

Department of Civil Engineering Annual Report 2007



DTU Civil Engineering
Annual Report 2007

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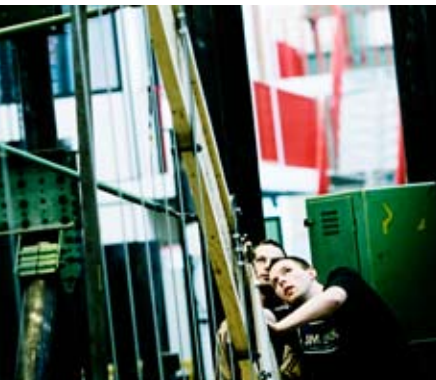
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Front Picture: PhD student Anders Ole Stubbe Solgaard, DTU Civil Engineering



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Management Report 2007:

A prosperous year for DTU Civil Engineering

DTU Civil Engineering is a university department within the building and construction sector.

Our mission is education, research, innovation, and public sector consultancy. Through our work we contribute to the generation of social and commercial value.

Our vision is to become a leading European Civil Engineering Department and a preferred partner for companies, authorities, and institutions in the building and construction sector.



Civil engineering education in Denmark started in 1857 when professor Ludvig Holmberg was employed at the Technical University of Denmark, then called "Polyteknisk Læreanstalt". Since then Danish civil engineers have contributed with science based engineering solutions to social and economic value creation both in Denmark and internationally. DTU Civil Engineering celebrated the 150 years jubilee with a series of activities culminating at the "B150 conference" in November 2007.

Today DTU Civil Engineering covers most civil and architectural engineering research disciplines and offers engineering education at bachelor, master and PhD level in all areas of civil and architectural engineering.

Research

DTU Civil Engineering's Strategy 2003-08 identified facilities management as a new focus area. Thus it was a great success when the foundation Realdania through a grant of 3.4 million € established the Realdania Research Centre for Facilities Management at DTU.

DTU Civil Engineering has increased its focus on international research publication, and the number of ISI papers increased from 30 in 2006 to 48 in 2007. This is a result of a decision to move publications from conference proceedings and reports to ISI journals when appropriate. The number of ongoing PhD projects increased; 13 PhD projects started in 2007.

DTU's Dean of Research organised an international research evaluation of the department. The evaluation consisted of a self evaluation report and a three day review by an international expert panel. The panel concluded that DTU Civil Engineering since 2003 has followed a clear road map for elevation of the department, and that the changes have moved the average research level upwards to "high national", and that individual research groups have moved their level to "high international". The self evaluation report and the expert panel report are available at www.byg.dtu.dk.

Education

Since 2003 civil and architectural engineering has attracted an increasing amount of qualified students. The number of applicants are now higher than the number we can admit on the Danish bachelor programmes, thus a limitation based on marks from the entry exam is used. The limiting average marks, using the Danish exams-scale, were 7.2 for BSc in civil engineering, 7.1 for BEng in architectural engineering, and 4.1 for BEng in civil engineering. Also the BEng programme in arctic technology experienced an increasing number of applications following a revision of the study programme.

Following the introduction of the Bologna declaration on higher education at DTU in 2004 the first students entered the MSc programme in civil engineering in September 2007. The civil engineering programme had the largest uptake among DTU's



MSc programmes. The Danish Accreditation Institution, ACE Denmark, approved the new MSc programme in architectural engineering, and the first master students began their studies in spring 2008.

The Faculty for Civil Engineering and Surveying at Technical University of Munich, TUM, and DTU Civil Engineering established a double degree programme in Civil Engineering as one of the initiatives under the strategic alliance between TUM and DTU.

Innovation

Collaboration with industry has high priority for DTU Civil Engineering and we increased both the number and the magnitude of industry sponsored research and development projects. Notably the High Tech Network for Low Energy Building, LavEByg, was granted a three year prolongation grant from the Ministry of Research. LavEByg includes nearly 100 companies dealing with energy efficiency technology for buildings.

The Centre for Arctic Technology, ARTEK, was instrumental in creation of an innovation house in Sisimiut, Greenland. This illustrates the potential of the unique link between research at international level at DTU, education in Greenland (Sisimiut) and Denmark (Lyngby), and local innovation in Greenland facilitated by ARTEK. A conference on arctic roads was held in Sisimiut in March. It is a great pleasure that the Greenland Home Rule has

decided to increase the support for ARTEK substantially in the years to come.

The Danish and German governments have agreed to establish a fixed road and rail link across Femern Belt connecting Denmark and Germany. This strategic project will become a pivot of civil engineering in Denmark in the years to come, thus we are pleased that the link owner, Femern Belt AS, has asked DTU Civil Engineering to participate in the project.

Organisation

As a consequence of the merger between DTU and a number of national research institutes and laboratories DTU Civil Engineering's group on construction, facilities and urban management moved to DTU Management, and the International Centre for Indoor Environment and Energy (ICIEE) moved from DTU Mechanical Engineering to DTU Civil Engineering on January 1, 2008.

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Organisation

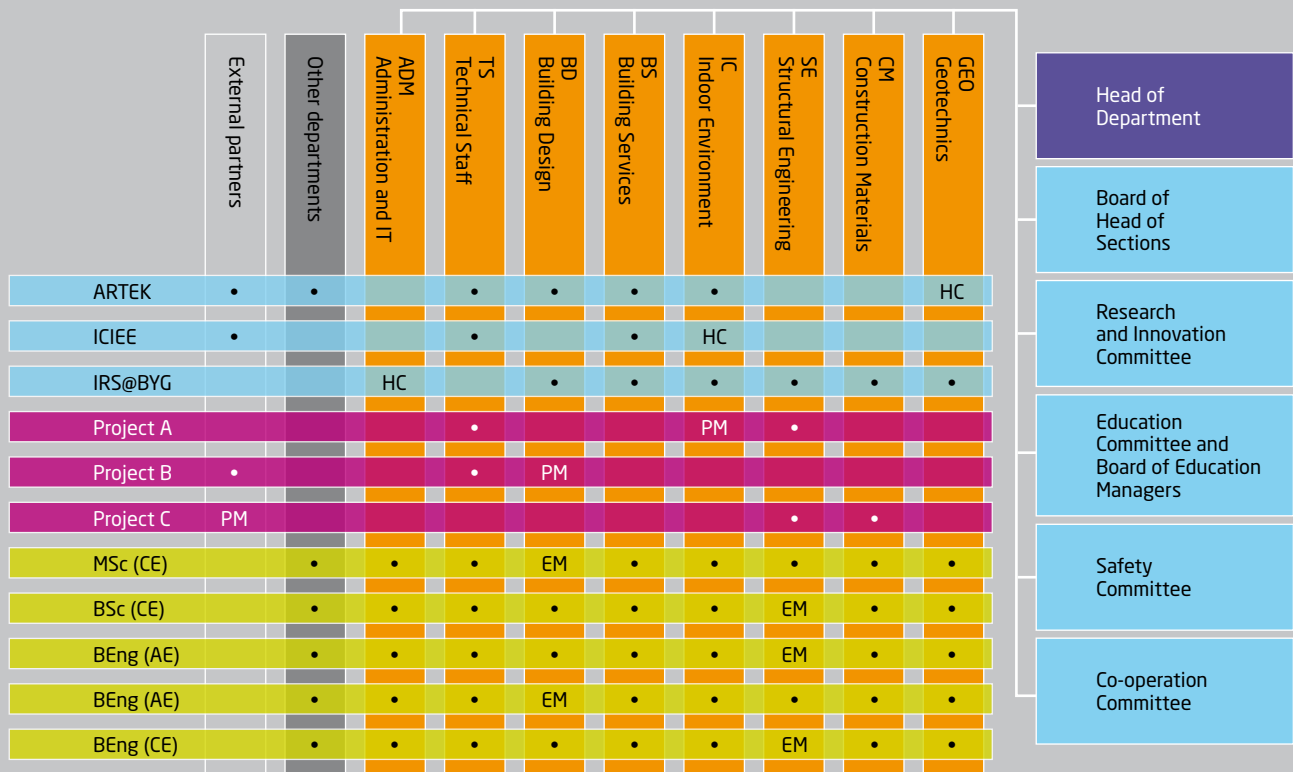


Figure: Organisation Diagram

Study Programmes and Education Managers:

- Building Technology (BSc).
Associate Professor Per Goltermann
- Arctic Technology (BEng). In Greenland,
Associate Professor Hans Peter Christensen.
In Denmark, Associate Professor Egil Borchersen
- Building Engineer (BEng).
Associate Professor Egil Borchersen
- Civil Engineering (M.Sc).
Associate Professor Kristian Hertz.
- Architectural Engineering (BEng).
Associate Professor Lotte Bjerregaard

Department of Civil Engineering hosts the following centres:

- IRS@BYG, The International Research School for
Civil Engineering. Head of Department Jacob S. Møller.
- ARTEK, Arctic Technology Centre.
Professor Arne Villumsen.
- ICIEE, Centre for Indoor Environment and Energy.
Professor Bjarne W. Olesen.

The Advisory Board:

- Professor (adj.) Louis Becker Architect MAA, AIA, RIBA
Design Director, Partner, Henning Larsen Architects.
- CEO Ingelise Bogason, ALECTIA.
- Division Director Niels Kjeldgaard, MTHøjgaard.
- Head of Office Lasse Sundahl, Danish Enterprise
and Construction Authority.
- Senior Vice President Carsten Winther,
Group Technology, Rockwool International.



A new research centre is established at DTU

Many organizations and institutions have participated in the formation of the new centre at DTU.

The centre aims to create a lasting and highly qualified environment for Facilities Management research at DTU in particular and in Denmark in general



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In 2007 it was decided to establish a new research centre concerning Facilities Management (FM) at DTU. The purpose is to strengthen research within this relatively new subject. FM concerns the management of the physical surroundings for the activities in an organisation and has developed as a new field of practice since 1990 in Denmark.

FM represents a new paradigm compared to the traditional view on building operation and maintenance with a technical focus on buildings. DTU Civil Engineering introduced FM in the department's strategy from 2003.

A pre-project was made in agreement with the private Danish foundation Realdania and carried out at the Department of Civil Engineering from March to September 2007. The result was a plan for the research centre and in October 2007 the Realdania adopted the plan together with a donation of more than € 3 million over a five year period.

Research profile

A central part of the plan for Centre for Facilities Management (CFM) is the definition of the research profile and themes. The profile is in short defined as research in:

- Space for humans
- Buildings with user value
- Property and infrastructure, that facilitates.

The main focus of the centre is the interrelationships between physical environments and social activities and how professionally managed and serviced physical surroundings can support and improve the conditions and activities of humans and organizations. CFM aims to create new knowledge and insight that can contribute to the strategic thinking about the built environment in relation to visions for the development of organisations and the needs of the users.

Seven project

From the beginning the following seven projects are planned:

1. Workplace Management
2. Facilities for Creative Environments
3. Implementation of Operational Knowledge in Building Projects
4. Sustainable Facilities Management
5. ICT-based Innovation in Facility Management Supply Chain
6. The Market for Facilities Management in Denmark
7. Strategic Partnerships within Facilities Management

CFM was initiated New Year 2008 with a physical and administrative base at a new Department for Planning, Innovation and Management at DTU, but CFM involves a number of other research institutions. The centre has a governance structure with a steering committee chaired by head of department Jacob Steen Møller, DTU Civil Engineering. The steering committee is supported by an advisory scientific committee with two professors from Norway and Sweden. As head of the centre I am responsible for the day to day management and administration of CFM.

CFM aims to create a lasting and highly qualified environment for FM research at DTU in particular and in Denmark in general. One of the measures is to start a number of PhD studies and it is expected that the results will be used in developing the teaching in Facilities Management at DTU and other educational institutions. The research will be mostly practice oriented and close collaboration with companies and organizations is planned.



The opening of the new centre was accompanied by jazzmusic

Electrochemistry for preservation of **cultural heritage**

A PhD project at DTU Civil Engineering is initiated due to a specific demand: a cheaper and more efficient method to extract the damaging salts in church vaults



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An item in the news in September 2003 pointed out the need for a cheaper and more efficient method for avoiding deterioration of the church murals and thereby the cultural heritage. Many church murals are damaged by salt in the vaults, and restoration is simply too expensive for some local parochial church councils, who has the ownership and the expenses. Financial support from the Villum Kann Rasmussen and Realdania foundations made it possible to initiate a PhD project on the subject at the DTU Civil Engineering.

The method

By application of direct current, a DC field, to a moist, porous material ion (dissolved salt) extraction will occur at high ion concentrations and water transport in case of low ion concentrations.

The principle of using electrochemistry for water transport and salt extraction from masonry has been known in Denmark and several other European countries for decades. However, due to a lack of documentation, such methods are not recommended for use by independent research institutes. Further more there are side effects from the application current that needs to be handled in a proper way before the electrochemical methods are safe to use.

In case of ion transport in an electric field the basic principle is simple attraction towards the electrodes in a liquid. Meanwhile the method is influenced from water content, ionic mobility, applied current, the non-uniform current distribution (figure) and especially electrode reactions. By electrode reactions the electrons in the electrodes are transformed to ions in the solutions, resulting in decomposition of the electrode material, acid/base production and decreased efficiency.

The invention

Water transport caused by an electric DC field in porous building materials is more complicated, because the water transport is proportional to the inner surface charge of the material. This means that the water transport is varying for each specific material. In case of bricks for example the inner surface charge is related to the original clay mixture and burning conditions. Documentation therefore includes extensive material characterization.

Benefiting from previous and present electrokinetic research at DTU Civil Engineering on soil, wood, fly ash and harbour sediments made it possible to overcome the side effects from the electrode reactions though new developments. Presently an inven-



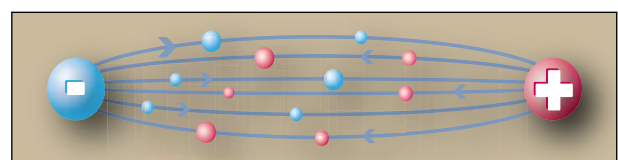
DTU Civil Engineering is planning a pilot plan experiment on church murals in the "Birds room" at the Carmelite monastery in Helsingør. The murals are damaged by salt and restoration is essential to save the cultural heritage

tion is taken over by DTU and the patent application is just about to be submitted.

Proven in laboratory

Through developments with single bricks it was possible to overcome the side effects and a high reduction in salt content from 1.0 wt% to a very low and unproblematic content of 0.01wt% was reached. On the basis of the present project the method is now considered proven in laboratory scale by advising engineers and researchers.

An experiment in a larger scale on a wall section has been carried out too, showing encouraging results. Shortly, a pilot plant experiment will be initiated at the Carmelite monastery in Helsingør in the so-called "Birds room" where presence of the salts is thought to be the main reason for deterioration of the painting. The PhD project is completed primo October 2008.



The electrochemical method for salt removal is not only applicable for church vaults. It can also be used for salt extraction from infected masonry of normal houses and a pilot plant for such treatment is seen here

A new shading system lights the dark and **saves energy**

DTU Civil Engineering has designed a solar shading device that reduces the energy demand in glazed buildings by reducing the solar gains and improving the utilisation of daylight



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The increasing need for energy savings and good daylight conditions in buildings brings about large challenges when designing facades for future buildings. The widespread use of highly glazed facades in office buildings results in large cooling demands which must be reduced with efficient solar shading devices. At the same time good daylight conditions are required in order to save energy for lighting and provide good visual indoor climate.

In buildings with large room depth compared to the window area, the daylight level is often insufficient in the back of the room to obtain a daylight factor of two percent. Furthermore the poor daylight conditions are worsened by the traditional fixed solar shading systems often used in modern glazed office buildings. Therefore there is a need for combined systems of flexible solar shading and light directing devices that, in addition to reducing the solar gain, will optimise the distribution and utilisation of the daylight. Such a solar shading system was developed at DTU Civil Engineering based on the idea of professor Svend Svendsen, and a full scale prototype mounted on a glass façade fitted in a test room at DTU (fig. 1 and 2).

Shading system

The shading system consists of variable horizontal glass lamellas with high reflective coating. The lamellas can be rotated in different positions depending on the requirements for solar shading or improved daylight conditions. On sunny days the lamellas are rotated into vertical position acting as an extra layer of solar control glass reducing the solar energy gain, but still allowing a good view out. On overcast days the lamellas are rotated 30 degrees with the reflective surface upwards. In this position the light from the sky is reflected into the room, up in the ceiling and further back in the room where the light is most needed (fig. 3).

Daylight measurements on the glass lamella system under overcast sky show that the daylight factor is reduced close to the façade where there is plenty of daylight. In the meantime the daylight factor, with the lamellas, is unchanged or even higher in the back of the room (fig. 4).



Fig. 1 The solar shading system with the lamellas in daylight redirecting position.



Fig. 2 The solar shading system with the lamellas in shading position.

Improved indoor climate

Consequently the light directing glass lamellas provide a better distribution of the daylight in the room resulting in improved visual indoor climate and reduced energy demand for electric lighting compared with traditional non transparent lamella systems. Under sunshine conditions the illuminance level in general and the solar gains are reduced resulting in energy savings for cooling and ventilation.

The same promising results have been found in preliminary calculations. Thus, the presented solar shading system is able to reduce the energy demand for cooling by controlling the solar gains and still maintaining good daylight conditions and a satisfactory view out. The project is carried out in co-operation with the Danish Building Research Institute.

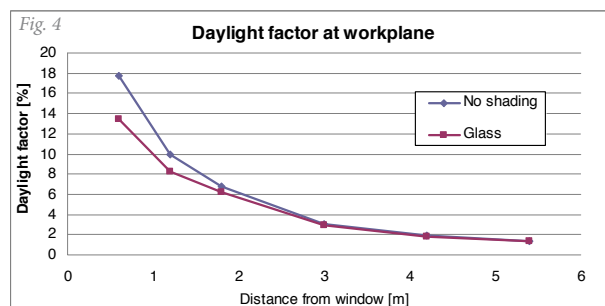


Fig. 4
Measured daylight factors for overcast sky. Blue: No lamellas. Red: reflecting glass lamellas tilted 30 degrees

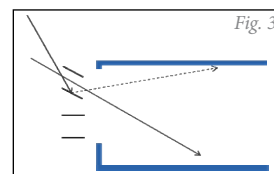


Fig. 3
Principle of the light directing lamellas

Simulated flights improve the indoor environment in aircraft

A study at the International Centre for Indoor Environment and Energy at DTU shows that even low levels of ozone in an aircraft cabin causes symptoms such as eye and nasal irritation, smarting eyes and headache.



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Physiological measurements performed inside the section of a simulated Boeing 767 aircraft cabin at the International Centre for Indoor Environment and Energy at DTU.

Boeing 787, Dreamliner, was presented for the public in 2007 at Everett Airport, Washington. The Indoor Environment System in the flight is created in co-operation with researchers at DTU Civil Engineering.



The environment in an aircraft cabin differs in several ways from other indoor environments e.g. offices and homes, due to the large number of occupants, the confinement of the passengers to their seats, and a much higher rate of air exchange. During flight, occupants experience low humidity (usually lower than 20 percent RH), reduced air pressure (as low as three-quarters that at sea level), and, at times, exposure to elevated ozone concentrations.

A three-row, 21-seat section of a simulated Boeing 767 aircraft cabin has been built in a climate chamber at the International Centre for Indoor Environment and Energy at DTU. The experimental facility simulates the cabin environment not only in terms of materials and geometry, but also in terms of cabin air and wall temperatures and ventilation with very dry air (comparable to that of outside air at altitude). This realistic simulation enables subjective assessments of the symptoms commonly experienced by passengers and crew during flights.

Human exposure studies

Six investigations have covered four environmental areas of study i.e. humidity, air purification techniques, ozone, and thermal effects, each investigation with four groups of 17 subjects acting as passengers and crew during 7-11 hour simulated transatlantic flights. These studies were sponsored primarily by the Boeing Company.

The humidity study, examining the optimum balance between fresh air supply and humidity, showed that increasing relative humidity in the aircraft cabin by reducing outside air flow did not reduce the intensity of symptoms typically experienced in the aircraft cabin. In stead it intensified complaints of headache, dizziness

and claustrophobia, suggesting that air pollutants rather than low humidity cause the distress reported by airline passengers. Three investigations studying the efficacy of various air purification technologies showed that a gas phase adsorption purification unit performed better than two different photo-catalytic oxidation units, although all three units greatly reduced the concentration of air pollutants in the cabin. The future Boeing 787 Dreamliner will therefore be equipped with the gas phase adsorption purification unit based on the DTU research.

A principal cause

Results obtained from the ozone investigation, supported by the US Federal Aviation Administration, indicate that the presence of ozone and ozone initiated chemistry in the aircraft cabin is a principal cause of a number of those symptoms commonly associated with the aircraft cabin e.g. air quality factors such as eye and nasal irritation and Sick Building Syndrome, SBS symptoms, such as smarting eyes, headache, dizziness and claustrophobia. It suggests that it would be beneficial to remove ozone at levels less than currently specified.

The last study, investigating the influence of air temperature on passenger comfort and symptoms, showed that cabin air temperature did not change symptoms typically observed in the cabin but affected the perception of air quality, air freshness, and thermal sensation, improving these perceptions when temperature was lowered.

Until now, subjects have spent more than ten thousand hours in the simulated cabin, and the study has resulted in numerous published papers.

New advanced models can improve concrete constructions

Researchers at DTU Civil Engineering have in co-operation with international researchers developed a method to estimate and predict the changing climate's effect on outdoor concrete constructions. The new knowledge can save money and prolong the lifetime of the constructions



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Outdoor concrete constructions are exposed to climate variations which can lead to durability problems. Common problems are chloride induced reinforcement corrosion, salt induced freeze/thaw damages, sulfate attack and leaching of calcium hydroxide. At the time being there is no method which in a stringent way can handle the outer climate variations and its effect on the durability of the concrete cover. The existing models treat almost always only constant outer climate conditions, and water saturated pores in the concrete, which actually has few real applications. Furthermore, most of these models does not account for the charged character of the important ionic species which being transported in the material, treating them as uncharged particles unaffected of other types of ions present.

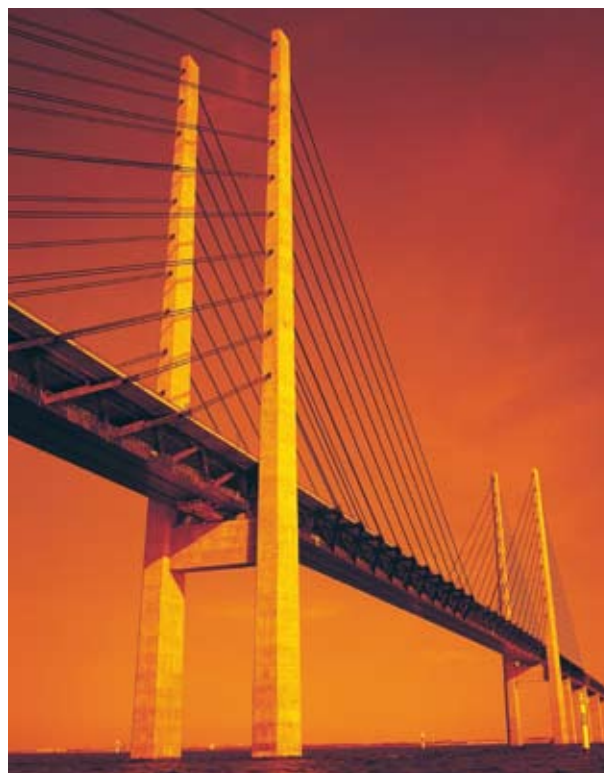
Important concrete constructions are today designed with regard to durability with heavily simplified methods of empirical nature based on data of experiments running for only a few years. In this constructions are designed for 100 years performance, without having in all parts quantifying all central material parameters and its empirical time dependence has not been fully understood and explained.

Such predictions become highly uncertain with the risk that high costs must be spent on reparations and maintenance at early ages. Another problem can also be that too strong demands are given on constructions using the rough models, which in turn contributes to difficulties in production.

New knowledge

Today, instead, there exist experimental evidence and verifications on the ionic multi-species diffusion, that is, diffusion of different types of ions, such as chlorides, hydroxide, and potassium, in the pore solution of concrete. New knowledge about how the moisture transport affects the ionic multi-species diffusion is also being established.

The effect of considering the ionic multi-species in durability models has during the last years been studied in Laval University in Quebec, Canada, Lund University and Chalmers University in Sweden, Technical University of Denmark and at Taiheiyo Cement in Japan. The moisture transport problem has been studied intensively in the Nordic countries and internationally for many years. In which way the moisture transport affects the ionic multispecies is in many part unknown, especially when considering the important coupling to the chemical interactions between ions in the pore solution and in the solid components of the cement in the concrete.



Øresund bridge:

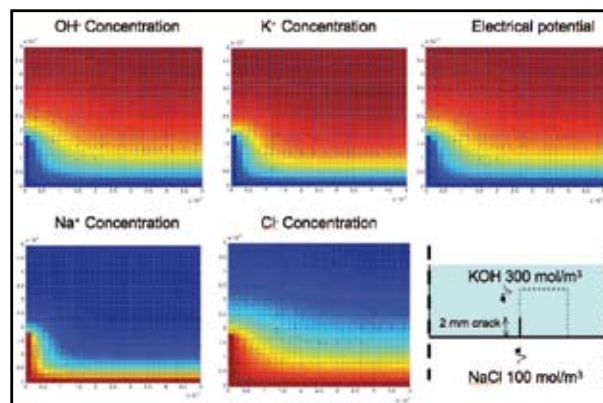
The choice of the concrete composition in Øresund Bridge is partly a result of research involving mathematical modeling of its degradation

Advanced methods

The modeling of this type of behavior is presumed to be important as it is now possible to model cases, which is much more related to the real occurring behavior as compared with the much more simple traditional models.

In the project advanced numerical methods are applied together with advanced so-called hybrid mixture theories defined within the continuum mechanics. The finite element method is used to solve the coupled transient differential equations which stems from the continuum approach using suitable constitutive assumptions.

Tailored programs are implemented in the project using non-linear solution techniques and the finite element method. Results from different simulations are compared with measurements of several different chemical elements in concrete. In this respect, mainly, measurements from an electron micro probe analyzer are used.



Example of calculated results regarding ionic concentrations in a domain of concrete exposed to seawater. Penetrating chlorides is harmful due to its ability to accelerate reinforcement corrosion



The Airport in Munich provides a fine example of what may be a result of an education at DTU and TUM.

Double Degree in Civil Engineering at TUM and DTU

A new agreement between Denmark and Germany on teaching and research means that Danish students can study in Munich.



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DTU Civil Engineering and the Faculty of Civil Engineering and Geodesy at the highly reputed Technical University of Munich (TUM) have made an agreement on teaching and research. The agreement is quite comprehensive and comprises a Double Degree in Civil Engineering. This means that students fulfilling the criteria can obtain a diploma as Master of Science in Civil Engineering from TUM as well as from DTU.

A specialised double degree has already been established in computational mechanics, but the new double degree comprises all aspects of civil engineering.

In addition to the double degree, the agreement comprises exchange of students for master projects and for course work, summer courses, PhD courses, exchange of faculty for teaching and research, research collaboration, organisation of common workshops and collaboration on accreditation of the departments. The first students already benefit from the new agreement including the most advanced knowledge from the two universities in their education.

New MSc in Architectural Engineering

Architectural Engineering educations are popular with industry and students. Therefore, DTU Civil Engineering has established a new study programme from spring 2008.

The Bachelor education in Architectural Engineering has proved to be a success attracting very qualified students. It is a Bachelor of Engineering education, which is designed to prepare the students for practise in three and a half year. However, many students prefer to extend their study with a Master of Science education in Civil Engineering often supplemented with courses from a school of architecture, and the companies of the building sector agrees that Architectural Engineers at a MSc level would be of interest for many applications.

The Department of Civil Engineering at DTU has therefore established a Master of Science education in Architectural Engineering. The new education contains two study lines: Structural Design and Functional Design, which in this context means building services, comfort, and building energy. The new study is offered from spring 2008.

Permafrost model predicts impacts of future climate changes

The Arctic Technology Centre at DTU Civil Engineering is involved in a research project on changes in permafrost in Greenland and Alaska. The results will enable decision makers to evaluate the impacts on society



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Everyone talks about climate changes and generally scientists expect temperature increases on a global scale. According to the fourth assessment report from IPCC – UN's Intergovernmental Panel on Climate Change – the average global temperature is expected to increase between 2.8 and 7.8 degrees C in the course of the coming century, and the polar areas are expected to see larger temperature increases than the rest of the globe. In Midwest Greenland the mean annual air temperature has increased by approximately four degrees C over the past decade, and this has had consequences for constructions and infrastructure.

The reason is that the temperature changes affect the thermal regime of the ground, and thereby the distribution of permafrost. Permafrozen areas may contain large amounts of ice, the volume of which may exceed by far the natural unfrozen porosity of the ground. Thawing permafrost may therefore result in large settlements and thereby greatly affect on existing roads, airport runways and buildings, as well as larger future construction and infrastructure projects.

Research project

The Arctic Technology Centre (ARTEK) at DTU Civil Engineering is presently involved in a research project on changes in permafrost

in Greenland and Alaska. The project is funded by the American research council, National Science Foundation (NSF, project ARC-0612533), and one of the goals is to integrate climate and permafrost modelling and make the results available in a form suitable for decision makers. The project is a cooperation between the University of Alaska Fairbanks (UAF), the Danish Meteorological Institute (DMI), ASIAQ (Greenland Survey) and ARTEK.

We are currently calibrating a climate driven permafrost model for the two regions (west Greenland and the northern part of Alaska) by means of data from new and existing climate and ground temperature measurement stations. DMI's regional climate model, which is being modified to unprecedented high spatial resolution of 5-10 km², delivers temperature and precipitation data for future climate scenarios as input to the permafrost model. The model will be used to calculate the effect of different temperature scenarios for the 21st century on permafrost distribution and thickness in Greenland and Alaska.

Focus of the project

The west coast of Greenland is the most densely populated area of the country, and thus climate changes are expected to have greatest



Data collection from the ground temperature measurement station in Kangerlussuaq (Søndre Strømfjord in Greenland).

impact on the society in this area. The project therefore focuses on this area, which is even more interesting because it spans several different permafrost zones. In cooperation with ASIAQ, ARTEK has established a series of measurement stations in towns representative of the different climate zones on the Greenlandic west coast. These investigations will result in a technical characterization of the geological materials found in the different areas, such as the ice content and strength parameters. The investigations have already shown large variations in local conditions in the different towns.

The large local variations emphasize the necessity of establishing reliable predictions of climate related impacts on constructions and infrastructure, in order to be able to prioritize in technological and economical decisions to the benefit of society. One of the main goals of the project is therefore to produce risk zonations for the Greenlandic towns, based on concrete technical investigations combined with a quantitative assessment of how permafrost will react to the modelled climate scenarios.

This will enable decision makers in Greenland to evaluate impacts on society with a special view to planning, mitigation and adaption to future climate changes.

Permafrost The term "permafrost" is used about any type of soil or rock, for which the temperature is below 0°C for two years or more. The definition is applied without regard to the type of material or phase of the pore water (ice/water). Approximate 25 % of the land masses of the world are covered by permafrost. Permafrost can vary in thickness from very thin sections to layers many hundred meters in thickness.



Example of a sensitive clay deposit which has a water content above the liquidation limit after thawing

Concrete elements

- from teaching to innovation



Buildings with prefabricated wall elements like Betty Sørensen Parken in Vejle, a home for old people, is popular, although window and doors requires large openings in the elements. This requires large shear capacities in the elements

Cooperation with the industry in teaching and student projects leads to innovations in modern practice. New simplified design formulas have been developed and lead to simpler and cheaper design procedures.



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Reinforced concrete is the world's most used construction material due to its cost-effective performance, this makes design of concrete structures one of the key qualifications all civil engineers must have. This is why DTU Civil Engineering teaches concrete structures to app. 300 students annually and why a large number of students each year choose to work with concrete in their projects.

Concrete has been used for many years, but there is still a large need for research, development and innovations in order to optimize the use of the material and perhaps also to reduce the use of cement and reinforcement in order to reduce the costs and environmental impact.

DTU Civil Engineering has been able to carry out a large number of student projects, where the students work together with the industry on relevant problems, leading to innovation, research and even scientific publications.

Performance of the elements

Precast elements are used extensively in Denmark, where 20-30.000 precast elements of lightweight aggregate concrete with open structure are used annually, corresponding to over 50 percent of the walls in the building structures. The elements use far less cement and reinforcement than ordinary concrete structures as the elements are lightly reinforced and as the concrete with open structure uses far less cement than ordinary concrete. The downside of these resource savings is that the verification of the performances may require additional work in some situations.

One of the time consuming activities in the design of precast concrete structures is thus the verification of the buildings overall

stability, where the elements need to perform as shear walls, where the low content of reinforcement leads to time consuming estimations. The estimations are traditionally based on quite simplified and conservative models, which only take a part of the elements into account.

Student projects

Teams of students have in their projects designed a number of elements, which were produced by the industry and later tested in full-scale in the laboratories at DTU Civil Engineering, verifying capacities of 10-25 times the required capacities. The students have also estimated the shear wall capacities of the elements, using traditional concrete plasticity theories in FEM-estimations and plasticity models for predicting the behavior and capacity of the walls.

As a result of these projects, simplified design formulas have been developed, leading to an integrated estimation of the shear wall capacities with 100-200 percent increase of the design capacities and a simpler design procedure. These formulas will be made available to producers, consultants, national authorities and the Code Committee later this year.

The future

The projects and the innovative cooperation with the industry have spawned a number of research and development projects, and have also lead to an increase of the student projects in the field of modern concretes, improved shear wall designs and even to projects in the field of reduced or alternative reinforcement – as e.g. the use of plastic fibers, which are not only durable and non-corrosive, but which can actually replace the traditional steel reinforcement.



Testing of 12 m² large panels with window holes revealed in-plane shear strengths of up to 450 kN.

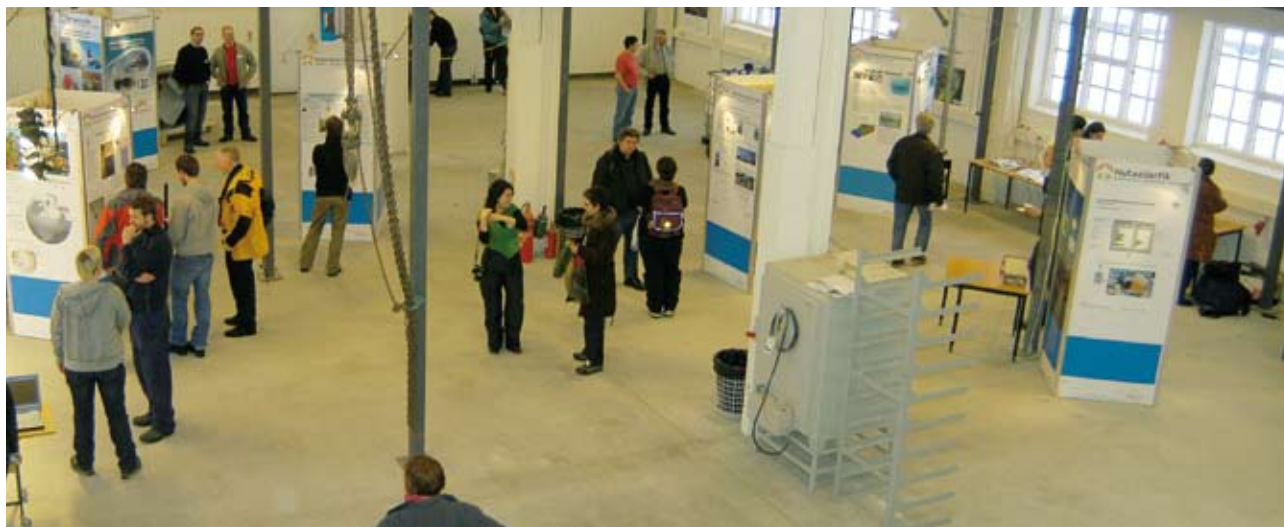
Nutaaliorfik

– a show window for new sustainable projects

The Greenland Innovation Centre was established in 2005 as an activity centre for the development of Arctic technology.



Artek student projects are currently being exhibited in the Greenland Innovation Centre. Here a student presents an installation of tubular heat collectors



The picture illustrates part of daily life in Nutaaliorfik – home for good ideas, models and innovative solutions in the fields of construction, energy and the environment.

Artek student projects are currently being exhibited in the Greenland Innovation Centre. Here a student presents an installation of tubular heat collectors



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In the old shipyard in the Sisimiut harbour area the Arctic Technology Centre, ARTEK, at DTU has got the opportunity to promote sustainable, innovative solutions in the fields of construction, energy and the environment. Solutions that show special consideration for Greenlandic society, the environment and the climatic conditions distinctive of Arctic areas are here exhibited.

The innovation Centre - Nutaaliorfik, in Greenlandic language-focuses on developing good ideas with the potential for transformation into sustainable business projects.

Filled with good ideas

The Innovation Centre was established in 2005 and after an extensive rebuilding it was opened for use the following year. It is now filled with good ideas, posters and models. Companies are exhibiting their products (heat exchangers, solar collectors, hydro power turbines, small waste water treatment plants etc).

Inventions made by ARTEK are also demonstrated here. An example is building materials – bricks and floor tile - produced of local raw materials.

Nutaaliorfik represents a natural development of the activities currently being run under the auspices of ARTEK. The best student projects developed during courses in Arctic Technology can be seen here in a physical model or as a poster – and the idea is to promote the ideas to the professional society. The final goal is to support and inspire so much that new innovative companies will be established.



Nutaaliorfik – the Greenland Innovation Centre is situated in the old shipyard in the Sisimiut harbour.

Self-Compacting Concrete, the **concrete of the future**



The extension to the Ordrupgaard Museum consists of structural elements, each with a unique geometry. The extension is made of glass and SCC cast in situ and is an example of the architectural freedom in structural design allowed by SCC.

Self-Compacting Concrete, SCC, was introduced in the 1980s and has continuously been an object for improvement and research. DTU Civil Engineering together with two other departments at DTU and the industry conduct a cross disciplinary project within technology and production science.

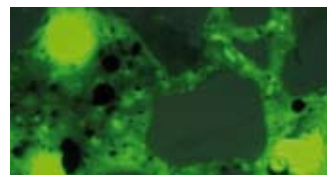


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Concrete is the world's most important construction material. In Denmark 10 million tons are produced annually. Conventional concrete requires vibration to overcome its yield stress and become compacted. Vibration is noisy, labour intensive, and can introduce inhomogeneities in the concrete. To overcome the need for vibration, Self-Compacting Concrete, SCC was introduced in Japan in the 1980s when new types of admixtures became available. SCC is a tailored concrete with special, engineered properties in its fresh state. SCC flows into the formwork and around reinforcement by its own weight. This drastically improves both productivity and the working environment during construction, and potentially improves the homogeneity and quality of the concrete. Moreover, SCC allows greater architectural freedom in structural design. SCC has since its introduction been an object for research in order to improve its properties, and at the Department of Civil Engineering at DTU research is focused on several aspects of SCC: from the impact of mix composition and mixing procedure on the rheological properties of fresh SCC, possible sources of error in testing to numerical modelling of flow and the engineering properties of the hardened material.

Challenges and opportunities

The main challenges and opportunities in using SCC lie in its robustness and the compatibility of constituent materials, the modelling of flow and virtual mix design, and last but not least, its sustainability. Robustness, i.e. the capacity of concrete to retain its fresh properties



Effect of mixing intensity and mixing schedule on the microstructure of a typical Danish SCC. Detail of fluorescence impregnated thin sections, area 2.0 x 1.2 mm. Photos were taken in UV light.

when small variations in the properties or quantities of the constituent materials occur, is vital for the success of SCC. SCC is generally more sensitive to variations in the content and properties of the constituent materials than conventional concretes. So it is essential to develop tools for the assessment and optimisation of mix design and casting. A major obstacle for further application of SCC is the lack of understanding of the form filling process, leading from time to time to problems such as segregation. Segregation significantly reduces the concrete quality which subsequently leads to problems during the service life of structures.

New prediction tools

It has in a recent industrial PhD project been demonstrated that a complete framework consisting of numerical, single fluid flow modelling and rheological testing and characterization can be established, yielding consistent results with the full-scale form filling of SCC. The industrial PhD project was undertaken by Lars Nyholm Thrane, Danish Technological Institute, in collaboration with Unicon, the Departments of Chemical and Biochemical Engineering and Civil Engineering at DTU.

Further work is planned in a cross disciplinary collaboration research project within technology and production science, focusing on solutions to scientifically unsolved problems in the construction industry. The project group consists of DTU Civil Engineering, the Department of Mechanical Engineering at DTU, and the Department of Chemical and Biochemical Engineering at DTU together with a group of associated partners from the industry and an international research institute. The main objective of the project is to improve the basic understanding of the flow behaviour of SCC. The research will produce tools for the prediction of the casting process itself (formwork filling and formwork pressure) along with the prediction of the occurrence of hidden defects such as heterogeneities and weak interfaces. The project will result in a modelling framework for numerical simulation of full scale casting of SCC. These prediction tools will facilitate optimisation of resources and reduction of CO₂-emission supporting the necessary sustainable development.

The Danish Government wants to double the number of PhD candidates in the following years, but many candidates in civil engineering choose to go on the job market instead of a pursuing career as a researcher. DTU Civil Engineering arranges annual PhD days to present the students with the possibilities as a PhD student.



The Technical University of Denmark and the departments plan a lot of arrangements every year to attract new students and PhD students. Besides the annual PhD days the university keeps an open house arrangement every year for students.

There is a **need** for more **PhD students**



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Fresh candidates in civil engineering are in big demand on the job market, and the candidates look forward to start in their first “real job” after education. Therefore, the possibility of entering into a career as a researcher has not always been sufficiently investigated before the candidates leave DTU

Regardless of this, it has been the goal of the Danish Government since its Globalisation Council completed its work in 2006 that the number of PhD candidates should be doubled within a short number of years, and an important purpose of this development should be to also get a significant number of PhDs into the industry. This was the background why DTU Civil Engineering, arranged a seminar on February 28, 2007 to explain about the possibilities to obtain a degree as PhD degree.

The seminar was arranged as a late afternoon event which included presentation by a number of representatives of stakeholders. The seminar addressed students in their last one or two years of studies so that it could directly stimulate them to consider a research career and so that they could possibly shape the last part of their studies in order to prepare for their continuation into research education.

New academic insight

Presenters at the seminar comprised young and experienced PhD candidates who now work in industry as contractors, building material manufacturers or consultants, or as researcher in a technological service institute. The candidates today have highly professional technical functions in their companies, or they possess strategic positions. The companies expressed that employment of a PhD means not only engaging a very skilled colleague to fulfill daily tasks in the business, but typically such a person also brings new academic insight, quality and thoroughness into the company. Furthermore, the PhDs are good contact points between the companies and universities and

they become ambassadors in initiating new types of projects and contacts. In another part of the seminar presentations by PhD candidates in progress were given: A freshman as a PhD student, a PhD student amidst his studies, and a PhD candidate who had just defended her thesis. The graduated PhD candidate expressed how the study had provided her with methods to obtain a feeling of high professional competence and overview, while she had gained a lot of good experiences in creating networks and establishing friends among colleagues and acquaintances from participation in conferences and external research visits.

Several forms of PhD projects

A representative from the PhD-administration at the Technical University of Denmark explained about the societal need for many new PhD candidates, and he explained about the different existing forms of PhD projects:

- Scholarships from DTU
- Projects financed by public or private research projects
- Co-financed projects with other research institutions or companies
- Industrial PhDs and Innovation PhDs

The seminar was attended by some 40 potential PhD-students, but also representatives of companies and some of DTU Byg's supervisors. It was interrupted by a pizza and beer break, during which some first initial contacts were established. DTU had a call for applications for PhD-scholarships a month after the seminar. Eight students applied for scholarship. Although not all of them directly got a scholarship, seven of them today are active as PhD students – hereof two as industrial PhD students. In comparison, five students applied the year before, and three of these are today ongoing.

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Christos Georgakis, Gregor Fischer

Marie Louise Pedersen

Time Dependent Stiffness of Laminated Glass
Henrik Stang, John Forbes Olesen

Joan Hee Roldsgaard, Martin Bjerre Nielsen

Time and Temperature Dependent Properties in Laminated Glass
Henrik Stang, John Forbes Olesen, Jens Henrik Nielsen

Dan Kallehave

Development and Application of Fibre Reinforced Lightweight Concrete
Henrik Stang, Per Goltermann

Anders Madsen

Plastic Stability of Plates
Jeppe Jönsson

Heidi Christiansen, Jens Zangenberg Hansen

Mechanical Properties of Bolt Groups in Glass Structures
John Forbes Olesen, Jens Henrik Nielsen

Thomas Olsen

Beam Element for Modelling of RC in SLS and ULS
John Forbes Olesen, Peter Noe Poulsen

Therese Back Laursen, Marlene S. Hagen Eriksen

Heat and Moisture Investigation of Seagrass as Thermal Insulation in Outside Walls
Kurt Kielsgaard Hansen, Carsten Rode

Katarzyna Wróblewska

Application of Surface Treatment for Protection of Reinforced Concrete Structures
Mette Geiker

Hallgrímur Örn Arngrímsson

RCC for Dam Constructions – Characterization of Aggregates
Mette Geiker, Henrik Stang

Kirsten H. Jürgensen

Binding of Water in Dense Cementbased Materials
Ole Mejlhede Jensen

Jacob E. Christensen, Janni Tjell

Shear Failures in Lightweight Concrete Slabs
Per Goltermann



Stinne Hede Poulsen, Kenneth Kleissl

Flange Induced Buckling

Peter Noe Poulsen, Jesper Gath, Thomas Hansen

Aldis Run Larusdottir

Measurement of the convective heat transfer coefficient
from thermo active building systems focusing on acoustic

Peter Weitzmann

Kim Nicky Petersen, Svend Pilgaard Larsen

Frame Corner of I-Beams

Sigurdur Ormarsson, Staffan Svensson

Mads Christiansen, Mikkel Christopher Askjær-Friis

Moment Stiff Corner of Kerto-frame

Sigurdur Ormarsson, Staffan Svensson

Jakob Hauberg, Christian Ulrich Barfoed

Post and Beam Connections with Glued in Bolts

Staffan Svensson, Sigurdur Ormarsson

Anders Abildgaard Albertsen

Glued Connections between Wood and Steel Plates

Staffan Svensson, Sigurdur Ormarsson, Martin Uhre Mandrup

Søren Terkildsen

Development of a Simulation Model of the Thermo Active
Building System

Toke Rammer Nielsen

Eva Maria Larsen

Development of Ventilation Solutions for Low Energy

Single-family Houses

Toke Rammer Nielsen, Peter Weitzmann, Svend Svendsen

Henriette Ryssing Menå

Development of Ventilation Solutions for Low Energy Apartments

Toke Rammer Nielsen, Peter Weitzmann, Svend Svendsen

Jeppe Egelund Szameitat

Development of Ventilation Solutions for Low Energy Apartments

Toke Rammer Nielsen, Peter Weitzmann, Svend Svendsen

Susanne Vedel Jørgensen

Utilization of Waste from Fishing and hunting as Energy Supply
for Sisimiut, Greenland

Arne Villumsen, Janne Fritt-Rasmussen

Adalbjorg B. Guttormsdottir

Electrodialytic Remediation of Heavy Metals from

MSW Incineration Fly Ash from Sisimiut, Greenland

Arne Villumsen, Pernille Erland Jensen

Nanna Isbak Thomsen

Depository for MSWI Flyash in Greenland

Pernille Erland Jensen, Arne Villumsen

Katrine Staal-Thomsen, Johanne Wibroe

Investigation of the Effect of Electrodialytic Remediation
of Oil Contaminated Arctic Soil

Pernille Erland Jensen, Janne Fritt-Rasmussen

Staff

| As of December 31 2007 | | 2007 | 2006 | 2005 | 2004 |
|------------------------------|---------------------|------|------|------|------|
| Scientific | Professor | 7 | 7 | 9 | 11 |
| | Associate Professor | 40 | 46 | 38 | 44 |
| | Assistant Professor | 7 | 10 | 15 | 15 |
| | Other VIP | 9 | 9 | 6 | 4 |
| | PhD Students | 42 | 37 | 44 | 40 |
| Total | | 105 | 109 | 112 | 114 |
| Technical and Administrative | Academic | 9 | 11 | 11 | 10 |
| | Clerical | 13 | 13 | 12 | 12 |
| | Technician | 20 | 18 | 22 | 22 |
| | Other | 7 | 5 | 5 | 4 |
| Total | | 49 | 47 | 50 | 48 |
| Total Department Staff | | 154 | 156 | 162 | 162 |

Education

| | | | | | |
|-------------------------|----------------------------------|-----|-----|-----|-----|
| STÅ ¹ -total | | 514 | 483 | 508 | 519 |
| Projects (students) | MSc | 88 | 85 | 92 | 74 |
| | BSc | 51 | 31 | 36 | 56 |
| | BEng | 119 | 130 | 62 | 82 |
| Admission (students) | BSc (Building Technology) | 58 | 62 | 72 | 60 |
| | BEng (Architectural Engineering) | 47 | 50 | 52 | 42 |
| | BEng (Civil Engineering-summer) | 84 | 75 | 63 | 58 |
| | BEng (Civil Engineering-winter) | 29 | 38 | 30 | 32 |
| | BEng (Arctic Technology) | 18 | 8 | 9 | 8 |

Research

| | | | | | |
|-----------------|-----------------|----|----|----|----|
| Refereed papers | Total | 67 | 45 | 61 | 63 |
| | Of these in ISI | 48 | 30 | 43 | 37 |
| PhD theses | | 13 | 5 | 8 | 10 |
| Doctoral theses | | 0 | 0 | 1 | 0 |

Finances

| | | | | | |
|------------------|------------------|--------|--------|--------|--------|
| Revenues | DTU-grant | 59.827 | 56.656 | 53.184 | 52.523 |
| | External revenue | 30.326 | 31.033 | 30.862 | 28.563 |
| | Total | 90.153 | 87.689 | 84.046 | 81.094 |
| Expenditures | Wages | 66.782 | 63.021 | 62.725 | 62.917 |
| | Other expenses | 23.954 | 26.420 | 19.628 | 16.445 |
| Total | | 90.736 | 89.441 | 82.353 | 79.362 |
| Result | | -583 | -1.757 | 1.693 | 1.732 |
| Available amount | January 1 | 6.200 | 7.957 | 6.264 | 4.532 |
| Carried forward | December 31 | 5.617 | 6.200 | 7.957 | 6.264 |

STÅ¹: 1 STÅ is one student annual work (1 STÅ=60 ects points)

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