Department of Civil Engineering
Annual Report 2012

DTU Civil Engineering
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Annual Report 2012

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Solar Decathlon Europe Project
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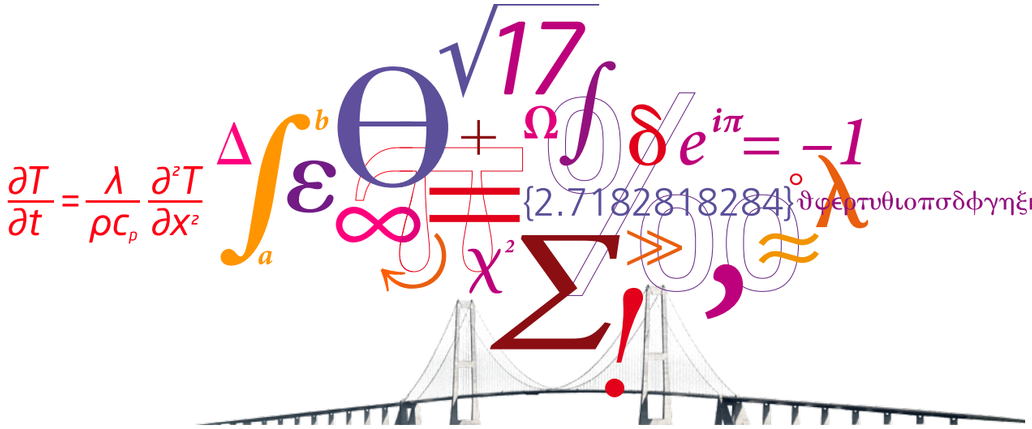

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Management Report 2012:

Meeting the challenges

Commitment – in the broad sense of the word – succinctly describes the spirit behind the driving force at the Department of Civil Engineering – DTU Byg in 2012. Important strategic societal challenges have been embraced, while several major changes to the dynamic boundary conditions of the organization have been taken on, assessed and adapted to. In the following, it is my pleasure to provide a brief overview of the department's activities and achievements over the past year and also to give you an idea of where we will be focusing our efforts in the year ahead.

Photo: Simon Klein Knudsen

Most significantly, the department has initiated three 'development areas', each of which addresses a major strategic societal challenge. These development areas are at the heart of the department's new strategy for innovation and services to the public and private sectors. Each of the initiated development areas – Zero Waste Byg, Sustainable Light Concrete Structures and Solar Decathlon – addresses the fundamental challenges of reducing energy consumption, reducing emissions to the environment and reducing raw materials consumption, all key factors for sustainable social development. The development area Zero Waste Byg is headed by Associate Professor Lisbeth Ottosen, Sustainable Light Concrete Structures is headed by Professor Kristian Dahl Hertz and Solar Decathlon is headed by Professor Bjarne W. Olesen.

Our initiative to strengthen the sustainable impacts of the activities of the department in Greenland is gathering momentum. Preparing Vision 125, which aims to develop our Arctic Technology Centre (ARTEK) into a full university centre on arctic technology and engineering in Sisimiut with an annual intake of 125 students, has progressed significantly. Together with the Greenland government and major industrial stakeholders in Greenland, the relevance of such a university centre has been assessed and confirmed and the scope of its activities defined. It is our objective that this activity will enhance and facilitate sustainable societal developments in Greenland – by preparing for and meeting the challenges associated with mining and offshore oil and gas exploitation. We look forward to the continued collaboration with the Greenlandic society on this important task, and we are keen to meet and talk with our partners in the newly established government of Greenland.

In 2012, the department's research performance has been evaluated by a panel of international experts. Various aspects relating to our research production and international standing were assessed, with suggestions being provided on possible areas for improvement. The overall result of the evaluation was very positive. While significant potential for improvement undoubtedly exists, the general picture is that the department's research performance is of a high international standing. The few critical points made by the panel generally resonated with our own thoughts on possible improvements and tie in completely with many of the initiatives which have already been initiated to support research quality within the department. In addition to the positive research evaluation, it is very satisfying to note that the department – in seventh place – again ranks in the top ten university civil engineering departments worldwide.

Activities centered on student interaction are important for the department. This is particularly true of the department's involvement in the DTU inter-departmental Grøn Dyst (Green Battle) contest. Moreover, in 2012 the department led the way at DTU in a multi-departmental student activity, the 2012 Solar Decathlon competition. This international competition between universities aims to involve students from different engineering disciplines in the design, construction and operation of uniquely designed eco-efficient houses with high standards of comfort and solar-based energy concepts. DTU excelled in the competition by developing the FOLD house. While we did not win the competition outright, we achieved the highest score among participants for one of the most prestigious contests, namely the development of a concept for integrating solar energy. For the department and for DTU as a whole, the Solar Decathlon competition was a huge success in facilitating innovation and collaboration within DTU and between DTU and industry. The Solar Decathlon competitions will be pursued by the department in future, and we have already qualified with ten other universities to participate in Solar Decathlon 2014, which is being staged in France.

Teaching activities are a core responsibility and a key area of interest for the department. The department is proud to report that, in the past year, eleven PhD students, 110 MSc students and 110 professional bachelor students graduated from the department's PhD School and engineering programmes. Students are showing a strong and increasing level of interest in civil engineering, while industry also needs good university graduates. This is a fortunate situation for the department and one which we embrace with great enthusiasm while fully appreciating our responsibilities towards society. Our task is to provide educational programmes which are relevant for the global community yet which also serve the needs of Danish society and, not least, ensure that the research insights, experience and best practice are passed on to new generations of engineers – for the benefit of society. To this end, our newly established honours student programme, sponsored by the Knud Højgaard Foundation, provides a unique instrument for advancing students with extraordinary track records and abilities. In the past year, we have been fortunate to sponsor and initiate a number of such honours students.

In 2012, it was announced that DTU would merge with the Engineering College of Copenhagen (IHK) in Ballerup. What was formerly known as IHK will now become DTU Diplom. The implication of this merger is that the professional bachelor programmes in civil engineering at DTU Diplom and at our department will be integrated. This process, which is still ongoing, is seen as a welcome chance to assess and modernize our professional bachelor educations in full synergy with our many new and competent colleagues from DTU Diplom. Quality, relevance and innovation are the leading principles in this process.

The high standard of activities in the department and our many achievements rest on the commitment and skills of all our staff. Faculty, research, laboratory and administrative personnel make important contributions towards the department's significant achievements. Our efforts to improve the daily routines within the department are bearing fruit and will continue to be a focus area in future. The organization of the department has witnessed some moderate but significant changes in 2012. First, we have all adapted our governance structure to integrate the management of our new development areas into the operational management of the department. As you will see from the enclosed organizational diagram for the department, the development areas have been organized as cross-disciplinary activities alongside our Artic Technology Centre (ARTEK). In addition, a new function in the departmental management, namely teaching coordinator, has been introduced to enhance the link between teaching activity management and resource management. Professor Per Goltermann has been appointed to this position and is now a permanent member of our management team.

It should also be mentioned that the planned generation shift in the management of our ARTEK centre has been successfully accomplished, and we are delighted to now announce the centre's new leader, Carl Egede Bøggild, who not only has a strong research profile and experience from the Arctic from his former positions at UNIS in Svalbard, Norway, and at GEUS in Denmark, but who also has strong personal relations with Greenland, where he was born and grew up.

I would like to emphasize – as always – that we greatly treasure our collaboration with the industry and governmental and non-governmental organizations. These partnerships are crucial for ensuring our relevance in all our core activities. Finally, I would like to take this opportunity to express my gratitude for the time, expertise, commitment and dedication shown by all employees of Department of Civil Engineering - DTU Byg as well as by all our colleagues and partners both in Denmark and internationally.

I wish you enjoyable reading.

Kind regards,

Michael Havbro Faber
Head of Department
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Organisation

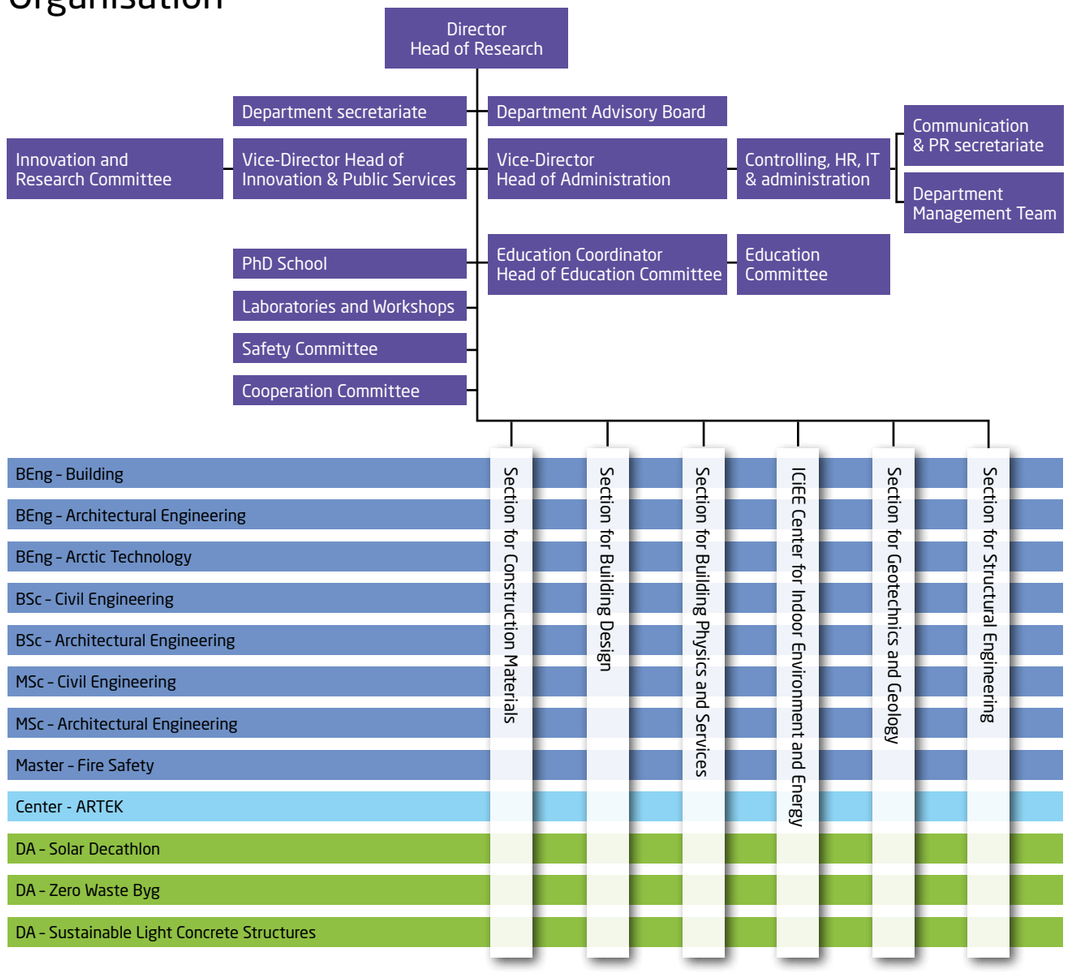

Figure: Organisation Diagram

Head of Department:

Professor Michael Havbro Faber

Deputy Head of Department
Professor Henrik Stang

Head of Administration
Søren Burcharth

Advisory Board:

Professor (adj) Louis Becker, ArchitectMAA, AIA, RIBA, Design Director, Partner, Henning Larsen Architects A/S

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Building Physics and Services
Professor Carsten Rode

Construction Materials
Professor Ole Mejlhede Jensen

Geotechnics and Geology
Professor Ida Lykke Fabricius

Indoor Environment
Professor Bjarne Olesen

Structural Engineering
Professor Jeppe Jönsson

Administration and IT
Head of Administration
Søren Burcharth

Laboratories and Workshops
Laboratory Manager
Jørgen Bjørnbak Hansen

Centres:

ARTEK, Arctic Technology Centre
Head of Center Carl Egede Bøggild

ICIEE, International Centre for Indoor Environment and Energy
Professor Bjarne W. Olesen.

Study Programmes:

Civil Engineering (MSc)
Associate Professor Staffan Svensson

Building Technology (BSc)
Professor Per Goltermann

Architectural Engineering (MSc)
Associate Professor Jan Karlshøj

Architectural Engineering (BSc)Associate Professor Toke Rammer Nielsen

Architectural Engineering (BEng)Associate Professor Lotte Bjerregaard

Building Engineering (BEeng)Associate Professor Anette Krogsbøll

Arctic Technology (BEng)Associate Professor Hans Peter Christensen

Redesigning construction materials towards a zero waste society

A new innovative development area, ZeroWaste Byg, at DTU Civil Engineering aims to use waste as a resource in building technology in cooperation with the building industry.

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Researcher Pernille Erland Jensen
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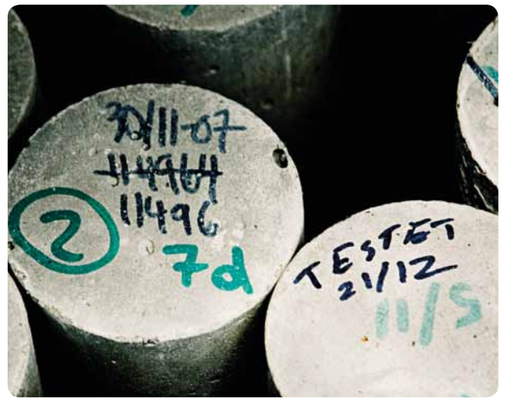
"Waste to resource" is a popular mantra in the environmental policy of Denmark and many other countries. It has come out of necessity: the World's population is growing, putting increased pressure on natural, primary resources and causing their scarcity and at the same time waste is piling up. This situation is untenable and points to the need for a much better life-cycle of material flow. Waste must be used as an alternative (secondary) resource replacing primary resources.

In the ZeroWaste Byg development area we have taken up this challenge in relation to building technology. The new raw materials offer unparalleled possibilities for the production of innovative construction materials. These could either be with characteristics that we already know today but using far less primary resources, or with new characteristics that fit future needs. For example, new types of concrete with permeable qualities that give a healthier indoor environment.

ZeroWaste Byg focuses on the use of particulate secondary resources (e.g. various ashes, dredged sediments and organic waste fibres) in construction materials. At the moment there is not enough knowledge of the effects of secondary resources on construction materials so the building industry cannot set relevant specification requirements for secondary resources. Such knowledge will come from the research. Coal fly ash and stone dust have both changed status from being problematic waste products to becoming valuable additives in concrete, we want to establish the scientific background for similar "good news stories".

New and innovative construction materials

ZeroWaste Byg was created in 2012 as an interdisciplinary development area at DTU Civil Engineering and researchers from all department sections are involved together with representatives from the building industry. The breadth of research ensures that the performance of the new construction materials is optimized from different perspectives. The new materials are investigated and designed on the basis of knowledge obtained from micron to macro scale, i.e. from materials science using advanced microscopes to structural engineering investigating large structural elements. The materials are also developed and designed for their



ZeroWaste Byg focuses on the use of particulate secondary resources (e.g. various ashes, dredged sediments and organic waste fibres) in construction materials. Photo: Simon Klein Knudsen.

aesthetic performance, minimal pollution emissions, effect on indoor environment (e.g. hygroscopic characteristics for maintaining constant relative humidity or absorption of air pollutants) and energy performance. By approaching the task in such a variety of ways, true optimization of the new materials is obtained.

Securing the secondary resources

Researchers in the ZeroWaste Byg team have developed an electrochemical technique for the extraction of various elements. With this technique the heavy metals can be removed (and if feasible recovered) and all resources can be used in an environmentally sound approach: urban mining of scarce elements and the mineral residue used in construction materials. Heavy metals in secondary resources must be removed before the resource is used in construction materials so there are no problems regarding toxicity when handling the material at its end of life. Further development of techniques to upgrade secondary resources to give specific characteristics to the construction material are also carried out.

The first three PhD projects

The topics of the first three PhD projects underline the broad perspective on use of secondary resources in construction materials within ZeroWaste Byg. The projects are: Alternative ashes in concrete – new aesthetics and structural performance; Electrochemical upgrading of different fly ashes for use in production of bricks and lightweight aggregates; and Hygro-thermal conditions and pollutant emissions from zero waste materials and their effects on humans. Each PhD student is supervised by researchers from different sections to ensure an interdisciplinary approach, and the synergy between the projects is fully explored through close collaboration.

Link: www.zerowaste.byg.dtu.dk

The ZeroWaste Byg team. From left Gunvor M. Kirkelund, Anja M. Bache, Ruut Peuhkuri, Per Goltermann, Lisbeth M. Ottosen, Jacob W. Schmidt, Pernille E. Jensen, Carsten Rode, Barbora Krejcirikova, Pawel Wargocki, Wan Chen and Annemette Kappel. Missing at the photo are Thomas Ingeman-Nielsen, Anders Stuhr Jørgensen and Jakub Kolarik. Photo: Simon Klein Knudsen.

Fire safety in space-craft and space infrastructures

Associate Professor Grunde Jomaas, DTU Civil Engineering, is part of a topical team assembled and funded by the European Space Agency. The team is part of the scientific advisory board for a NASA-funded experimental series on material flammability in microgravity.

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The project, Spacecraft Fire Safety, will investigate and improve the scientific understanding of fire behaviour in microgravity, which is currently widely unexplored and limited. The end goal is to refine the models for fire phenomena in space and introduce new design constraints and procedures for fire-risk mitigation in spacecrafts. The project will involve a series of ground-based experiments. The results from these ground-based experiments will be used for de-sign of and comparison with the results from the scheduled flight experiments on the unmanned Cygnus spacecraft from Orbital Sciences. The flight experiments will take place after this supply vehicle (Cygnus) detaches from the International Space Station (ISS) and before it is destroyed during its atmospheric re-entry. The principal impact of this project will be the production of a complete and unique set of experimental data. This data collection will enable the development of a forecasting tool for fire develop-ment in microgravity environments.

Optimized fire-safety strategies

Work conducted on smaller samples and for shorter experimental durations has shown that fire behaviour in low-gravity is very different from that in normal-gravity, with differences observed for flammability limits, spread behaviour, flame colour and flame structure. Spacecraft Fire Safety will conduct its tests at an appro-priate scale to understand microgravity fire science well enough to impact on adequate safety design and model development. Currently, the design of space vehicles does not include optimiza-tion of fire-safety systems. This is mainly because there are no tools that enable quantitative performance assessment. As a result, fire safety is typically an add-on feature to design. Holistic fire-safety design is a goal for this research collaboration.

The present assumptions of safety, based on normal gravity tests and protocols and extrapolated to microgravity on the basis of modelling tools, have been demonstrated to carry significant uncertainty. All existing modelling tools that enable extrapolation of empirical results to real microgravity performance have been challenged by the emergence of phenomena normally ignored because they are masked by buoyancy.

International collaboration

The engineering team and the scientific team have to communicate carefully in the planning of these experiments, as the timeline is filled with milestones that have to be passed in order to meet the understandably strict safety and design requirements for placing a 'passenger' in a supply vehicle to the International Space Station. Key accomplishments in 2012 were: overpressure testing in a vacuum facility at NASA Glenn Research Center, sample selection experiments in university laboratories and in the microgravity sci-ences glovebox onboard the ISS, experimental rig design and flight selection and approval.

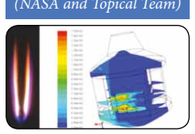
In addition to the representation of DTU, the scientific team has members from Hokkaido University (Japan), University of Queensland, Brisbane (Australia), Lomonosov Moscow State University and Scientific Research Institute for System Analysis (Russia), ZARM,University of Bremen (Germany), Université Pierre et Marie Curie (France), University of Edinburgh (UK), Case Western Reserve University (USA), University of California, Berkeley (USA), Belisama R&D (France) and NASA Glenn Re-search Center (USA). Communication of this truly international collaboration mainly takes place through teleconferences, phone calls and email exchanges. However, fruitful physical meetings for the entire team have also been arranged in Noordwijk (ESA-ESTEC), Versailles and Cleveland (NASA GRC).

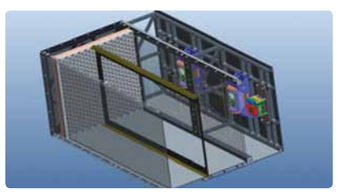
Given the long timeframe and scope of this research, the team members are continuously exploring funding options, both locally, nationally and through further international collaborations.

Safety Assessment (NASA and Topical Team)

Hardware Development and Installation (NASA)

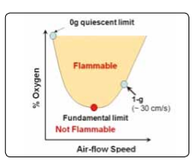
Supportive Experimental and Numerical Research (NASA and Topical Team)





Cygnus Flight Experiments

Data Transmission and Post- Processing (NASA)



Data Exploitation (NASA and Topical Team)

Supportive Experimental and Numerical Research (NASA and Topical Team)

The multi-million dollar project referred to as Spacecraft Fire Safety has an unprecedented scale for a material flammability experiment in micro-gravity, as the unmanned, pressurized environment on the Cygnus spacecraft from Orbital Sciences allows for the largest sample sizes ever to be tested for material flammability in microgravity. Furthermore, the experiments will have a duration that is unmatched in scale, as compared with typical microgravity research facilities such as drop towers (about 5 seconds) and parabolic flights (about 20 seconds). Three flights with experiments have been scheduled to take place in 2015 and 2016.

Super-light structures with holistic solutions

A new development area at DTU Civil Engineering deals with environmen-tally friendly structures. The first super-light product is the SL-deck which is mass produced at Perstrup Concrete Industry.

Professor Kristian Hertz
Section of Building Design
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Panteon - An inspiring sustainable structure built of light aggregate concrete. Photo: Kristian Hertz.

Sustainable Light Concrete Structures is a development area at DTU Civil Engineering. Super-light structures constitute a part of the development area, and they use light concrete in the areas where strength is not needed, so that buildings can save on materials, energy, and CO_2 production.
This is increasingly important in today's world, where the amounts of energy and CO_2 in the operating of buildings is reduced drama-tically, while the amounts used in construction is increased, so that now, in many cases, they outweigh those used in operation.
The development area deals with holistic solutions, which means that the structure should not only be able to bear its load, but also fulfill its requirements for acoustics, fire safety, thermal insulation, in-door climate, etc, and for bridges to be suitable to carry a road or rail tracks. The development area covers structures of massive light concrete as well as sandwich structures and the new super-light structures invented at DTU.

Super-light structures and pearl-chains

Super-light structures and pearl-chains are new principles for structural design developed by Professor Kristian Hertz at DTU Civil Engineering. The technologies are being brought to market by start-up company Abeo Ltd which holds the patents and other intellectual property rights. Abeo won a world championship in cleantech for these super-light structures which can reduce CO_2 by 20-50 percent compared with other concrete structures – more compared with steel solutions. In a super-light structure arches of strong concrete are placed only where strength is needed, and light concrete is used to fill out the shape and stabilize the stronger areas. Arches are made affordable by using pearl-chain technology, where concrete is prestressed to an arch shape – or to any other shape such as vaults or double curved rib-shells etc. The first super-light product is the SL-deck, which has strong properties in regards to fire resistance, acoustics, flexi-ble design, fixed-end supports, and long spans. It has been full-scale tested and applied in building design, and a mass production is now being established at Perstrup Concrete Industry. Pearl-chain bridges are now developed which can be built with span-widths from 15 to 100m at almost half the cost of other bridges.

*Super-light SL-deck element.
Photo: Kristian Hertz.*

Arch of SL-deck elements for a pearl-chain bridge. Photo: Kristian Hertz.

DTU took part in Solar Decathlon Europe 2012 and will attend again in 2014

The new project that DTU Civil Engineering put forward was selected from a group of more than 40 university teams. The aim of the project is to develop new knowledge and focus on creating attractive low-energy housing, that has a good indoor environment and makes use of renewable energy sources.

Professor Bjarne W. Olesen
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For the first time DTU took part in Solar Decathlon Europe 2012, the global competition for Energy Plus houses. Students from DTU Civil Engineering worked with students from DTU Environment, DTU Management Engineering and DTU Informatics (now DTU Compute) to develop, construct and operate the house which they called "FOLD". They were supported by Real Dania, the Danish Energy Agency and several industrial sponsors including Grundfos, Rockwool, Uponor and Schneider Electric.
In September 2012, DTU students took their Energy Plus house "FOLD" to Solar Decathlon Europe 2012 in Madrid, the first time DTU had taken part. The house received first prize in the category of how well the solar cells were integrated into the building - a very important discipline. In the overall competition the house came 10th.

DTU will participate again in Paris

The new project put forward by DTU Civil Engineering in November 2012 was selected from a group of more than 40 university teams, to be among the 20 teams that will compete in the 2014 competition in Versailles, France.

Professor Bjarne W. Olesen, who will again be faculty advisor for the DTU team, was very happy that the DTU team had been selected for the second time. The goal of the competition is to create new knowledge and focus on building attractive low-energy housing, that has a good indoor environment and uses renewable energy. This international competition gives participating universities the chance to get together and produce knowledge on sustainable housing with the required comfort, quality and usability, that modern society demands.

"We are proud to again be among the competing 20 university teams, where the students, as part of their curricula will design, construct, build and operate a house that, through solar power, produces more energy than it uses.

"The entry requirements for the 2014 competition are somewhat different from SDE2012 in Madrid. This time it must be shown how the house can be adapted to urban conditions – terraced house, multi-family dwelling unit etc. The students must also show how the house can fit into the government's Energy Strategy for a smart-grid and within the infrastructure of an urban development. This creates additional challenges, which address the future requirments of buildings and communities," says Bjarne W. Olsen.

Looking for sponsors

Solar Decathlon is an international competition and universities participate from all over the world (China, Japan, Egypt, Brazil, Chile, USA and several European teams). The Solar Decathlon project is not just about the final competition in Paris; but also includes submitting reports to the organisers during the design, development, construction and testing phases. These reports are also evaluated by different jurors during the final competition.

From DTU's side, the competition starts in the spring semester of 2013. The project will be managed by DTU Civil Engineering in cooperation with teachers and students from other DTU departments and possibly some institutions from outside DTU too.

The Solar Decathlon project is one of DTU's Blue Dot Students' Projects, which are sustainable projects driven by students. One of the main tasks is to motivate the students so that, hopefully, a core group of students can participate all the way through the final in Paris in June-July 2014. DTU is now looking for sponsors (industry, organisations, research funding etc.), who can work with the students and teachers, or supply products and funding.

Martin Lidegaard, Minister for Climate, Energy and Building, introduces "FOLD" in June 2012. The DTU's concept for a future Energy Plus house, took part in Solar Decathlon Europe 2012 in Madrid in September2012. Foto: Thorkild Christensen.

DTU students participated at Solar Decathlon Europe 2012 in Madrid in September 2012 for the first time with their Energy Plus house "FOLD". The house received first prize in one of the very important disciplines, how well the solar cells were integrated into the building.

Innovation
as a key driver

DTU Civil Engineering – DTU Byg has taken the initiative to strengthen its innovation and collaboration with the private sector and governmental and non-governmental organizations. Innovation Day 2013 is the first of a series of networking sessions with our stakeholders.

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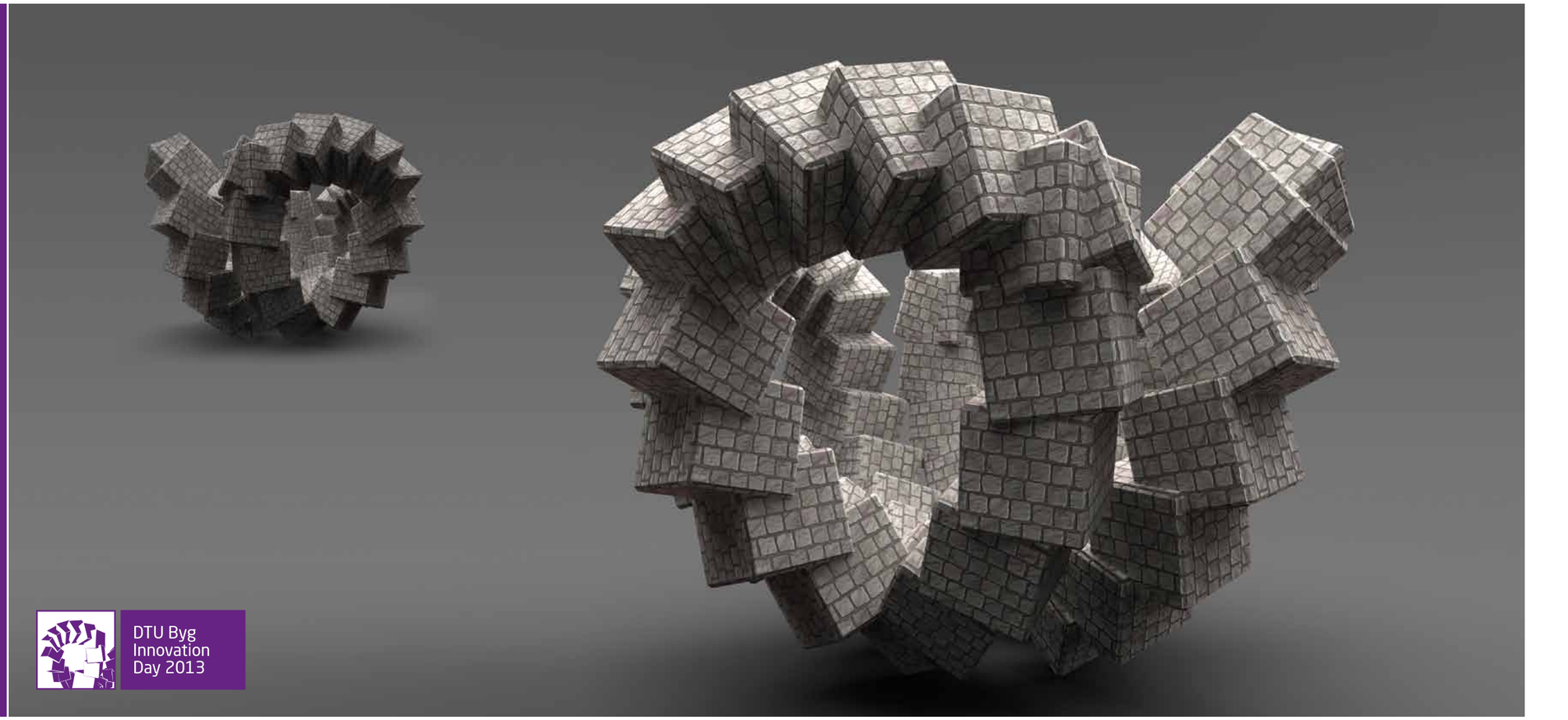

As already pointed out by Head of Department Michael Havbro Faber in the foreword, we treasure our collaboration with the private sector and governmental and non-governmental organizations, not just because innovation in the building sector is a buzzword at the moment, but because we truly believe that innovation should be a key driver behind all our activities.

Much is said about the difficulty of promoting innovation in the building sector, and it is certainly a challenge for all stakeholders to innovate in what is a fragmented and – by its nature – a conservative sector. However, the current and future major challenges associated with establishing a more sustainable built environment force us all to take the innovation challenge very seriously, and we at DTU Civil Engineering – DTU Byg are very much aware of our responsibility in this respect.

The department strives to integrate innovation in everything it does including its core activities, teaching and research. While classical innovation activities such as patenting and supporting start-ups originating from our research play an important role, we also believe that direct – hands-on – collaboration, interaction and outreach activities provide the key to effectively contributing to innovation and the most effective way of bringing our competences and research results into play in the innovation chain.

In teaching, special courses as well as exam projects are often carried out in direct collaboration with industrial partners in the building sector. Furthermore, the department engages in in-service training though its own master programme in fire safety and through various providers.

Public sector consultancy is carried out on a contractual basis and through the department's researchers participating in committees for normative and pre-normative work.
Innovation is integrated in research through research projects with a strong industrial participation, in particular industrial PhD projects, innovation consortia, the Danish National Advanced Technology Foundation and EU Framework projects.

Three new development areas

As a special instrument to enhance activities in the area of innovation and public sector consultancy, in 2012 the department launched its so-called 'development areas'. The development areas focus on the major challenges currently faced by society, with sustainable development and innovation as the overall theme. The development areas are organized as interdisciplinary activities at the department, and aim to enhance cross-disciplinary research and – through the involvement of external stakeholders in industry and the public sector – facilitate innovation and public sector consultancy in key areas. The development areas are dynamic activities founded on and cutting across the department's organizational structure with a limited lifetime, typically five to ten years. Currently, the development areas comprise Solar Decathlon, Zero Waste Byg, and Sustainable, Light Concrete Structures.

The Solar Decathlon development area, headed by Professor Bjarne W. Olesen, is a targeted means of engaging collaborative student-based research across the entire DTU domain with the committed participation of industry as providers and sponsors. The Solar Decathlon development area organizes the department's participation in the international Solar Decathlon Europe (SDE) competition, which challenges collegiate teams to design, build and operate solar-powered houses that are cost-effective, energy-efficient and attractive. The winner of the competition is the team that best blends affordability, consumer appeal and design excellence with optimal energy production and maximum efficiency. In 2012, the Technical University of Denmark participated in SDE 2012 in Madrid, Spain, with a dedicated team led by Associate Professor Lotte Bjerregaard Jensen, along with students from nineteen other universities from fifteen countries and four continents. The DTU team won first prize in the Solar Systems integration contest and, in December 2012, the next team from the department qualified to take part in the prestigious competition SDE 2014.

Long-term sustainability is incompatible with open materials cycles. Building materials have traditionally been based upon an open cycle of material flow, which in the long term is untenable. The development area Zero Waste Byg, led by Associate Professor Lisbeth Ottosen, seeks to rethink materials cycles in the production of building materials, thus placing the built environment centrally in society's material cycle. Research and innovation focus are directed at the increased replacement of natural raw materials with secondary resources in production. In addition, strong emphasis is put on recycling to the greatest possible extent at the end of a building's service life. Such rethought building materials strongly support waste minimization in society, as the building industry is a major materials consumer on a volume basis. The redesigned building materials open up possibilities for producing materials with new and innovative characteristics, as well as materials with new compositions but which have similar characteristics to the traditional materials we know today.

It is necessary to consider CO_2 emissions from construction if we want to develop environmentally-friendly building techniques. The development area Sustainable, Light Concrete Structures, led by Professor Kristian Hertz, is developing concrete structures that cut CO_2 emissions compared with traditional concrete structures. In sustainable, light concrete structures, strong and light concretes cooperate in carrying loads, for example plane sandwich slabs or walls. In super-light structures, as patented by DTU, a strong concrete is placed in any curved shape where the main forces are calculated to be, and the rest of the shape is filled out by a lighter material that stabilizes and protects the strong concrete from impact and fire and provides the final structure with advantages related to acoustics, indoor climate etc. The first super-light structure, the SL-Deck, was implemented in the first building in 2012, and is expected to be mass-produced from 2013. It offers wide elements with flexible shapes, long spans, fixed ends, possibilities of blade connections, point supports as well as extreme fire resistance, high acoustical insulation and sound dampening.

Innovation Day 2013

The development areas – their concept, content and their properties as vehicles for innovation – are being presented at the department's Innovation Day, which is being held on 12 September at DTU. The day also offers the opportunity to network with the researchers at the department.

For more information on DTU Byg Innovation Day, please visit http://www.innovationday.byg.dtu.dk/. Hope to see you there!

A DTU campus in Sisimiut, Greenland

For the last 12 years DTU has carried out Arctic technological research and trained Arctic Engineers from Greenland and Denmark. Now the goal is to establish a modern, research-based university centre, a DTU "Arctic campus", in Sisimiut, Greenland with a yearly intake of 125 students by 2025.

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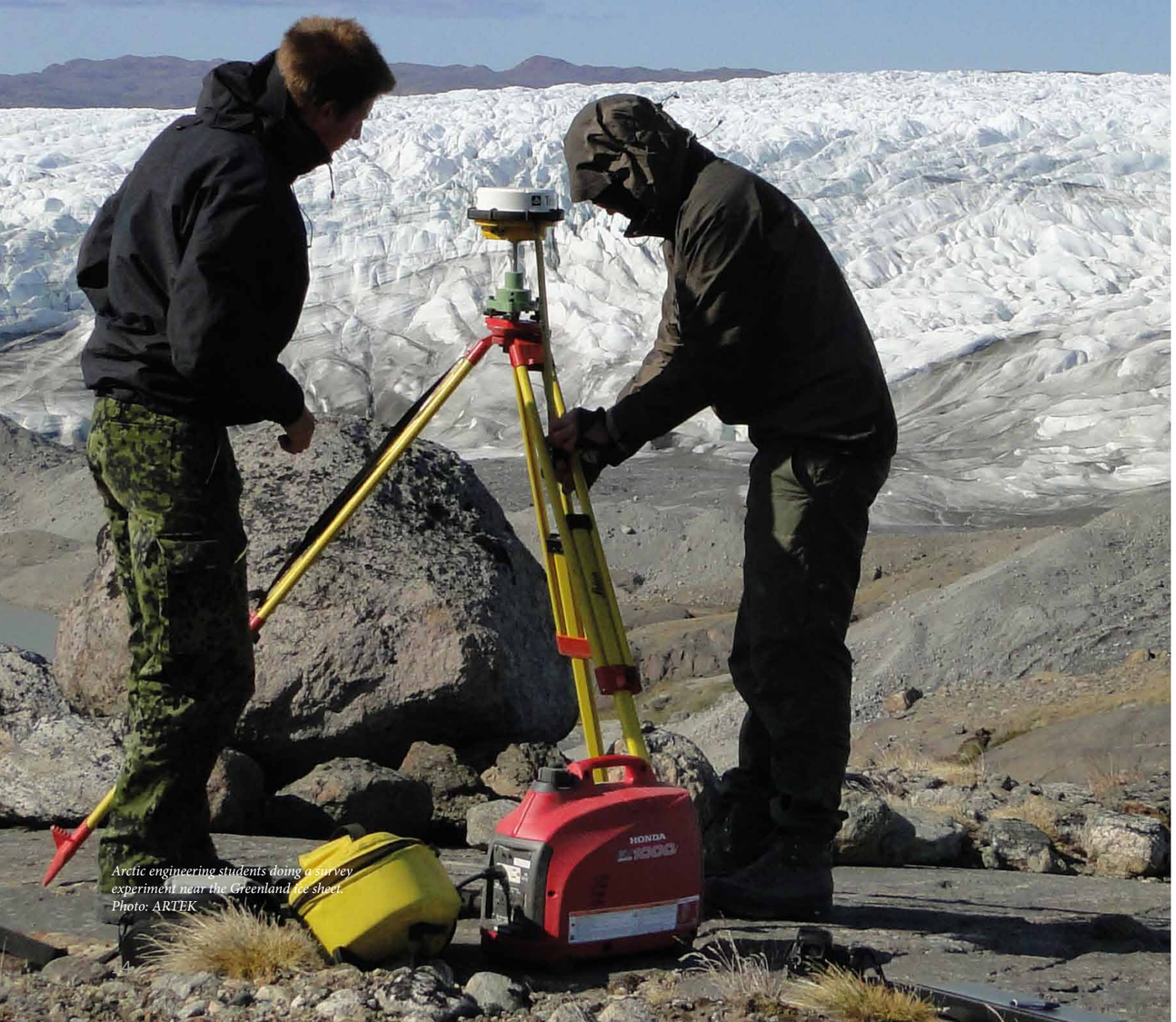

Arctic engineering students doing a survey experiment near the Greenland ice sheet. Photo: ARTEK

Arctic engineering students involved in road construction. Photo: ARTEK

Geotechnical investigations for Arctic engineering students in the vicinity of Sisimiut. Photo: ARTEK

In 2000, the Arctic Technology Centre, ARTEK, was established to carry out Arctic technological research and to train Arctic Engineers from Greenland and Denmark. It was an equalpartner collaboration between DTU and the Greenland government. Since then nearly 40 people have earned a bachelor degree in Arctic engineering, attending semesters in both Sisimiut and at DTU in Lyngby. To establish an Arctic engineering educational tradition in Greenland in just 12 years that now has more than 20 students enrolling each year, is a significant achievement . The bi-lateral configuration of ARTEK involving both Greenland and Denmark is also noteworthy and seen in only very few places.

A university campus in Sisimiut

The successful establishment of ARTEK has fostered an ambition to develop the Sisimiut facility into a research-based university centre, a DTU "Arctic campus", located in Sisimiut and also admitting international students. At present the students spend the first three semesters in Sisimiut and the remaining six at DTU in Lyngby, abroad and at an internship in a company. Organisationally ARTEK shares facilities with Tech Collage Greenland in Sisimiut. The goal is to develop a DTU campus and to offer more of the lectures in Sisimiut, to offer an international semester, and a master's as well as a bachelor degree, which would be taught by faculty staff living in Sisimiut and actively undertaking research all year round. The advantage of placing more of the education physically in Sisimiut is the easy access to full-scale, in situ practical training and projects in the real Arctic instead of a limited cold-room experiment at a "southern campus".

Challenges

Sisimiut is inherently a rather isolated town (no roads lead to it) with 5,000 residents, inside the Arctic Circle and no university tradition. Such a setting forms a challenge for establishing and running a modern university campus. Besides the infrastructure needed, a major challenge will be to recruit students and faculty staff to such a new and initially unknown campus at a sufficient rate to meet the goal of having 125 students a year by 2025.

However, experience learned from establishing a university centre 1250 km further north on Svalbard (UNIS) can be adapted to the special Greenland conditions.

At a workshop for interested parties held in Ilulissat in June 2012, full support was given to develop a campus in Sisimiut. The attendees at the workshop were from the oil and mining industry, from private and public enterprise in Greenland, local municipalities and the Greenland government.

Estimates from industry on the future demand for Arctic engineers highlighted a demand well beyond the present rate of production. Even 125 new students a year will not be enough to fulfill the demand for Greenland. Moreover, the international demand for expertise in Arctic technology is clear with the opening up of the Arctic Ocean, climate change and the oil and mineral resources waiting to be exploited in the Arctic. Currently very few universities (if any) offer a bachelor level degree in Arctic engineering and, only a few offer a master's degree. The need for Arctic technology expertise and a DTU campus in Sisimiut is evident.

Snow on roof friction experiment in Sisimiut. Photo: ARTEK

What's in the air at a cozy place?

Researchers from the International Centre for Indoor Environment and Energy measured the concentrations of ultrafine particles in 56 homes in Copenhagen. The study suggests that our exposure to ultrafine particles in our homes depends more on what we do than on how polluted the air is in the city.

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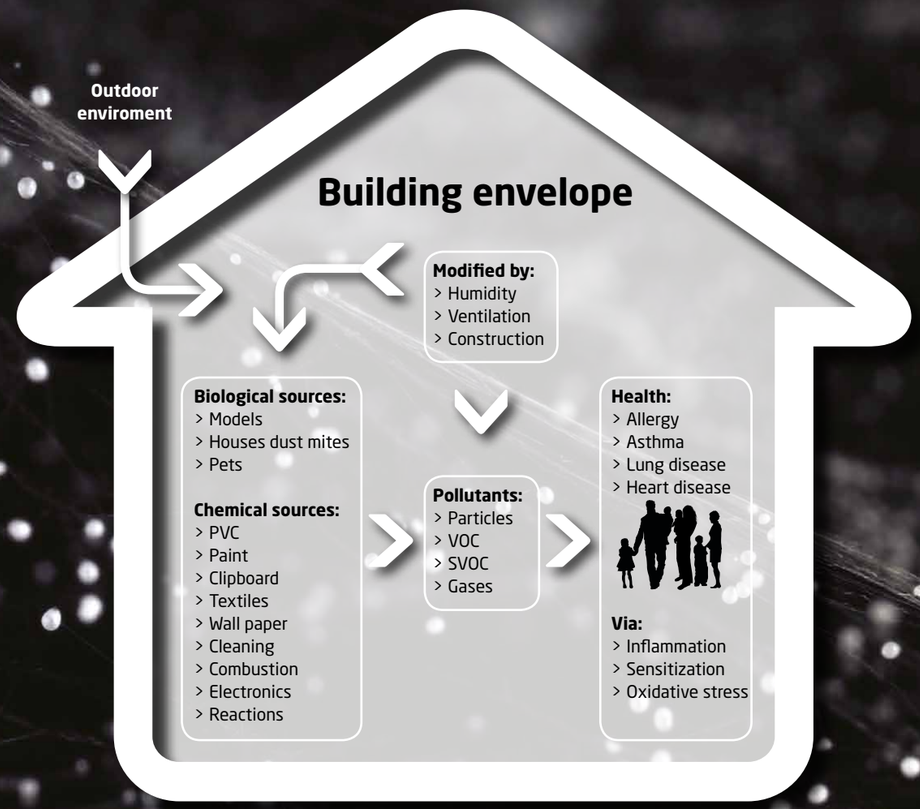

Figure 1. Associations between the building, indoor climate and health.

A review panel assembled by the US Health Effects Institute recently concluded that experimental and epidemiologic studies provide suggestive evidence of adverse health effects from short-term exposures to ambient ultrafine particles. Those are particles smaller than 100 nm in diameter. Ultrafine particles enter the indoor environment from outdoors, but they also originate within the indoor environment. Major indoor sources include cooking, tobacco smoking, candle and incense burning and the use of gas and electric appliances. Compared with larger particles, ultrafine particles have higher deposition rates in the lower respiratory tract. Studies show that a large fraction of our total daily ultrafine particle exposure occurs in the home due to indoor sources. But what are the indoor activities responsible for our particle exposure and how much do they actually contribute to our total particle exposure?

Answering these questions was one of the many goals of "The Center for Indoor Air and Health in Dwellings" (CISBO – Center for Indeklima og Sundhed i BOliger). CISBO, which is supported by the Realdania Foundation, is a cross-disciplinary research consortium which aims to provide knowledge on the indoor environment and its impact on humans, develop a scientific basis for improving the built environment and promote healthy buildings, with a special focus on private housing (Figure 1). The consortium consists of DTU, Aarhus University, the National Research Centre for the Working Environment, the Danish Building Research Institute at Aalborg University and Copenhagen University. Number concentrations of particles between 10 - 300 nm in size were continuously measured over a period of about45 hours in 56 residences of non-smokers in Copenhagen. The occupants filled in a diary regarding particle related activities. These were used to identify source events and apportion the occupants' exposure among sources. To characterize the occupants' exposure, the daily integrated exposure was calculated, by integrating the concentration over time (units: particles per cm3·h/d).

Indoor sources of particles

Source events clearly resulted in increased particle concentrations. At the same time as the particle concentration increased, the average particle diameter decreased in the home (Figure 2), because freshly generated particles are smaller in diameter than the ones already present in the air for some time. This happens due to coagulation over time, which alters the size of particles as they age.

The highest particle concentrations were measured when occupants were present in the home and they were awake. The lowest concentrations were observed when the homes were vacant or the occupants were asleep. Thus, close to 90% of the occupants' daily integrated exposure occurred while the occupants were awake. Indoor sources were responsible for approximately 70% of the daily exposure, compared to the contribution from background particle levels entering from outdoors. The most important sources were candle burning, cooking and toasting. Candle burning occurred in half of the homes and, on average, was responsible for almost 60% of the exposure. In the homes where cooking occurred, it was responsible for a third of the total residential exposure.

Unknown health effects

Elevated particle concentrations, and so the exposure to those particles, persist for several hours even after a candle is blown out or the cooking ceases. Consequently, occupant-related source events contribute substantially to residential ultrafine particle exposure. It seems that we can control a large portion of our exposure to ultrafine particles at home by adapting our behaviour. However, it is currently unknown how these particles impact on our health. On the other hand, most of us would probably find our days less appealing without the coziness of a home-made meal and candles on the dinner table.

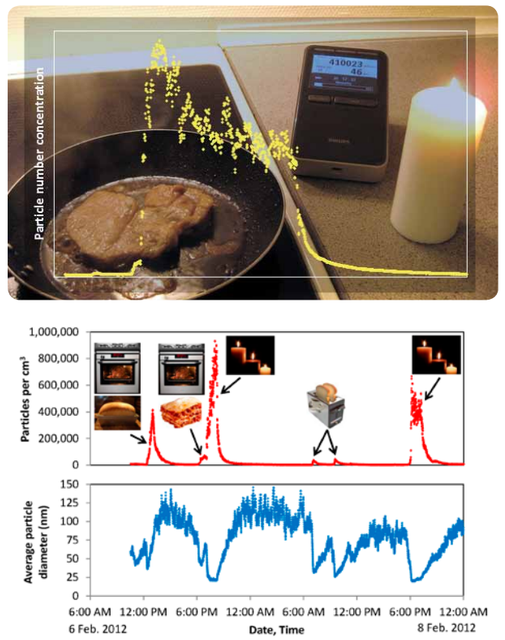

Figure 2. Illustrative time-series of indoor particle concentrations and average particle diameters.

Hybrid ventilation saves energy and improves thermal comfort

Ventilation solutions consume a substantial part of a building's total energy consumption. And even more so when very low-energy buildings gain their market share. A project at DTU Civil Engineering shows that a combination of mechanical and natural ventilation, a hybrid ventilation system with heat recovery and night cooling, is the most sustainable solution.

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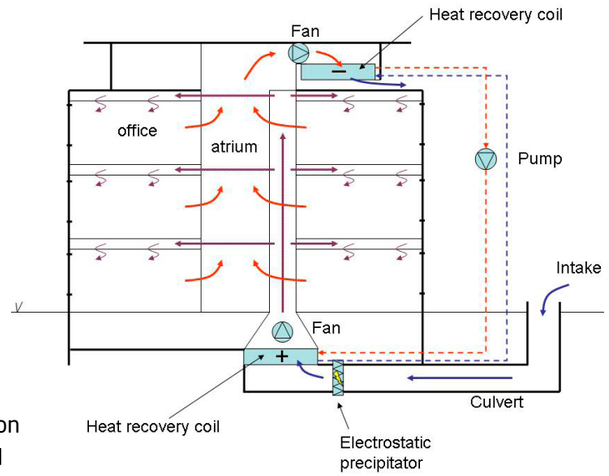

Figure 1. Principle of stack and wind-assisted mechanical ventilation with heat recovery.

Figure 2. Prototype heat exchanger.

Mechanical ventilation is usually based on costly plant installations, space-consuming duct penetrations and electricity-driven fans. Generally, installations are not integrated into the building early on in the design process, because historically the design of buildings has been segregated into the construction side and the installation side. By considering ventilation as an installation separate from the rest of the building, its interaction with the building is ignored.

Natural ventilation solutions demand a different approach to building design. The ventilation scheme makes active use of the building's rooms to supply and extract air, and in general the ventilation design and building design are not segregated activities. In fact, designing in natural ventilation forces the gap between architecture and function to be bridged. However, natural ventilation wastes heat into the atmosphere and the supply of fresh air through openings in the facade causes draughts and complaints, especially in winter.

The hybrid ventilation approach is to combine the advantages of both natural and mechanical ventilation to achieve control, thermal comfort and heat recovery with low electricity consumption.

Full-scale test

The project was supported by Elforsk, with the participation of DTU Civil Engineering, Dantherm Air Handling and ALECTIA. DTU Campus Service kindly sponsored a full-scale test-setup in building 118 and LeanVent ApS sponsored special energy-saving dampers.

The objective of the project was to develop a heat recovery system for hybrid ventilation with centralized yet separate intake and exhaust. By separating intake and exhaust, the system design allows the natural forces of stack and wind to assist the mechanical fans in driving the ventilation airflow. However, to avoid wasting heat, recovery of heat must be built into the concept. But conventional heat exchangers obstruct the airflow, severely reducing the advantage of the hybrid ventilation concept.

Consequently the project partners developed heat exchangers made from plastic tubing which caused little obstruction to the airflow. Because of the use of cheap plastic tubing it was also possible to build heat exchangers with a very large heat transfer area, which leads to high heat recovery efficiency. One exchanger has more than 5 km of plastic tubing inside it, and it takes two exchangers to build a system.

Improvement of the prototype

Results from the full-scale testing show an expected heat recovery of 63% with ultra-low fan power consumption, of 10 times less than conventional systems.

In addition, the design of the system improved the free night cooling potential, as running the fans at night is very cost effective. This saves on electricity which would otherwise have been consumed by a cooling machine.

The potential of heat recovery in systems where the intake and exhaust are separated is immense. Not only for energy-efficient comfort ventilation in offices and schools but also for ventilation in industrial processes, laboratories and hospitals. Additional work has already been initiated with the partners to improve the prototype in terms of production feasibility and efficiency.

Creating benefits for all in the design of the indoor environment

Arsen K. Melikov became a professor at the Department of Civil Engineering, DTU, in 2012. His teaching and research areas cover ventilation and indoor environment in buildings and vehicle compartments. To create a healthy, comfortable and stimulating indoor environment with reduced energy use will require a paradigm shift from designing communal environments to designing individually controlled ones.

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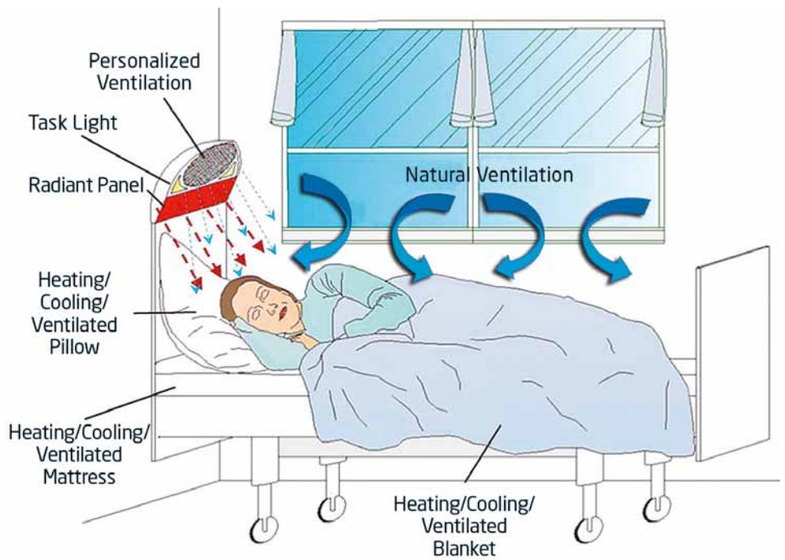
The indoor environment affects an occupant's health, comfort and performance and the energy used for heating,, ventilation and air-conditioning (HVAC) in a building is substantial. Yet, in many buildings the indoor environment is mediocre. Today, many countries have adopted ambitious energy-saving goals. To meet these goals, buildings are being supplied with less ventilated air. However, this is a dangerous energy-saving strategy because it will negatively affects occupants' health. In public buildings, for example offices, it will contribute to a decrease in work performance. On the other hand, an increase of outdoor clean air supplied to spaces has a positive impact on health and performance, but increases energy consumption. It is possible to continue with design practice as it is, but is this the right choice?

Are indoor environment designers really at a crossroads? Wouldn't it be possible to design an indoor environment that improves occupants' health, comfort and performance and saves on energy? That would create benefits for employees (well-being and comfort), employers (increased performance of staff and less energy used) and the whole of society (less sick-leave days, decreased health-care costs, energy savings). Yes, this win-win solution is possible, but not with the present strategy and systems of "total volume" design which aim to achieve a uniform indoor environment for an "average", unknown occupant. In reality, the needs of a room's occupants are quite different because huge differences exist between people's personal preferences for temperature and ventilation, that can depend on what they're doing and the clothes they're wearing. Present total-volume ventilated principles are inefficient because clean and cool ventilation air is supplied far away from occupants and by the time it reaches them it has mixed with room air and become warm and polluted. There is also little flexibility in the use of space and it is difficult to control air distribution.

Paradigm shift

In order to create benefits for all, a new design approach is needed. There needs to be a paradigm shift from the design of communal indoor environment to design of individually controlled micro-environment at each workstation is needed. There is need for development of advanced heating, cooling and ventilation methods and systems based on control of pollution (heat and contaminants) and air distribution. Today's bulky, centralized HVAC systems that are attached to the building shell, need to be replaced with decentralized, micro-environment systems and intelligent, wearable, personal HVAC devices that sense, predict and respond to an individual's needs. Some of the knowledge needed for this development already exists and new knowledge will be gained by collaboration between engineers, architects, medical doctors, physiologists, ergonomists, psychologists and other specialists. The effort will bring numerous inventions, innovations, novel technologies and products. The development may be fast, as fast as it has happened in many other fields of our life.



Individually controlled, bed micro-environment that can be used alongside mixed or natural ventilation, e.g. in hospitals, care homes for the elderly, etc.

Is everyone in the building safe?

In May 2012, DTU Civil Engineering conducted a large evacuation experiment with 100 participants to investigate what effect the composition of a population has on a total evacuation time. Preliminary results indicate that precautions should be taken.

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During the past decades there has been an increasing focus on accessibility to buildings. This focus on accessibility has led to an increased presence of people with disabilities in all types of buildings. People with disabilities and able-bodied people need to be equally safe in the case of a fire. Performance-based fire-safety codes are implemented worldwide, allowing fire-safety engineers to use engineering tools to demonstrate the safety level of a building. Models for the prediction of evacuation times have been developed accordingly. However, input data to these models is often based on homogeneous groups of able-bodied adults, which is not representative. Consequently it is questionable whether the models deliver reliable results. The safety level in buildings might be affected and the probability of people being exposed to untenable conditions increased. Evacuation characteristics of heterogeneous groups made up of children, able-bodied adults, elderly people and people with impairments are therefore needed. Buildings are also categorized according to type of occupancy and only one category is available for buildings with vulnerable people in them. A design which doesn't allow part of the population to take part in an evacuation, but leaves them to be rescued by the rescue service at a later stage of the fire development, should be avoided.

Evacuation of vulnerable people

DTU Civil Engineering, Section of Building Design leads the EU project KESØ "Competence center for Evacuation Safety in the Øresund region", a project developed in collaboration with The Department of Fire Safety Engineering and Systems Safety at Lund University. The scope of the project is to extend the knowledge on evacuation characteristics of vulnerable people and evacuation practices and procedures of complex building designs such as tunnels and high-rise buildings.

In May 2012 PhD student Janne Gress Sørensen and associate professor Anne Dederichs conducted a series of large evacuation experiments in Korsør. The setup for the experiments assumed a fire incident in an IC3 train inside a tunnel simulating the rail connection between Zealand and Funen – The Great Belt link. The experiments involved 100 participants who were able-bodied adults, children, elderly people and people with different impairments.

The composition of the participants was chosen to match the demographic profile of Denmark's population as closely as possible. The objective of the project was to study how the composition of people influenced the total evacuation time and to survey people's behaviour during the evacuation. Data on walking speeds and flow characteristics was collected. Experiments with mixed groups were conducted as well as control experiments with a reference group of only able-bodied adults.

Helping hands

Preliminary results from the study show significant differences in the total evacuation time and behaviour for the heterogeneous group compared to the homogeneous reference group. The total evacuation time for the mixed group was double that of the homogenous group. This underlines the importance of an increased focus on the people actually present in a building environment.

During the experiments, altruistic behaviour was observed among the participants. People were surprisingly good at lending a helping hand to fellow participants and assisting each other in other ways. These results indicate that evacuation models developed with data based on homogeneous groups of able-bodied people, might give misleading results.

Evacuation exercises conducted from an IC3 train in a tunnel. The test population comprised able-bodied adults, children, elderly people and people with different impairments. Photo: Kaare Smith, DTU.

Test facility – A full scale model of the rail connection of the Great Belt link. Photo: Janne Gress Sørensen.

Snapshot of the evacuation exercise where an able-bodied adult (blue cap) let an elderly person (pink cap) pass by. Photo: Janne Gress Sørensen.

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The world's largest study of the indoor environment in commercial kitchens

The International Centre for Indoor Environment and Energy (ICIEE) at DTU Civil Engineering has conducted a study on the thermal conditions of the working environment in more than 100 commercial kitchens in the USA during summer and winter. The study shows that employees generally feel the working environment is warm and they'd like it cooler; but they still find it acceptable.

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At present there are no specific standards or criteria used in the design, evaluation and guarantee of the indoor environmental conditions in commercial kitchens. General evaluation criteria for thermal comfort is inadequate and unsuitable for practical application in kitchens. To establish a database on the indoor environmental conditions in commercial kitchens in the USA the American Society of Heating, Refrigeration and Air Conditioning (ASHRAE) initiated and partly sponsored a large study. This was led by ICIEE (DTU Civil Engineering) together with CIA (Culinary Institute of America) and the US company KEMA. The study was primarily focused on the thermal conditions of the working environment, which are mainly influenced by radiant heat. Appliances, size and arrangement of the kitchen zones, the number of employees and high activity levels during "rush" hours, add further complications to an evaluation of the indoor thermal environment in kitchens. Based on standardised methods, a procedure for collecting data for the physical environment and subjective reactions in commercial kitchens was established and tested at CIA and a couple of kitchens in and around DTU. This procedure was then used in more than 100 commercial kitchens in both summer and winter in different climatic zones in the US (Figure 1). Two researchers and two master's students from ICIEE worked as two teams to collect the data in the selected cities.

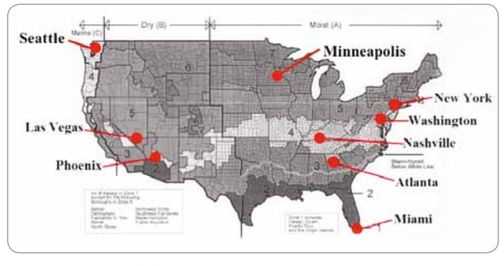

Figure 1. Investigated Climate Zones in USA.

Spot Measurements at the Cooking-Line.

Institutional Kitchen View with Physical Measurements at the Food-Preparation Zone.

Two questionnaires

Data collection included several types of measurement: outside air temperature and humidity, performance of the heating, ventilation and air conditioning (HVAC) system (supply, make-up, and transfer air temperature and relative humidity), indoor (thermal) environment, and physiological and subjective evaluation of kitchen employees. The intention was to collect data for the physical environment (physical parameters) and personal factors such as clothing and activity, so as to be able to calculate existing indices for evaluation of thermal comfort and/or heat stress. Measurements were taken in three different kitchen zones : cooking, food preparation, and dishwashing, which are considered to have different thermal conditions in a commercial kitchen. Datacollectors were installed for one week to record kitchen operative and air temperatures (to and ta), relative humidity (RH) and CO_2 (ventilation rate). During the field studies the subjects were asked to fill in two questionnaires: one general long-term assessment and one on their immediate evaluation of the environmental conditions.

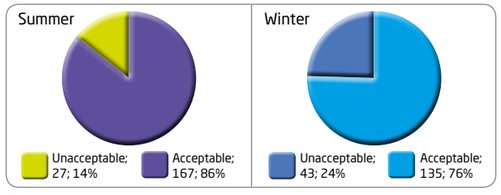

Figure2. Acceptability of Kitchen Thermal Conditions.

You can't please everyone

Continuous measurements in the three kitchen zones were taken for one week in all kitchens, in both summer and winter. The results showed that during working hours it is always much warmer to work in the cooking zone. They also showed that the kitchens do not cool down overnight. Spot measurements of thermal parameters at three heights in the three zones, together with subjective evaluations, were performed in 39 kitchens during the summer and in 35 kitchens during the winter. Altogether 373 employees responded to the questionnaires. The measured conditions covered a wide range of temperatures (15-42°C) and humidity (10-80% relative humidity). It was not possible to find a temperature that everyone was happy with. However, in ranges of working temperatures, between 20-25°C, received the lowest level of dissatisfaction at about 11%. The dissatisfaction increases progressively on both sides of this range. When asked, only 14% of respondents in summer and 24% in winter (figure 2) found the working environment unacceptable. However, 60% would like to have a cooler working environment in summer, and 40% would in winter. Although less people want a different temperature in winter, there are still more dissatisfied employees then. This can be explained by the larger temperature difference between outside and inside in winter. The established database will receive further analysis in the future and will be a valuable benchmark for the indoor environment in commercial kitchens.

Murals preserved by Civil Engineering techniques

Civil Engineering has many faces and is not just restricted to traditional areas but can also be used to solve other problems in Danish society. At DTU Civil Engineering, research is focused on one unsolved problem that of salt induced deterioration of murals.

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Early Danish art is dominated by indoor decorations in churches, such as murals, and they are a large part of the Danish cultural heritage. Indeed, one of the twelve works in the Canon of Danish Art and Culture is a mural from Undløse church, Zealand.
In a study of 330 Danish churches, around a tenth had murals suffering from salt induced deterioration which is considered one of the biggest challenges to the future preservation of these paintings. At DTU Civil Engineering, there is ongoing research into an electrochemical method for extracting the damaging salts in church vaults and so decreasing the salt induced deterioration these cause. The process was developed, documented and patented in a laboratory as part of a PhD study at DTU Civil Engineering. In follow-up research projects, the focus has been on adapting the method to in situ conditions including additional parameters such as working with several materials, different climatic conditions, dissolutions of salt (deliquence point) and salt mixtures and side effects. Throughout the process, in cooperation with The Royal Danish Academy of Fine Arts, Schools of Architecture, Design and Conservation - School of Conservation, the murals have been treated with the respect they deserve as part of our Cultural Heritage.

Figure 1. The murals were lost in some areas of the vault of Rørby Church, Zealand as a consequence of salt deterioration. In the bottom of the picture a wooden construction is seen, which is a part of a climate chamber to ensure a specific climate for minimizing further salt induced deterioration. Photo: Nordic Conservation.

Research in 2012

Electrochemical induced desalination is only possible once the salts are dissolved. When using electrochemical desalination on church vaults the amount of water added to dissolve the salts must be kept to a minimum to avoid cracking, to minimise the risk of transporting salts deeper into the construction and to avoid microbial activity. One way to do this is to establish a relative humidity that corresponds to the deliquence point of the salt. The deliquence point for a single salt such as sodium chloride is common knowledge. However, for salt mixtures, determining the deliquence point is anything but simple. Several simulation programmes are available to predict the deliquence point of salt mixtures but for these, several assumptions must be made so some people consider them unreliable. Thermodynamic calculations have also been carried out in cases with a limited number of salts, however in a several-hundred-year-old church vault the number of salts is unlimited. The Section for Construction Materials has dynamic vapour sorption (DVS) equipment at its disposal. This equipment can monitor weight changes at programmable changing climatic conditions.

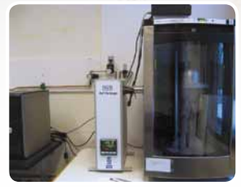

Figure 2. The dynamic vapour sorption (DVS) equipment.

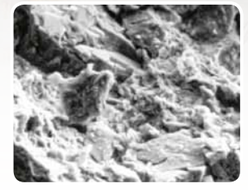

Figure 3. Scanning electron microscope picture of an electrochemical desalinated brick.

Since the deliquence point is related to weight changes, determining the deliquence point in single salts is used to calibrate the DVS. In this project the precision of the DVS was challenged, the deliquence point of salt mixtures and the deliquence point of salt mixtures in combination with a construction material were investigated (figure 2).
In addition in 2012, there have been ongoing tests into the minimization of the adverse effects of the electrochemical desalination. This has included using the Section for Construction Material's scanning electron microscopy (SEM), see figure 3. As this is to develop the technique of desalination, it naturally fits into the research arm of Civil Engineering and shows clearly how Civil Engineering is being used outside its traditional area of application.

Future research thanks to donations

To continue the research into using electrochemistry to preserve murals, several related projects will carry on in future years thanks to donations of: DKK 50,000 from Direktør Ib Henriksens Fond, DKK 747,000 from Augustinus Fonden, DKK 1,732,200 from The A.P. Møller and Chastine Mc-Kinney Møller Foundation and DKK 100,000 from the Ministry for Gender Equality and Ecclesiastical Affairs. These donations have been received with joy and humility.

A glass structure: Oslo Opera. Photo: Jens Henrik Nielsen.

A tested glass beam, fails similar to a concrete beam – although cracks and reinforcement is much easier to see. Photo: Per Goltermann.

Hundreds of student projects each year:

A new innovative concept for supervision and acceleration of innovation

A new concept introduced at DTU Civil Engineering leads to better project performance, improved learning and improved students' skills for presentation and reporting. A win-win situation.

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The student projects normally focus on a topic from DTU Civil Engineering research fields and the industry's needs for innovation and investigation. This leads to many useful results, as the department currently has 250 student projects a year – a number expected to increase to 300-350 within a few years.

DTU Civil Engineering has recently introduced a new project concept, which improves learning, optimises supervision and leads to a much better allocation of the laboratory facilities. The new concept uses project groups centred on a specific target. The groups consist of three to five independent projects, with a team supervisor and the students are all located in the same project office, which stimulates peer review and peer discussions and enables group supervision. Each group presents their project at midterm in a small seminar for all groups, supervisors, key contacts and interested industrial partners – this not only builds presentation and communication skills, but also gives each team the best possibility of finalising its project properly.

The new concept has been tested independently on groups both of projects requiring fairly similar skills (diploma and bachelor-projects) and on groups with different skills (diploma, bachelor and masters-projects).

ZeroWaste group

The ZeroWaste group offers "fairly similar skill" projects in the use of alternative ashes in concrete production (where the ash replaces the cement or the filler). These projects all start with the same initial classification tests on a specific type of ash. The special behaviour

of each project's ash quickly leads to an individual approach in the innovative experiments, with the aim of producing an environmentally safe concrete with improved performance. These projects produce an initial screening and investigation into the problems, solutions and opportunities in changing the ash from a potentially harmful waste product into an environmentally safe product, which actually improves the concrete quality (the projects in 2012 involved 700 tests by the students, on waste material from five industrial processes – a significant number, which can boost research and innovation).

Glass group

The Glass group has offered "different skills" projects in the use of glass in structures. These projects, which combine testing, theory and numerical modelling, may be quite different but still related. The projects will often be able to use data or information from investigations done by other projects in the group, even if they work on quite different levels. The results have been used in scientific publications, course material at DTU and in training and post-graduate education for professional engineers at the Danish Construction and Concrete Institute.

The experiences of both types of groups is that this style of working leads to better project performance, improved learning, much better use of the lab facilities and improved student skills at presentation and reporting.

The concept has the added benefits that the supervisors can focus on the most relevant part of the supervision and less on basic details, it leads to a more reliable production of useful results – a fact which benefits both the research groups and speeds up industrial innovations – and it adds to the education of professional engineers. In short, this is a win-win-win concept.

The ZeroWaste students in autumn 2012. Photo: Per Goltermann.

Innovative building system uses high performance concrete for energy efficiency

Connovate® uses high performance concrete as sandwich elements and facade renovation panels as part of a new state-of-the-art building system. The pilot project is a cooperation between DTU Civil Engineering, Building Innovation and private companies.

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Background

The building sector is changing rapidly. The EU's energy policy prioritises cutting energy and using renewable sources. As the building sector is responsible for about 40% of the EU's energy consumption, the need for appropriate action is understandable. In Denmark, energy use in new buildings must be reduced to about 20 kWh/m2 /year by 2020. Buildings can meet this targets by using highly insulated building envelopes, high performance windows and heat recovery ventilation systems. Connovate® began as a development project with private companies Arkitema and Ambercon and the Building Innovation Lab. From 2010 to 2013 the project continued with the support of the Danish National Advanced Technology Foundation. Connovate® focuses on the development of state-of-the-art building elements using high performance concrete sandwich elements and facade renovation panels as part of a new building technique. A global focus on environmental issues and a need for sound industrial building techniques have created opportunities for product development within the concrete industry. This new building system represents the next step in the construction industry's increasing use of pre-fabricated elements offering the end-user a high-quality product at a competitive price.

Setting new standards

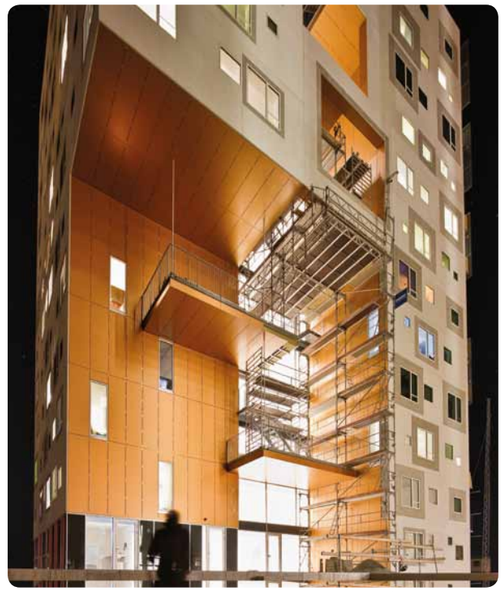
Highly insulated sandwich elements made of high performance concrete offer efficient insulation with a minimum wall width as the concrete plates are only a few centimetres thick. To produce a new building system which offers superior performance, high quality standards and at a competitive price, there has to be a high degree of development and research in areas such as the composition of high-performance concrete powder, structural integrity, fire protection, thermal performance and integration of technical services.

Developing areas finished and curently under investigations include: Integrated structural and material modelling analysed the cracks that appeared in thin plates when subjected to different temperatures.

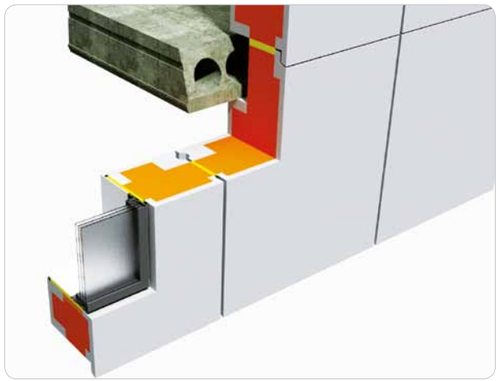
Extensive fire resistance modelling included investigations of the influence of insulation, shear connectors, geometry and various load cases on the fire performance of the system. Focus on optimizing thermal performance by considering different insulation types and thicknesses, and minimizing the thermal bridge effects with new design proposals for window openings and other connections.

New solutions for integrated ventilation, heating and cooling systems.Those will work well with respect to energy efficiency, the indoor environment and minimizing the cost of building components. Over the last year, tremendous progress has been made and two construction projects have been built using first generation high performance concrete sandwich elements. Preparations have been made for full scale experiments, which will be carried out in 2013 in a specially designed experimental building. The building is under construction at the address Nordvej 121C, DTU, DK-2800 Kgs. Lyngby and is expected to be completed in 2013. The Connovate experimental building will enable investigations by many stakeholders and researchers participating in the project which should continue to show interesting results and good progress in 2013.

For further information about Connovate: www.connovate.dk



Student accommodation tower block at Aarhus harbor built from Connovate sandwich elements made of high performance concrete. Building has been long listed for the prestigious British sustainability price WAN Sustainable Buildings Award 2012.



Detail of Connovate sandwich wall element made of high performance concrete with connection to window opening and hollow core concrete deck.

Villa Vid: The pilot Connovate project. The first house built from Connovate sandwich elements made of high performance concrete in cooperation with Building Innovation (Real Dania).

Villa Vid: The pilot Connovate project. Interior look.

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Student accommodation tower block at Aarhus harbor built from Connovate sandwich elements made of high performance concrete.

More funds, faces and facilities – a year with growth and construction plans

DTU Civil Engineering continues its financial and physical growth, and in 2012 the department saw a 22% revenue increase and expanded its academic staff. The continued growth has necessitated an expansion of the existing buildings with a brand new building to house teaching, studio and workshop facilities. The new building will be completed in 2013.

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The inner green hall at ground-floor level where you can sit in peace and quiet and chill or check emails on your laptop. CCO Arkitekter.

In 2012, DTU Civil Engineering boosted its revenue from externally funded projects. DTU Civil Engineering's revenue from externally funded research and innovation projects has been steadily increasing for several years, but in 2012 in particular, the department saw significant revenue growth of 22%. Basic appropriations remained constant which means that the department's revenue totals almost DKK 140 million. Externally funded revenue, primarily from research foundations, programme funding, private foundations, public sector consultancy and commissioned projects, constitutes 35% of the total revenue and thus an increasing part of the overall department finances.

Due to the continued increase in external project, public sector consultancy and innovation activities, the department in 2012 also worked hard to formulate and develop a plan for expansion and modernisation of the physical framework, i.e. both offices and laboratories. The aim of the activities is to gather all employees and laboratories 'under one roof' and close to each other in order to generate synergies across fields, upgrade infrastructure facilities to an international standard and ensure effective utilisation of the buildings.

New building 127

With an annual intake of 60 students, the continued phasing in of a new Bachelor of Architectural Engineering programme also in 2012 proved a highly attractive option among the programmes offered by DTU Civil Engineering. 2013 is expected to see the completion of a new building which will house teaching, studio and workshop facilities that will match the department's expanding teaching activities.
DTU Civil Engineering's positive development has enabled DTU Civil Engineering to take on a number of new academic staff members, among other things within the high-ranking strategic focus areas. In 2012, the average number of full-time employees was 202, including 58 PhD students, while the academic staff accounted for approx. 75% of the total number of full-time equivalents. Organisationally, the academic staff members are affiliated with a number of sections engaged in educational activities, research, innovation and public sector consultancy. Add to this the department support functions responsible for laboratories/workshops, finance, HR, administration, IT, communications and management services. The figure on page 43 shows DTU Civil Engineering's various staff categories and financial data.

The new building 127 totals 2,000 square metres and will primarily house DTU's architectural engineering study programmes. The building viewed from the existing orchard which will function as a green 'hub'. Illustration: CCO Arkitekter.

Challenging soil conditions under the Fehmarnbelt and elsewhere in Denmark

Palaeogene clays are found in large areas under the Fehmarnbelt. These clays are challenging for civil works due to the very fine grained composition of clay minerals. Experts from DTU Civil Engineering contribute to development of the newest research and knowledge on soil investigations and geotechnical issues.

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To a large extent, every time a great infrastructure project is carried out it produces new knowledge and experience. An enormous amount of tests and investigations are performed, some of them quite unusual. It is the perfect opportunity to share the experiences among geotechnical engineers all over Denmark and increase their levels of understanding. An example is the spin-off from the Great Belt bridge project, where the understanding of the behaviour of glacial till and the design methods it suited were improved and afterwards implemented in geotechnical engineering practices in Denmark. Now we have the chance to do the same with Palaeogene clays as a spin-off from the pre-investigations for the fixed link across the Fehmarnbelt. A huge amount of results from field measurements and laboratory tests on soil have been collected, and Femern A/S has generously opened its data base of results for research purposes.

Early in the planning process, Femern A/S established expert groups on various key topics. Associate Professor Ole Hededal and Research Professor Emeritus Niels Foged, both DTU Civil Engineering, are members of the geotechnical expert group formed to advise on soil investigations and geotechnical issues. In 2012, the tasks were mainly concerned with how to formulate advanced soil models based on a huge amount of experimental results and how to communicate these advanced results in a way that bidding contractors and their consultants could use when pricing the fixed link or parts of it.

Photo: Femern A/S

Parallel research

Parallel to this work, Associate Professor Anette Krogsbøll, DTU Civil Engineering, Ole Hededal and Niels Foged have in 2012 included results from Femern A/S in their research about deformation properties of Palaeogene clays. The experiments carried out in the DTU Civil Engineering geotechnical laboratory showed that clay from Little Belt recovers most of its original porosity when unloaded from a high stress level to the stress level that is found close to the seabed today. This is in contrast to the general perception that older Danish deposits such as clay till – having been subjected to huge overburden pressures from the ice cover during the ice-ages – are able to "remember" their overburden. The Palaeogene clays seem to "forget" the pre-consolidation and as a result, these clays have a greater potential for deformations in loading and unloading conditions. A key observation from the investigations is that the Palaeogene clay needs to be tested and interpreted in a different manner than, for example clay till. These initial results were presented at the 16th Nordic Geotechnical Meeting in Copenhagen.

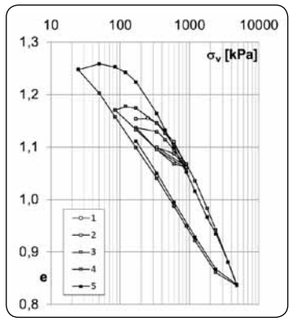
New group established

After the Nordic Geotechnical Meeting in Copenhagen, another group of experts was established among members of the geotechnical society in Denmark. Anette Krogsbøll and Niels Foged participate in this group together with members of Danish consulting companies and Aalborg University. The main focus is to support consolidation of the knowledge gained from the Fehmarnbelt project and other projects in Denmark, where properties of Palaeogene clays are important for the design of structures. DTU Civil Engineering contributes to the development of new test methods and in the interpretation of results partly by initiating student projects. The aim for DTU Civil Engineering is to include the most up-to-date knowledge in its teaching and to ensure that new engineers can contribute new and valuable knowledge in companies afterwards.

Upcoming activities at DTU Civil Engineering include a PhD project and several student projects at master's and bachelor's level – all as a direct consequence of the work carried out during 2012 at DTU Civil Engineering and in the expert groups.

Sample of Palaeogene clay

Photo: Femern A/S



Axial stress (σv) versus void ratio (e) for a sample of Palaeogene clay tested in an oedometer test. The numbers refer to load sequence – starting with 1. Void ratio is the ratio between volume of voids and volume of solids.
The sample was loaded in several load cycles below 900 kPa and finally twice to the level of 4800 kPa with almost the same stress-void ratio path.

Emil Tang Engelund – 2012 'PhD of the year'

Wood
Water
Interaction

The 2012 'PhD of the year at DTU Civil Engineering' award is presented to Emil Tang Engelund for his thesis 'Wood – Water Interaction'. The assessment committee emphasised, among other factors, the relevance to society and the high professional quality of his work.

The 2012 'PhD of the year at DTU Civil Engineering' award is presented to Emil Tang Engelund for his work and activities in connection with his PhD thesis 'Wood – Water Interaction'.

The award was based on several factors, including relevance to society and the high professional quality of Emil Tang Engelund's work. As an industrial PhD student, Emil Tang Engelund has worked with the project 'Wood – Water Interaction' which was conducted DTU Civil Engineering in collaboration with the Forest & Landscape at the University of Copenhagen, and the Center for Wood Technology at the Danish Technological Institute. Emil Tang Engelunds's project supervisors were Associate Professor Staffan Svensson, DTU Civil Engineering, Senior Researcher Lisbeth G. Thygesen, University of Copenhagen, and Center Manager Niels Morsing, Danish Technological Institute.

Emil Tang Engelund has conducted innovative and, in many respects, groundbreaking research as he has applied complex mechanical models used in the scale level of wood cells to challenge already accepted system assumptions concerning about wood properties in the interaction with water.

This research was only been possible due to Emil Tang Engelund's phenomenological, experimental and theoretical understanding of physics, mechanics and wood materials technology.

Emil Tang Enge Lund's research has produced five ISI journal articles and six papers.

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Per Goltermann, Arne Egerup

Rasmus Joachim Pedersen
Boligbyggeri i massivt træ
Per Goltermann, Arne Egerup

Ulrik Sloth Christensen
Udvikling af metode til energirenovering af enfamiliehuse
Svend Svendsen, Sanne Hansen, Lies Vanhoutenghem

Jonas Amkjær, Nicky Wollesen
Almene boliger, Parkvænget skælskør
Per Goltermann, Arne Egerup, Lars Bundgaard (ex)

Christian Stoklund Winther
Optimering af moderne kontorbyggeri ved brug af detaljerede beregningsmodeller. Jørgen Erik Christensen

Marchel Pedersen, Steen Winterskov-Andersen
Ny tagetage - fra loftrum til beboelse
Per Goltermann, Per Kjærbye, Arne Egerup

Montader Nabil Shaker, Hussein Al-Nema
Rubber bearing damper for structures
Einar Thór Ingólfsson, Imad Mualla (ex)

Signe Lindberg Iversen
Solar Decathlon 2013
Toke Rammer Nielsen, Teresa Zurcyka, Lotte Bjerregaard

Abdullah Tahtah, Obaidullah Walli
Betons bearbejdelighed og styrke udvikling
Kurt Kielsgaard Hansen

Janne Frederikke Meldgaard Rynkjøb
Geotechnics at the Nordhavn project. Ole Hededal

Malte Larsen
Vontex shedding and galloping on bluft bodies. Holger Koss

Kasper Brændegaard
Indeklima i to identiske daginstitutioner i Hillerød Kommune
Jørn Toftum

Ghita B. Hansen
Damped frame structures. Einar Thor Ingolfsson

Cetin D. Yilmaz, Khushai Khan Shah
Bygningsprojektering af Casa Entreprise
Anette Krogsbøll, Arne Egerup, Per O. Kjærbye

Khuram Saleem
Projektering af LMGE-domicil, kontorbyggeri. Arne Egerup

Ahmed Hassan
Geoteknisk og konstruktiv dimensionering af fundament til landbaseret vindmølle. Ole Hededal

Matthias Koch
Eksperimentelt studie af tværbelastede T-samlinger i træ, med mekaniske samlemidler
Sigurdur Ormarsson, Finn Larsen, Thomas Larsen (ex)

Thomas Morsing Larsen, Tim Nørgaard Christensen
Undersøgelse af højisolerede ydervægge med udnyttelse af diffus solstråling. Svend Svendsen

Jimmi Thimgaard Pedersen, Mikkel Posenbæk Poulsen
Eksperimentel analyse af foldning af stålkonsolplader
Jeppe Jönsson, Einar Thor Ingolfsson(ex), Jesper Gath (ex)

Yue Zhang, Ferhat Kücükgongcü
Flintholm Company House, projektering
Arne Egerup, Per Kjærbye, Salman Pey, Per Goltermann

Qader Gulomar, Khalid Daud
Projektering af DTU's nybygning 328
Per Goltermann, Arne Egerup

Qader Gulomar
Projektering af MTH-Byggeri
Per O. Kjærbye, Per Goltermann

Khalid Daud
Ingeniørprojektering af erhvervsbyggeri
Per O. Kjærbye, Per Goltermann

Balal Ahmed
Novo Nordisk (kantine/kontorbyg)
Arne Egerup

Jens Gustaf Hansen Wodschow
Novo kontorbyggeri i Hillerød
Anette Krogsbøll, Arne Egerup

Peter Møller Harpsøe
Procesoptimering af tagboligbyggeri ved udvikling af præfabrikerede elementer. Søren Peter Bjarløv

Jens Christian Buchardt
Anvendelse af jordankre til understøtning af dybe udgravninger
Ole Hededal

Bo Kjartan Staunsholm
Avanceret solvarmeanlæg til brugsvandsopvarmning
Simon Furbo, Elsa Andersen

Jon Børgesen, Kent Weile Nielsen (læser på DTU MEK)
Test af PVT panel
Simon Furbo, Jianhua Fan

Sabine Svendsen, Liv Rosenmai
Use of sewage sludge ash in concrete-influence of phosphorous on strength. Lisbeth M. Ottosen, Mette Geiker

Rasmus Steensbro
Evakuering af personer med nedsat syn fra Vágar Lufthavn
Anne Dederichs

Jacqueline Ellermann Viborg
Undersøgelse af indeklima i DTU's auditorier
Geo Clausen, Jørn Toftum

Danny Vergara, Sean Barry Hudson
Design af gangbro af glasfiber Kompositmateriale
Henrik Stang, Jeppe Jønsson, Ib Blom Andersen (ex), Michael Birk Jensen (ex)

Andreas Fangel
BIM-baseret kalkulation i designprocessen
Jan Karlshøj

Line Sommermark Tejnø, Pernille Christensen
Undersøgelse af et limsystems fugt- og temperaturbetingede egenskaber ved limning af natursten. Kurt Kielsgaard Hansen

Jonas Madsen, Mads Wendt-Larsen
Eksperimentel undersøgelser og teoretisk bestemmelse af hulrandsbæreevne i træsamlinger. Staffan Svensson

Sibel Kilinc, Michelle Blaabjerg Johannesson
Selvkompakterende betons bearbejdelighed og styrkeudvikling
Kurt Kielsgaard Hansen

Bedriye Kaplan
Brugeradfærdens betydning i designfasen af energirenoveringsprojekter. Rune Vinther Andersen

Rikke Dahl Jakobsen, Kim Lundsten Wittrock
Indeklimarenovering på Maglekildeskolen
Geo Clausen, Jørn Toftum, Rune Jacobsen (ex)

BSc theses

Ellen Stærk Nicolajsen, Grith Martinsen
Karakterisering af spildevand i Sisimiut med særligt fokus på antibiotika resistente bakterier
Pernille Erland Jensen, Ragnhildur Gunnarsdottir, Arne Villumsen

Julie Koefoed Bielefeldt
Sørestaurering af Spejdersøen i Sisimiut, Grønland
Pernille Erland Jensen, Morten Holtegaard Nielsen

Oliver Blach
Fysiske materialeegenskaber ved jernoxdstabiliseret jord
Anders Stuhr Jørgensen, Sanne Skov Nielsen

Peter Bjørn Jensen
Bundaske fra affaldsforbrænding som tilslag i beton
Björn Johannesson, Thomas Astrup, Claus Pade (ex)

Jakob Berg Johansen
Tilgængelighed og design af 3D bygningsinformation
Jan Karlshøj, Markus Lampe

Saffa A.H. Allami
Ingeniør projektering af Pihl-byggeri. Per O.Kjærbye, Per Goltermann

Michail Golubjev
Design og statisk beregning vha. BIM. Per O.Kjærbye, Flemming Vestergaard

Just Nordbud
Udvikling og undersøgelse af vejledning i integreret design af bygninger i lavenergiklasse 2020. Svend Svendsen

Jesper Hyllekilde Andersen, Ejnar Erland Videbæk
Fugt- og temperaturs indflydelse på træs tangentielle styrke - numeriske og eksperimentelle studier
Sigurdur Ormarsson, Finn Larsen

Nina Friis
Glaciofluviale sedimenter nær Kangalussuaq i Vestgrønland
Morten Holtegaard Nielsen, Johan Ploug

Michael Steffensen, Jacob Svejgaard
Beregning og udformning af tensegrity rumkonstruktioner
Henning Agerskov

Martin Buhl
Udvikling og analyse af højisolerede klimaskærmskonstruktioner
Svend Svendsen

Ann-Sofie Bjørke
Analyse af standardtestmetode for kemisk svind af cementpasta
Ole Mejlhede Jensen

Ahmad Aziz Taha El-Wali, Ali Abdul Hussein
Undersøgelse af sammenhængen mellem ultralydshastighed og styrke af natursten. Kurt Kielsgaard Hansen, Bent Grelk (ex)

Merdzan Ismaili, Christian Ejlertsen
Undersøgelse af den fotoelastiske konstant i glas for enakset varierende spændingstilstande. John Forbes Olesen, Jens Henrik Nielsen

Peter Sally M. Jacobsen, Christian E. Haugwitz-H.-R
Hudrauliske egenskaber af sintret glas
Ida Fabricius, Claus Køller (ex)

Pil Nørringgaard, Iben Brøndum Andersen
Mekanisk opførsel af glas ved høje temperaturer - langtidspåvirkning
John Forbes Olesen, Jens Henrik Nielsen

Randi Nielsen, Anne Kathrine Bach Vestergaard
Mekanisk opførsel af glas ved høje temperaturer - hukommelses-effekter.
Jens Henrik Nielsen, John Forbes Olesen

Andreas Myrhøj Stengel Hansen, Daniel Nielsen
For-/efterspændte mekanisk armeret glasbjælker
Jens Henrik Nielsen, John Forbes Olesen

Christian Lundsgaard
Mechanical properties of amonia-absorbing salt
Henrik Stang, Agata Klukowska (ex)

Casper Vestergaard Nissen
Håndtering af kompleks geometri med BIM
Flemming Vestergaard, Hans Peter Nielsen

Christoffer Marxen Knøste, René Borup Knorborg
Metode til planlægning af vidtgående energirenovering af parcelhuse
Svend Svendsen, Matinde Grøn

Donations 2012

COWIfonden
In-Situ Afbrænding af Olieprøver. 235.000
Project manager Grunde Jomaas

Bjarne Saxhofs Fond
Thermo Active Building Systems - Performance in practice and possibilities for optimization. 501.400
Project manager Jakub Kolarik

Bjarne Saxhofs Fond
Development of new total heat recovery ventilation technology for energy conservation in buildings. 495.800
Project manager Lei Fang

Bjarne Saxhofs Fond
Energy performance of combined radiant and convective systems for energy efficient indoor environment. 501.400
Project manager Zhecho Dimitrov Bolashikov

Saxhof Foundation
Opgradering og udvidelse af klima målestation ved DTU Lyngby. 501.400
Project manager Janne Dragsted

Knud Højgaards Fond
Postdoc NN Omdøbes. 1.250.000
Project manager Michael Havbro Faber
Direktør Ib Henriksens Fond
Konserveringsmæssig undersøgelse af ny elektrokemisk metode til bevaring af kalkmalerier. 50.000
Project manager Inge Rörig-Dalgaard

Augustinus Fonden
Konserveringsmæssig undersøgelse af ny elektrokemisk metode til bevaring af kalkmalerier. 747.000
Project manager Inge Rörig-Dalgaard

A.P Møller og Hustru Chastine Mc-Kinney Møllers Fond til almene Formaal
Bevaring af kalkmalerier på saltbelastede hvælv med strøm, er metoden ved målet? 1.732.200
Project manager Inge Rörig-Dalgaard

Ministeriet for Ligestilling og Kirke
Bevarelse af kalkmalerier. 100.000
Project manager Inge Rörig-Dalgaard

BMT Instruments
Materialedonation af 18 trådløse fugt- og temperaturfølere til eksperimenterende opgaver og undervisning.
Lån af Modtagerboks for de trådløse sensorer inkl. software og online monitoreringssystem. 35.000
Project manager Alfred Heller

COWIfonden
Sammenhæng mellem luftporestruktur og isdannelseshastighed i beton. 74.000
Project manager Marianne Tange Hasholt

Martha & Paul Kern-Jespersens fond
Støtte til indkøb af Rotronic fugtfølere. 40.000
Project manager Kurt Kielsgaard Hansen

DONGEnergy
Siliceous ooze sediments, diagenesis and grain properties. 1000.000
Project manager Ida Lykke Fabricius

DONGEnergy
Dynamic deformation characteristics. 100.000
Project manager Katrine Alling Andreassen

Staff

As of December 31 2012		2012 [1]	2011 [1]	2010 [1]	2009	2008	2007	2006	2005	2004
Scientific	Professor	12	10	9	9	7	7	7	9	11
	Associate Professor	41	37	37	42	40	40	46	38	44
	Assistant Professor	29	23	21	7	8	7	10	15	15
	Other VIP	12	14	18	7	9	9	9	6	4
	PhD Students	58	55	49	64	51	42	37	44	40
	Total	152	139	134	129	115	105	109	112	114
Technical and Administrative	Academic	10	9	9	9	9	9	11	11	10
	Clerical	9	9	9	10	11	13	13	12	12
	Technician	23	22	21	25	21	20	18	22	22
	Other	8	11	9	7	5	5	4		
	Total	50	51	50	50	50	49	47	50	48
Total Department Staff		202	190	184	179	165	154	156	162	162

2010[1]-2012[1]:Calculated in FTE, full-time equivalent

Education

		2012 [1]	2011 [1]	2010 [1]	2009	2008	2007	2006	2005	2004
STÅ[1]-total		622	589	555	496	494	514	483	508	519
Projects (students)	MSc	110	111	80	69	74	88	85	92	74
Bachelor	BSc	32	51	27	20	34	51	31	36	56
Diplom	BEng	110	86	98	61	84	119	130	62	82
Admission (students)	BSc (Building Technology)	61	57	67	63	65	58	62	72	60
	BSc (Architectural Engineering)	62								
	BEng (Architectural Engineering)	50	49	42	46	45	47	50	52	42
	BEng (Civil Engineering-summer)	80	79	81	79	82	84	75	63	58
	BEng (Civil Engineering-winter)	37	35	39	31	39	29	38	30	32
	BEng (Arctic Technology)	23	24	23	17	19	18	8	9	8

Research

		2012 [1]	2011 [1]	2010 [1]	2009	2008	2007	2006	2005	2004
Refereed papers	Total	100	80	92	53	50	67	45	61	63
	Of these in ISI	91	66	87	46	47	48	30	43	37
PhD theses		11	14	8	8	3	13	5	8	10
Doctoral theses		0	0	0	0	0	0	0	1	0

Finances

		2012 [1]	2011 [1]	2010 [1]	2009	2008	2007	2006	2005	2004
Revenues	DTU-grant	79704	83263	73.944	70.340	66.718	59.827	56.656	53.184	52.523
	External revenue	58777	48789	34.348	44.188	46.489	30.326	31.033	30.862	28.563
	Total	138481	132052	108.292	114.528	113.207	90.153	87.689	84.046	81.094
Expenditures	Wages	94731	88532	83.843	77.830	68.846	66.782	63.021	62.725	62.917
	Other expenses	42897	36989	34.034	34.471	31.933	23.954	26.420	19.628	16.445
Total		137628	125521	117.877	112.301	100.779	90.736	89.441	82.353	79.362
Result		853	6531	-9585*	2.227	12.428	-583	-1.757	1.693	1.732
Available amount	January 1	20757	14076	(11.281)	9.054	7.839	6.200	7.957	6.264	4.532
Carried forward	December 31	21376	20575	(1.696)	11.281	9.054	5.617	6.200	7.957	6.264

*Deficit caused by transition to a new income accounting principle.
STÅ[1]: 1 STÅ is one student annual work (1 STÅ=60 ects points)

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