlab program that combines Digital Erosion Imaging and Wind Climate Data to “draw” a human wind comfort map of the investigated area. This program will be part of a new method to investigate and predict city life quality.



Erosion test on a city model in a wind tunnel experiment. The granular material is eroded by the airflow and reveals the magnitude of the ground-near air speed between the buildings and on open areas.



Digitally analysed erosion test showing areas exposed to ground-near winds (blue) and sheltered areas (red). The image is based on only one wind direction.

A candidate for this project should be interested in:

- Advanced Matlab programming.
- Wind Tunnel Testing.
- Systematic experimental research work.

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B.Sc.-Project (20ECTS) – Cluster Projects:

Premature shear failure in slender concrete beams and slabs designed by plasticity methods

Premature shear failures in concrete slabs optimized by the yield line method have recently taken place in practice. This may possibly be explained by the extensive moment redistributions required by the yield line method combined with the limited deformation capacity of shear failures. The objective of the project is to evaluate this hypothesis through a systematic parameter study.

Keywords: concrete beams and slabs; plastic theory; shear failures.

It has in practice been observed, that concrete slabs designed and optimized by the yield line method may suffer premature shear failure at a load level, which is lower that the ULS load. The slabs were one-way slabs without shear reinforcement.

The observed failures may possibility be explained by the fact, that design by plastic method requires extensive moment redistributions. This means that in the cracked elastic state, the distribution of moments may perhaps be more critical in relation to development of shear cracks and shear failures. Premature shear failure may therefore take place if the SLS load is close to the ULS load

In the project(s) we will carry out a systematic assessment of the safety against premature shear failure in beams and slabs, for which the flexural reinforcement has been optimized by plastic methods. The tasks involve:

- ULS design of flexural reinforcement in typical structures with full utilization of moment redistribution.
- Estimates of stiffness distribution in the cracked elastic state.
- Estimates of moment distribution in the fully cracked elastic range.
- Evaluation of shear crack development and risk of sliding failure in cracks on the basis the elastic moment distribution (and possibly on the basis of crack width estimates).
- Evaluation of total safety against premature shear failure for different ratios between ULS and SLS load.

Premature shear failure in concrete slab optimized by yield line method

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M.Sc.-Project (30ECTS)

Estimates of stress redistributions in concrete structures designed by the stringer method

The objective is to investigate different possibilities to develop operational guide lines for how to select suitable admissible stress distributions for ULS design of concrete structures, which are modeled as stringer systems. The guide lines should support engineers in practice to avoid combinations of extensive stress redistributions and failure modes with limited ductility.

Keywords: concrete structures; plastic theory; deformation capacity; stress redistribution; design guide lines.

The plasticity lower bound stringer method is frequently used in practice to design concrete structures. The method is quite popular among design engineers because it allows the use of very simple stress states and leads to equally simple reinforcement layout.

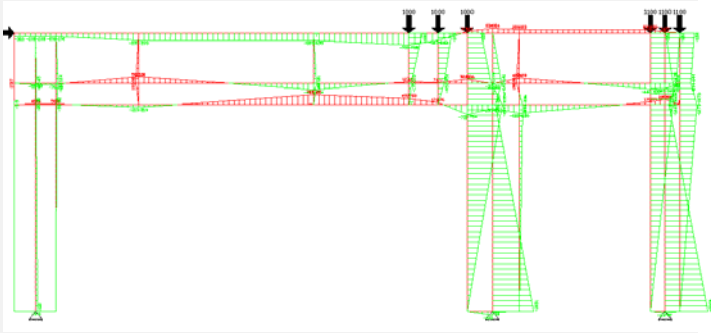
Since reinforced concrete only has limited deformation capacity, it is necessary to have guide lines and code rules for how to carry out design by plasticity methods. For example, in the plastic design approach for slender continuous beams, there are rules for how to choose the plastic moment distributions to ensure that they do not deviate too much from the elastic ones.

Similar guide lines do not exist for the stringer method. One of the reasons for this is the lack of knowledge about the stress distribution in stringer systems in the cracked, elastic range. This makes it impossible to evaluate the extent of stress redistribution when the stringer system evolves from the elastic cracked state to the ultimate limit state.

In this project a simple method to estimate the stress distribution for stringer systems in the cracked, elastic range will be investigated. The basic idea is to use simplified stress distributions (basically the same type of distributions used in ULS design) to obtain approximate solutions for the elastic, cracked state by minimizing the complementary elastic energy of the entire system. This will provide an estimate of the load level, which defines the transition from elastic to in-elastic behavior. On this basis, a comparison of the state of stress at the transition load and at the ultimate load may be carried out for each point on the structure.

Based on the comparison of stress states at the two load levels, the following questions are addressed in the project:

- Is it possible to formulate a suitable measure to describe the relative demand for stress redistribution at each structural point? Ratios between stresses at the two load levels and ratio between concrete stress inclinations will most probably be parts of this “measure”.
- For each structural point, is it possible to link the relative demand for stress redistribution to the expected failure mode in order to evaluate the possibility to actually achieve the required stress redistribution?
- For cracked concrete, the strength and the stiffness properties at each structural point depend on the reinforcement content in a similar way. Can this information be used to formulate code-like “deem to satisfy” rules for how to choose stress fields for ULS design?



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M.Sc.-Projects (30ECTS) – Cluster projects

Experimental studies of load carrying capacity of joints between precast concrete elements

The objective is to develop new solutions for how to establish structural continuity between precast concrete elements, which are suitable for highly stressed zones and more construction friendly than the traditional solutions. The development works include experimental studies of strength and robustness of different types of structural joints, new as well as traditional ones.

Keywords: precast concrete structures; joints; structural continuity; experiments.

For concrete structures built with precast elements, the joints/connections between the precast elements play a crucial role for the load carrying capacity and robustness of the structure. In many cases, the joints are the weak parts in the structure. This is so because in practice, the final design and layout of joints are often compromises between solutions that are buildable and solutions that are sound from a structural mechanics point of view.

The traditional joint layouts (e.g. U-bar joints between walls with shear keys) were originally developed for simple concrete structures. These solutions are not always suitable for structures with complex statical systems or for tall buildings, where the joints may be highly stressed. Using the traditional solutions in such situations may lead to problems in the assembly/construction process as well as problems in obtaining sufficient load carrying capacity.

In the project(s), we investigate different ways to design joints in order to obtain solutions, which are suitable for highly stressed zones as well as more construction friendly. The basic idea is to combine traditional reinforcement bars with high ductility and flexible steel wires with high ultimate strength. Tests will be conducted to study the strength and robustness of the new joint solutions. Comparisons with traditional solutions are carried out.

The solutions to be developed and tested in the project(s) may include: a) In-plane joints between walls loaded in shear; b) T-joints between walls loaded in shear and shear-tension; c) L-joints between walls and slabs loaded in shear and combined shear-bending.

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M.Sc.-Projects (30ECTS)

Progressive collapse in concrete structures subjected to sudden loss of key support elements

The objective is to investigate the applicability of a simple energy balance approach to evaluate the robustness and risk of progressive collapse in concrete structures subjected to sudden loss of a key supporting column or wall. The approach will be used to analyze the effectiveness of the code requirements to continuity tie reinforcement for prevention of progressive collapse.

Keywords: concrete structures; robustness; progressive collapse; energy balance.

Assessment of the structural robustness is mandatory when designing important or high rise buildings. In general, it is also very valuable to carry out an assessment of the structural robustness. Such an exercise can reveal weaknesses in the statical system in relation to progressive collapse and unforeseen overload. The current best practice for verification of structural robustness in concrete structures is very primitive. The best practice consists of static analyses of new loading paths and supply of prescriptive continuity reinforcement to make stress redistributions possible.

In this project, we investigate more refined methods to evaluate the robustness of concrete structures (built with precast elements) for scenarios involving sudden loss of key column- or wall element. In such situations, redistribution of stresses in the remaining structure will take place as a dynamic process involving release of potential energy and dissipation of energy in zones experiencing large plastic deformations. By considering energy balance at the end of the stress redistribution process, robustness and safety against progressive collapse may be more accurately evaluated.

The idea is to carry out the analysis by identifying one or more failure mechanisms related to the loss of a supporting element and allow the mechanisms to evolve in ways that involves large deformations. This makes it possible to calculate the accumulated plastic energy as the mechanism evolves. On this basis, a criterion for energy balance may be established for assessment of structural robustness.

A number of typical modes will be analyzed. In this context, a parametric study will be carried out to assess whether or not the prescriptive continuity reinforcement required by design code is sufficient in all cases.

Progressive collapse due to insufficient robustness (Ronan Point)

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Special Course/BSc/MSc – Project (5-30ECTS):

Aerodynamic Load Coefficients on Telecommunication Tower – Wind Tunnel Testing on Scaled Section Models

This project focuses on the determination of static wind loads on telecommunication towers. The loads shall be investigated in wind tunnel tests for different configurations of wind condition and antenna equipment.

Keywords: *wind tunnel testing; aerodynamic load coefficients; telecommunication tower; smooth/turbulent flow; antenna equipment*

With increasing demand in telecommunication the structural resistance of telecommunication installations such as towers and masts is used to its limit. In order to do that accurate coefficients describing the wind load are required.

The core part of the project is a series of wind tunnel tests on different mast sections in different configurations regarding flow and antenna equipment. Scaled models and basic test program exist from previous studies.

Depending on the project format (special course/BSc/MSc) the experimental part can be extended with additional tests and comparison to full-scale wind tunnel tests and to literature.

The experimental investigation of the wind loads on telecommunication tower elements is part of a collaborative research project.

Candidates for this project shall be interested in:

- Wind tunnel testing (preparation and performance).
- Systematic and structured reporting and documentation of the study.
- Presentation of results in easy-to-use graphs and tables.
- Advanced investigation of scaling effect on the aerodynamic load coefficients (only for BSc and MSc-projects).

Example of the structure of a telecommunication tower. The wind loads on the tube-shaped elements are affected by scaling effects, which makes the design of suitable wind tunnel models challenging.

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MSc-Project (30ECTS):

Concrete shells built from prefab elements - design and analysis

The gothic vaults of Westminster Abbey and the ribbed ferrocement shell in Palazzetto de la Sport by Nervi is just two examples of shell structures with two interesting properties: they are built out of prefabricated elements and they are compression-only structures. Could this concept be used for modern concrete shell structures?

Interior, Westminster Abbey, London, built 1245 -1517.

Interior, Palazzetto de la Sport, Rome, 1957.

Background

The oldest buildings on earth that are still in service are compression-only structures built from stone or brick. Reinforced concrete was in the early days considered by architects and engineers as a fluid, homogeneous and continuous material that made completely new forms and types of structures possible. Among other things it was considered ideal for thin shell structures. But since the industrialization of building industry in Denmark the concept of prefabricated elements has made reinforced concrete synonymous with simple building blocks that can be just stacked. Also now reinforced concrete compared to other building material suffers from high environment impact.

The question is if recent developments in the concrete industry regarding recipes, fiber reinforcement, thin wall elements and production methods, combined with new methods of conceptual and computational design and old methods of structural analysis can generate new architecturally and environmentally interesting solutions.

Project outline

1) A study of structural theory on masonry (compression-only) structures. Graphical statics and Cremona diagrams could be part of this.
2) An investigation into methods for form finding of compression-only shell structures. The software "RhinoVault" from ETH could be part of this.
3) An investigation into the different possibilities for structural systems from this concept including rib shell structures and plate shell structures.
4) An investigation into the how such structures could be produced, erected, used and perhaps taken down and rebuilt.
5) Design proposals for shell structures built from prefabricated concrete elements, taking aesthetical, structural, environmental and practical aspects into consideration.

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MSc & BSc-Projects

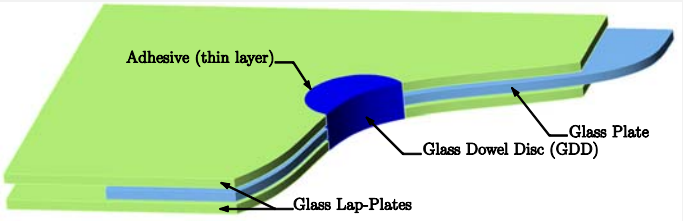
Bolted joints in tempered glass using Glass Dowel Discs (GDD)

The project investigates the strength of bolted joints in tempered glass using a tempered glass disc as the bolt.

Keywords: Experiments; numerical modelling; Structural Glass.

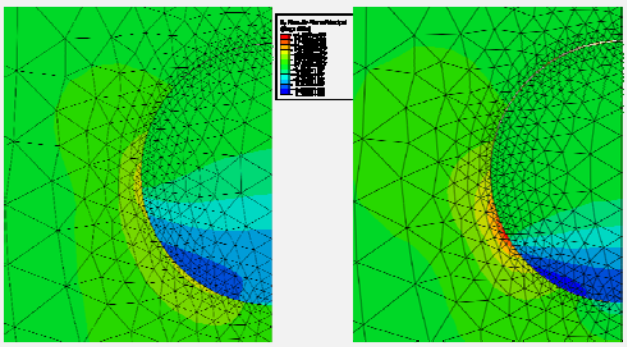
Bolted joints in tempered glass introduces stress concentrations where the stresses are transferred and therefore, joints are most often the critical part when designing load-carrying glass structures. DTU Byg is carrying out research within this area where a new concept for a transparent joint has been suggested. Pilot tests have shown a promising concept.

Projects within this area will consists of experimental work along with analysing the experiments by setting up and using a FE-model. The goal for these projects are to gain a better understanding of the mechanisms under usage and failure and thereby develop the concepts for such joints.



Components of a GDD joint.

Pilot test of a GDD.



FE-modelling af a GDD.

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MSc & BSc-Projects

Investigating the residual stresses and strength of tempered glass

The project investigates the strength of tempered glass by determining the residual stresses and comparing these with numerical simulations.

Keywords: Experiments; numerical modelling; Structural Glass; Photo elasticity; statistics.

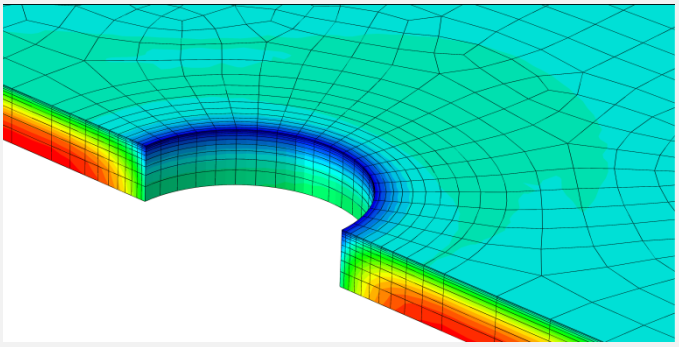
The strength of tempered glass is governed by the residual stress state in the considered specimen along with the inherent strength of the glass. This indicates that the strength of tempered glass is not a constant, but varies with different parameters. The apparent tensile strength is often written as

$$f_{TG}(\sigma(t), x_i) = f_{AG}(\sigma(t)) - \sigma_r(x_i)$$

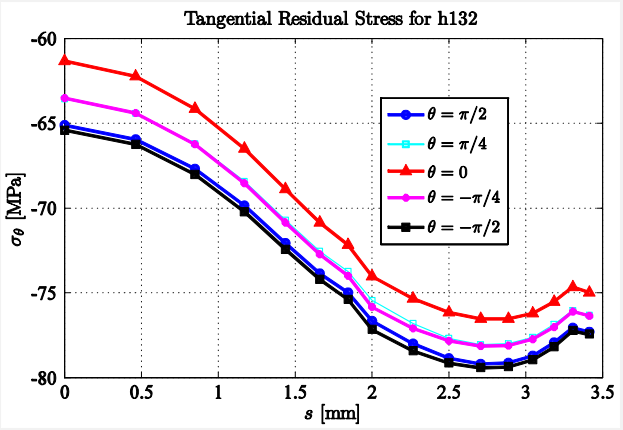
Which is dependent on both the loading time and the spatial variation of the residual stresses.

Knowledge of the residual stress state in tempered glass is therefore needed in order to design load-carrying structures in glass.

Several projects within this area are offered ranging from rather experimental investigations of the photoelastic properties, measurement and analysis of the residual stresses in tempered glass to more numerical investigations of the influence from different parameters on the residual stress state.



FEM model of the residual stresses in tempered glass.



Residual tangential stress at a hole in tempered glass.

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MSc & BSc-Projects

Advanced FEM modeling of structures and structural components

The project aims at investigating a particular structure or structural component by means of the Finite Element Method mainly using commercial software like ABAQUS. In some cases this can be combined with experimental work for validating the FE-model.

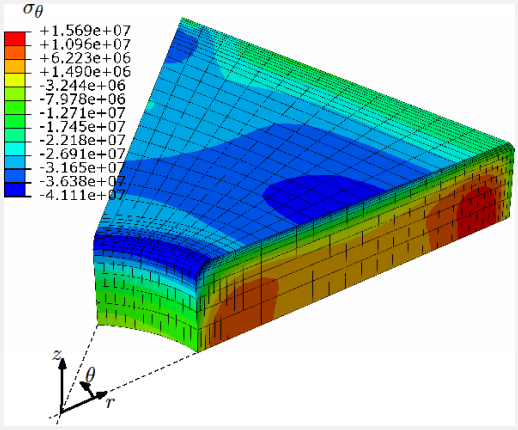
Keywords: Numerical modeling; non-linear behavior of materials and structures; experiments.

The Finite Element Method is still gaining an increasing popularity among researchers and designers due to its many applications. This project aims at investigating existing problems in civil engineering, e.g. behavior of laminated glass plates, stress distributions for certain supports, bolted joints, etc.

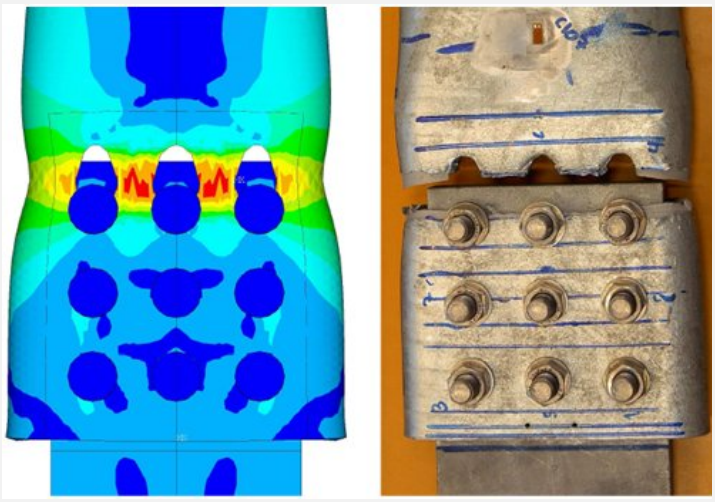
Validation and verification of the performed analysis is an important part of these projects. In some cases experimental work might be relevant in other such information might be retrieved from existing literature.

The courses 11305 and 11345 or similar are required for these projects.

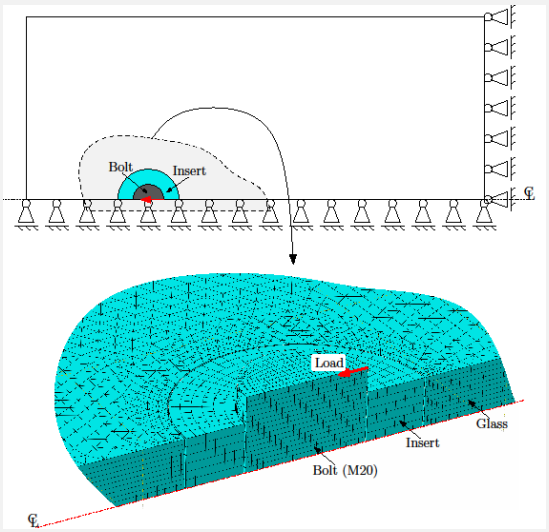
If several students sign up for these projects a small group supporting each other will be formed.



FEM model of the residual stresses in tempered glass.



FEM model results and experimental results of a tensile tests of a bolted joint.



FEM model for a bolted connection.

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MSc-Project (30ECTS):

Concrete shells built from prefab elements - design and analysis

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Project outline

1) A study of structural theory on masonry (compression-only) structures. Graphical statics and Cremona diagrams could be part of this.
2) An investigation into methods for form finding of compression-only shell structures. The software "RhinoVault" from ETH could be part of this.
3) An investigation into the different possibilities for structural systems from this concept including rib shell structures and plate shell structures.
4) An investigation into the how such structures could be produced, erected, used and perhaps taken down and rebuilt.
5) Design proposals for shell structures built from prefabricated concrete elements, taking aesthetical, structural, environmental and practical aspects into consideration.

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BSc/MSc-Projects:

Modelling of flexural behaviour of reinforced concrete structures with detailed description of crack propagation

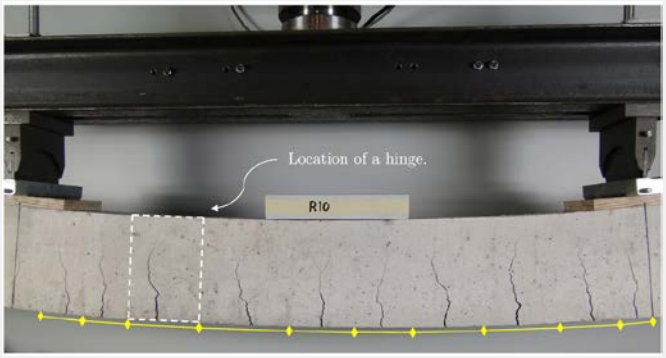
This research field is concerned with the development of numerical models and tools for the detailed analysis and design of reinforced concrete structures in bending, taking into account the effects of cracking of concrete and de-bonding of the reinforcement.

Keywords: Numerical modelling, programming, non-linear fracture mechanics, structural response, mechanical strength degradation, (experiments)

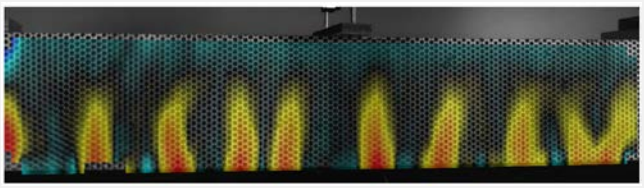
Simulation tools for overall structural analysis must be very efficient to be of interest in the everyday design process. Therefore, the effect of cracking on the structural performance of structural members has been integrated into ordinary member elements for use in finite element programs.

These elements allow for the modelling of reinforced concrete structures taking into account the effect of cracks on the stiffness of the structure, and thereby the distribution of sectional forces. Furthermore, this tool permits a precise prediction of the cracking in terms of crack spacing and crack width.

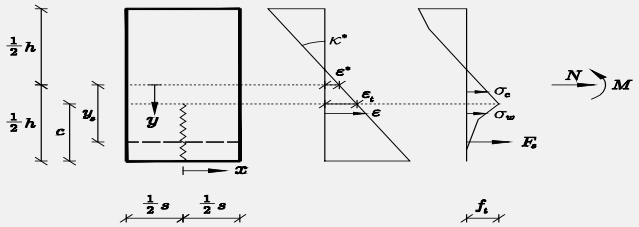
Different projects dealing with further developments of this concept are offered.



Middle part of a beam in four-point bending. A number of so-called hinges have formed and the location of one of these is illustrated[1].



Visualization of cracks in middle part of a four-point bending beam at early stages of loading[1]. Produced by the digital image correlation equipment Aramis.



Adaptive hinge model for numerical implementation.

[1] From MSc project by J. Rahbek and S. S. Pedersen, 2011.

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MSc-Project (30ECTS):

Detailed modelling of crack propagation in reinforced concrete structures

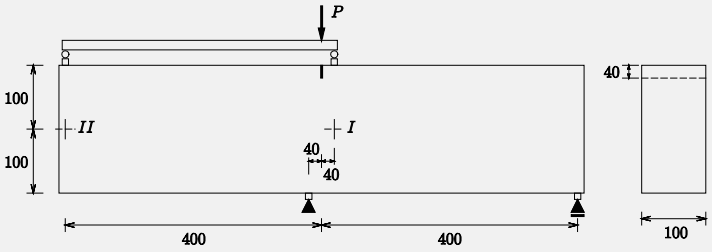
This research field is concerned with the development of finite elements for the detailed analysis of reinforced concrete structures applying the embedded crack concepts in a novel formulation.

Keywords: Numerical modelling, programming, non-linear fracture mechanics, structural response, mechanical strength degradation, (experiments)

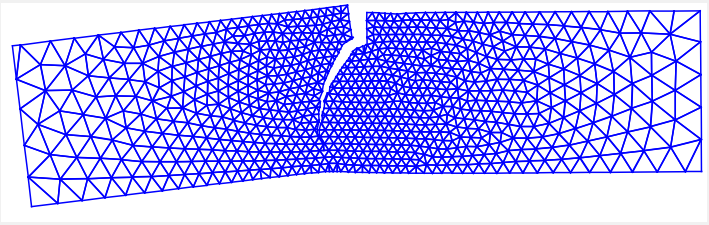
The finite element simulation of fracture processes in concrete structures poses a serious challenge. This has to do with the effect that cracks separate the continuum into more or less entangled sub-regions, thereby breaking down the usual way of modelling structures.

Recently two distinct FE methods have been developed, one with an appealingly simple concept, and one that is much more complicated but also much more efficient. The two approaches serve different purposes. Where the complicated approach is suited for detailed analysis of few cracks in 2D, the simpler approach lends itself to large scale analysis with a multiplicity of cracks in 3D.

Different projects dealing with further developments of the simpler concept are offered.



Test setup for the testing of a notched beam in four point loading



The deformations of the specimen from the above setup modelled by CST-elements with an embedded crack. Deformations are exaggerated.

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MSc-Project (30ECTS):

Numerical and experimental study of moisture-related strains and stresses in laterally loaded multi-dowel timber connections

The project is focused on an experimental method used to measure strain fields in climate-sensitive structures exposed to hygro-thermo-mechanical load action. The experimental finding will be used to calibrate the finite element model for multi-dowel timber connections.

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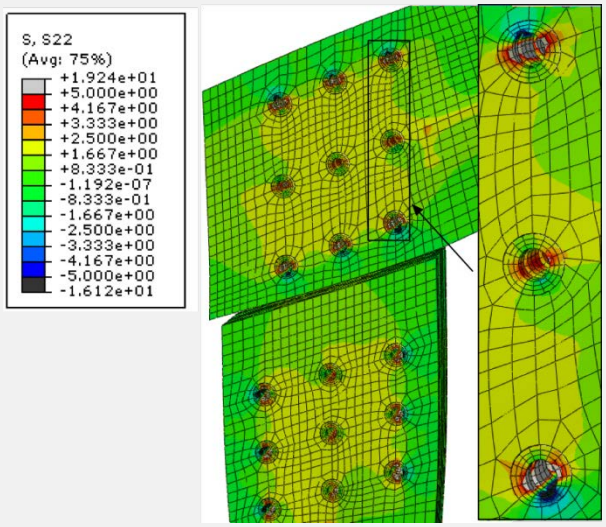
Keywords: Wood, simulations, moisture, multi-dowels connection, slotted-in steel plates

There is a need on more advanced analysis to study how cyclic climate variation affect the stress development in glue laminated (glulam) timber structures. The weakest points in laminated timber structures are the connections. They are sensitive for moisture induced deformations because of the local mechanical constraint from the steel fasteners. The main purpose here is to develop a good simulation tool for connection design based on rational solid mechanics, material modelling and use of modern computer methods for strength and deformation analysis. The modelling results will be verified through advanced experimental tests where deformation and fracture is studied in a new facility consisting of a special designed climate chamber merged with a stiff steel frame that enables simultaneous mechanical and environmental load action to take place within the chamber.

The decisive feature of the climate chamber is its specially designed double glass window with a heating system that keeps the glass free of hoarfrost and of condensed moisture. The clean glass window enables strain-field and crack-propagation development under variable climate conditions to be studied by use of the ARAMIS system (a digital optical photogrammetric measuring system).

The main focus of the experimental work is to test different multi-dowel timber joints (with and without slotted-in steel plates) under different combinations of mechanical loadings and varying climate condition. The aim is to get better knowledge of the local strain fields that occur around the fasteners during the climate variation.

The connections will be modelled with a full 3D analysis in ABAQUS where the interaction between the fasteners and the wood material is modelled as a full contact interaction. The wood material is assumed to be an orthotropic material in reference to elastic and shrinkage behaviours. Model adaptivity will maybe be used to reduce the computer time and to find suitable coupling conditions between beam and solid elements. The simulation results will be compared with the experimental strain field results in areas adjoining the mechanical fasteners.



Typical distribution of moisture-related stresses (perpendicular to the grain) in a moment stiff multi-dowel frame corner with slotted-in steel plates.

The climate chamber used together with the ARAMIS system.

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MSc-Project (30ECTS):

Crack growth

M.Sc.-students are offered a study regarding the observed crack growth in the Storstrøm Bridge

Keywords: steel crack growth

In the project the following should be determined or calculated.

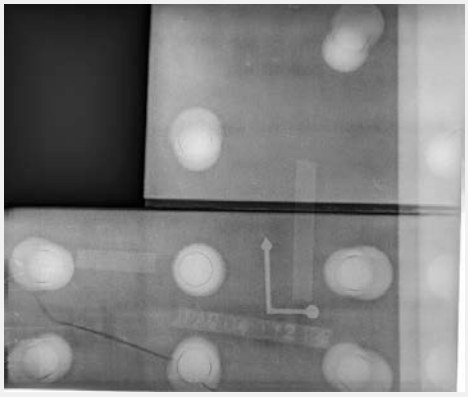
Project 1
Fracture mechanics data for the steel used by means of the so-called CT- or CTT-tests. (1 M.Sc.-project)

Project 2
Comparison between observed crack growth and calculated crack growth. (1 M.Sc.-project)

The x-ray picture shows an observed crack (cf. Ingeniøren). The crack is located in a plate on the faces of which plates are riveted. That's why the crack was difficult to find by ordinary inspection.

The calculations are done by standard empirical crack growth formulas (Paris etc.) and a theoretical crack growth formula developed by M.P. Nielsen. Rather extensive FEM-calculations are required.

Inside the bridge during the repair



X-ray picture of a crack

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MSc-Project (30ECTS):

Design of Stainless Steel Composite Highway Bridges with Reduced Maintenance Costs

The purpose is to develop design for composite highway bridges based on the use of stainless steel girders and prefabricated concrete elements. The goal is to reduce the life cycle cost as compared to traditional bridges. The project is carried out in collaboration with the Danish Road Directorate, which has a high interest in the project and in a final life cycle cost analysis.

Keywords: Stainless steel design, composite girders, high way bridges, structural bridge design, corrosion, assembly, stability, buckling, cross-section classes, fatigue, design.

In a lot of European countries (e.g. Great Britain) there is a great focus and development within composite bridges due to a large steel industry. However in Denmark only a few older bridges with composite design exist probably due to a large concrete industry, traditions and, good experiences with reinforced concrete. Perhaps it has also been due to a wish not to paint or maintain painted structures and maybe also due to corrosion problems on older bridges.

Nowadays the Danish Road Directorate is much more open towards the idea of composite structures if the total life cycle cost and environmental impact, including maintenance cost and disturbances of ongoing traffic during construction, can be reduced. Reduction of maintenance cost may be obtained by use of stainless steel.

The objective of this project is to develop overall and as detailed design solutions for continuous highway bridges based on the use of stainless steel girders in composite action with a reinforced concrete deck.

In the design, different modular configurations as well as girder layout will be examined to minimize the material consumption as well as the construction time. The overall geometry and important load cases are to be found in collaboration with the Danish Road Directorate.

The Design of the concrete deck has to be based on prefabricated elements and includes design of the shear connections to the girders. The design work will probably involve fatigue calculations as well as estimation of girder vibrations. The stainless steel design is to be performed on basis of Eurocodes using EN1993-1, EN1993-1-4, EN1993-1-5 and finite element analysis may become relevant.

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