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Annual Report 2009

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Department of Civil Engineering
Annual Report 2009

DTU Civil Engineering
Department of Civil Engineering

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Annual Report 2009

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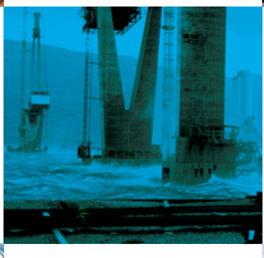
Front Picture: Laboratory Technician Louise Schmidt Ryhding





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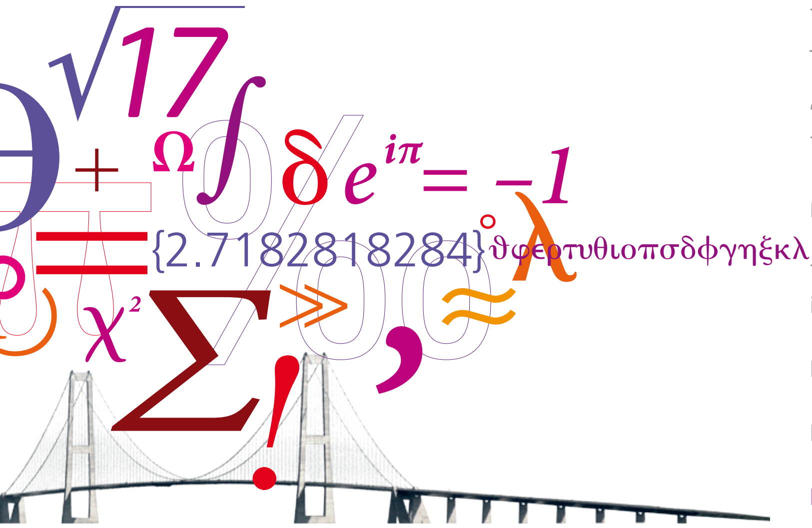
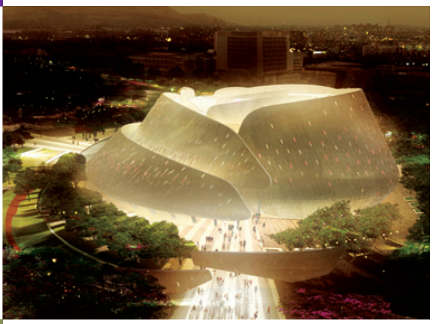

Management Report 2009

Civil engineering, the challenge of **sustainability**

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

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

Our vision is to become a leading European civil and architectural engineering department and a preferred partner for companies, authorities and institutions in the building and construction sector.

It is with great pleasure that I present the annual report 2009 for the Department of Civil Engineering at the Technical University of Denmark – DTU Byg. Indeed, I am not in a position to take credit for the leadership behind the impressive results from DTU Byg in 2009. However, I am proud of having contributed to and being part of the organization and it is my pleasure to introduce you to the annual report for 2009.

A university department is a very diverse and complex institution, and this holds true in particular for a department in a technical university, bearing in mind that activities range from maintaining knowledge in classical fields and fundamental research in promising areas of technical science to participating in innovation and developing cutting-edge emerging technologies. Further, activities take the form of teaching, basic research, innovation and interaction with industry as well as public sector consultancy. A common denominator for all these activities is that they aim at scientific progress in the service of society through the application of technology.

'Service of society' clearly is a broad term, which will be defined differently in different ages. At present, and I am sure also in the future, the concept of sustainability plays a major role in defining 'service of society'. Simply mentioning concepts like the global depletion of resources, the climate change challenge and the threat from global pollution should make us all think and act. Clearly, a huge responsibility rests on present and future generations of engineers to provide the scientific and technological basis for meeting these huge challenges. In particular, civil engineers will play a central role in this: e.g. making sure that energy consumption in buildings is reduced from the current massive level, that new infrastructure is sustainable with minimized energy and material consumption and that the huge investments made in new infrastructure are long-lasting, just to mention a few of the important issues facing modern civil engineers. The activities at DTU Byg clearly reflect such efforts.

In this year's report you can read about ongoing, exciting research into solar energy collectors for sustainable housing and their development, and you can read about the visions of our new Professor Carsten Rode in building physics – the scientific field necessary to ensure our understanding of the complex physical processes taking place in a building, an understanding which is essential when introducing new, highly insulated and energy efficient living and working spaces. What happens when the indoor climate in buildings – in this particular case schools – is neglected and not properly considered in building design and operation is described in an article about a study of the indoor climate of our public schools in Denmark.

Our work in protecting the huge investments in a durable and safe infrastructure is exemplified in two articles: one describing DTU Byg's commitment and participation as independent advisors in the Femern A/S Geotechnical Expert Group and another which describes cutting-edge, important research into improved corrosion resistance of steel in reinforced concrete structures – rein-

forcement corrosion being one of the most important deterioration mechanisms in our civil infrastructure and which thus plays a major role in the expected service life of reinforced concrete structures. It is very rare that completely new building construction concepts are developed, patent protected and commercialized. Therefore I encourage you to read the exciting article about the new 'Super Light' construction system, which will reduce energy and material consumption during construction considerably, while at the same time releasing new architectural potential.

Clearly, it is not enough to understand and develop technologies, we also need to understand how technologies potentially influence the environment and how the environment and the (changing) climate influence our buildings and infrastructure. Wind engineering is an important part of this picture, and you can read about our new, strategic efforts in this field exemplified through investigations of urban space quality. Mitigation technologies need to be in place when accidents happen with potentially severe consequences for our ecosystems. There is increased focus on oil extraction in the Arctic regions and an interesting article describes our work in developing and assessing technologies for fighting oil spills in this sensitive environment.

Since we are living in an aging society with an aging infrastructure, conservation and repair is of growing concern, and it is necessary to develop new and environmentally friendly technologies to meet new challenges. Researchers at DTU Byg have employed electro-chemical methods in the development of a new conservation method for archaeological wooden objects. All our activities are interlinked with education directly or indirectly. A large amount of resources are spent not only on basic teaching but also on activities that maintain our study programmes at the highest level and ensure a close relationship between our research and our teaching. These activities are described in three articles dealing with investigations into the quality and relevance of our study programmes, how educational activities can produce innovation and how innovation can be incorporated into education and, finally, our successful efforts in establishing an Arctic Engineering study programme in Greenland.

To meet societal demands for not only good engineers with a solid education but also for engineers with a research background, DTU Byg is focusing on PhD programme. To highlight this effort we have decided to appoint and celebrate 'PhD of the year at DTU Byg' among the PhD candidates that finished their work in 2009. You can read about PhD of the year 2009 together with the panel's reasons and the presentation of his work.

I hope you enjoy reading the report.

Acting Head of Department

Henrik Stang
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Organisation

	External partners	Other departments	ADM Administration and IT	TS Technical Staff	AT Arctic Technology	BD Building Design	BPS Building Physics and Serivce	IC Indoor Environment	SE Structural Engineering	CM Construction Materials	GEO Geotechnics
ARTEK	•	•		•	HC	•		•			•
ICIEE	•	•		•			•	HC			
Project A				•				PM			
Project B	•			•		PM					
Project C	PM								•	•	
PhD Programme			HC		•	•	•	•	•	•	•
MSc (CE)	•	•	•	•	•	•	•	•	EM	•	•
BSc (CE)	•	•	•	•	•	•	•	•	EM	•	•
MSc (AE)	•	•	•	•	•	EM	•	•	•	•	•
BEng (AE)	•	•	•	•	•	EM	•	•	•	•	•
BEng (AT)	•	•	•	•	EM	•	•	•	•	•	•
BEng (CE)	•	•	•	•	•	•	•	•	•	•	EM

Head of Department

Board of Head of Sections

Research and Innovation Committee

Education Committee

Safety Committee

Cooperation Committee

HC: Head of Centre
PM: Project Manager
EM: Education Manager
• : Project/Education Participant

Figure: Organisation Diagram

Sections:

- Arctic Technology
  Professor Arne Villumsen
- Building Design
  Professor Kristian Hertz
- Building Physics and Services
  Professor Carsten Rode
- Construction Materials
  Professor Ole Mejlhede Jensen
- Geotechnics
  Associate Professor Ole Hededal
- Indoor Environment
  Professor Bjarne Olesen
- Structural Engineering
  Professor Jeppe Jönsson
- Administration and IT
  Søren Burcharth
- Laboratories and Workshops
  Jørgen Bjørnbak Hansen

Centres:

- ARTEK, Arctic Technology Centre
  Professor Arne Villumsen.
- ICIEE, Centre for Indoor Environment and Energy
  Professor Bjarne W. Olesen.

Study Programmes:

- Civil Engineering (MSc)
  Associate Professor John Forbes Olesen
- Building Technology (BSc)
  Professor Per Goltermann
- Architectural Engineering (MSc)
  Associate Professor Jan Karlshøj
- Architectural Engineering (BEng)
  Associate Professor Lotte Bjerregaard
- Building Engineer (BEng)
  Associate Professor Anette Krogsbøll
- Arctic Technology (BEng)
  Associate Professor Hans Peter Christensen

Advisory Board:

- Professor (adj.) Louis Becker, Architect MAA, AIA, RIBA. Design Director, Partner, Henning Larsen Architects
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Head of Department (acting):

- Professor Henrik Stang

A partnership **with great mutual benefits**

The cooperation between Femern A/S and the Technical University of Denmark works as a driver for development of new knowledge of geotechnical engineering

At the end of Denmark in Rødby, the Fixed Link to Germany will take off. Illustration: Femern A/S

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The Section for Geotechnical Engineering of DTU Civil Engineering is involved in the Fehmarn Belt fixed link project. Associate Professor and Head of Section Ole Hededal and Research Manager Niels Foged serve as members of the Femern A/S Geotechnical Expert Group. The group is acting as independent advisors to Femern A/S in order to ensure the level of quality by reviewing and discussing critical geotechnical aspects of the different technical solutions. Currently the focus is on the geotechnical investigations and laboratory tests. One of the major soil mechanical challenges is geological formation denoted Palaeogene clay. This formation was assessed to be complicated with respect to predicting long-term deformation, i.e. either swelling when unloaded or settlements when loaded. Already in the early stages of the Fehmarn Belt project, it was realised that better knowledge about the Palaeogene clay would be needed. Therefore Rambøll Danmark A/S and Femern A/S initiated an industrial PhD in coperation with DTU Civil Engineering. Ole Hededal acts as supervisor to an industrial PhD project being conducted by Sara Gottlieb.

Several aspects

There are several aspects of the project that need to be considered. First of all, the Palaeogene clay is highly plastic with a very complex mechanical and rheological behaviour of which there is limited experience both in Denmark and internationally. Secondly, part of the formation has been dislocated and disturbed by the glaciers during the ice ages. This has caused changes in the material structure, e.g. fissures, and thereby in the mechanical response. The purpose of the PhD project "Deformation and strength properties of highly plastic, fissured Palaeogene clay" is to extend the knowledge of the Palaeogene clay in the Fehmarn Belt. The work will focus on the mechanical and physical/rheological properties of the clay from an experimental point of view. Working with highly plastic clay requires good, reliable laboratory equipment. These days the soil mechanics laboratory at DTU Civil Engineering is upgrading its mechanical testing devices, i.e. triaxial test apparatus and CRS equipment, to meet the requirements of the clay. At present the Constant Rate of Strain, CRS, apparatus has been upgraded with a new oedometer cell, pressure actuators to control back pressure, pore pressure transducers and a new control program. All of these improvements have been made possible thanks to a contribution from our industrial collaborators. Grontmij-Carl Bro sponsored the back pressure system and GEO has supplied the control system for both the CRS and the triaxial test system and is offering on-going technical support.

Interesting results

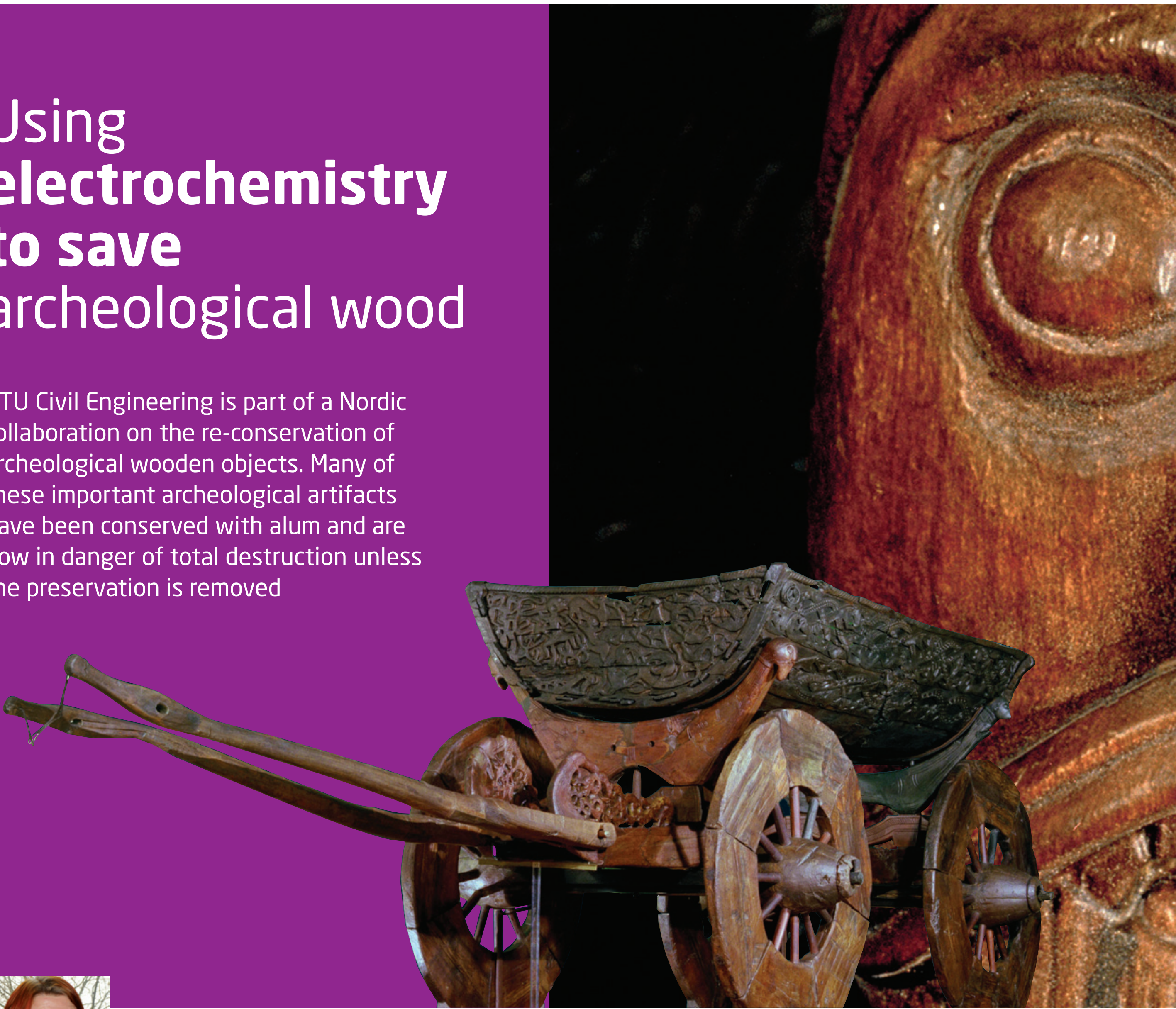
The first test on the Fehmarn Belt samples in the CRS has been conducted successfully and the second is about to happen. With the new equipment, new ways of controlling and analysing the tests have been made possible. Some very interesting results have been obtained, which may affect the test procedures and evaluation of the commercial Fehmarn Belt program.

The fact that the tests of the PhD project are conducted in the geotechnical laboratory of DTU Civil Engineering is of great value to discussions in the Expert Group. The close contact between the two projects makes the information flow fast and easy. Hence, any new knowledge may be easily conveyed to the fixed link project.

The soil samples taken from 50-100 m below the seabed are stored in container under controlled climatic conditions. Photo: Femern A/S

Using **electrochemistry to save** archeological wood

DTU Civil Engineering is part of a Nordic collaboration on the re-conservation of archeological wooden objects. Many of these important archeological artifacts have been conserved with alum and are now in danger of total destruction unless the preservation is removed



Cart from the Oseberg Viking Age-find – partly alum-treated. Excavated in 1904. Viking Ship Museum, Oslo. Photo: Museum of Cultural History, University of Oslo / Eirik Irgens Johnsen

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When archaeologists find waterlogged wood in archeological excavations, the wet wood may appear to be in good condition with the original shape and ornamentations intact. However, when such finds are more than 2000 years old, like the wood in the Iron Age Hjortspring find dated 350 BC, the wood may be severely decayed and only the presence of water prevents the wood from disintegrating.

The conservators in the museums therefore have to treat the wood before it is dried and ready to put on display in the museums. From 1850-1960, a hot solution of alum ($KAlSO_4$) was the preferred treatment both in Denmark, Norway and Sweden. This means that many important finds like the Hjortspring find and part of the Norwegian Oseberg find from the Viking Age (800 AD) - considered the most richly ornamented Viking Age find in the world - have been treated with alum.

However, we now know that the alum treatment does not provide adequate protection of the wooden objects and there is a need for re-conservation before important parts of our cultural heritage are lost forever. A Nordic collaboration involving the Technical University of Denmark, the National Museum of Denmark, the University of Oslo and the Swedish National Heritage Board are currently trying to work across borders in an attempt to solve the problems of the alum-treated wood and find suitable solutions for re-conservation.

Extraction of alum

In alum-treated wood, the ingress of alum into the wood is often limited to the outermost millimetre, and the inner part of the object is thus left untreated. The shape of the object may thus be preserved, but the untreated wood in the centre has often shrunk/collapsed during drying, causing internal cracking. The alum treatment makes the wood heavy and brittle and the treated wood is also subject to structural pulverization which may eventually cause the total destruction of the artifact. The disadvantages of the alum treatment method have resulted in different attempts at re-conservation. At the Danish National Museum this is presently done by extracting the alum in water followed by re-conservation with polyethlylenglycol (PEG) – a suitable conservation method by today's standards. At DTU Civil Engineering we have developed a method whereby an

Detail of cart from the Oseberg find. Photo: Museum of Cultural History, University of Oslo / Ove Holst

Removal of alum from archeological wood using an applied electric field. Experimental set-up

applied electric field is used to remove salt ions from porous materials. The method was originally used for the decontamination of soil, but the principles can be transferred to other porous materials with unwanted ions, like alum-treated wood. A low voltage DC field is applied across the wood and the alum ions (K^+, Al^+ and $SO_4{}^{2-}$) are transported by the electric field out of the wooden object.

The wood we use for the electrokinetic experiments is original alum-treated pieces from the Hjortspring and Nydam finds (supplied by the Danish National Museum) and from the Oseberg find (supplied by the Museum of Cultural History in Oslo, Norway).

The only method

The method has the advantage of faster extraction of the alum, but more importantly it may be the only method for removing alum if soaking the object is to be avoided. Extraction by soaking may still be the best solution for smaller objects in relatively good condition, whereas electrokinetic removal may be suited for larger or more fragile objects.

Severely damaged alum-treated wood from the Iron Age Viemose find. The picture represents a worse-case scenario if no acction is taken to re-conserve these vulnerable objects. Photo: Inger Bojesen-Koefoed

The next generation of building structures is born

A new and innovative technology can reduce materials consumption and CO_2 emissions. In addition, it will revolutionize modern architecture and construction practice

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Spectacular architecture is possible by applying new technology, such as this project by Henning Larsen Architects: the Massar Children's Discovery Centre in Damascus, Syria. This type of design is a dream today, but can become widespread because the super-light structures and the pearl-chain method enable soft, organic forms to be built less expensively and more simply. Illustration: Henning Larsen Architects

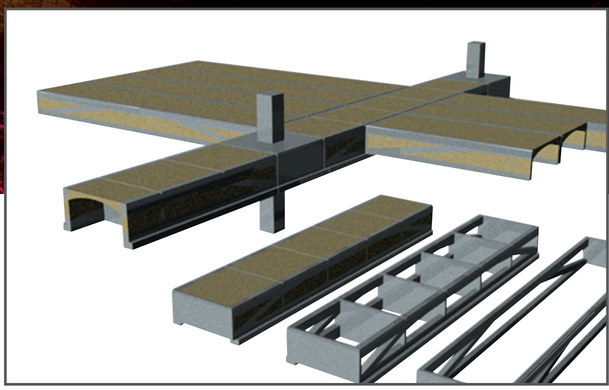
A new technology for load-bearing structures has been developed based on two patented principles by Professor Kristian Hertz at DTU Civil Engineering: Super-light structures and pearl-chain reinforcement.

By redesigning the traditionally expensive and energy-intensive steel and concrete constructions a new generation of structures is created that will set a new standard for resource efficient and sustainable building technology. The new structures are made of concrete, but are often less than half the weight of conventional structures, and thereby the costs and CO_2 emissions relating to manufacture, transport and construction are proportionally reduced. This is why the new structures are called "super-light". The new structures consist of a minimal skeleton of ordinary heavy concrete embedded in a concrete of very low weight. Just as the soft parts of a body are needed for the skeleton of a human or an animal to remain in place, the lightweight concrete fixes, stabilizes, and protects the skeleton of strong concrete. This leads to extremely resource-economical structures so light that they can float on water.

Very different structures and complete buildings have been designed and evaluated, and almost everywhere you get benefits which previously have been considered unthinkable such as:

- 50% cut in materials consumption
- 50% cut in energy consumption and CO_2 emissions
- 50% price reduction
- No need for scaffolding
- Cheaper moulds
- Faster construction
- Improved durability
- Good thermal insulation comparable to that of wood structures without the problems of rot and fire
- Improved moisture absorption reduces indoor climate regulation costs
- Good possibilities for drilling holes and cutting grooves for new services after the building is finished
- Increased protection from fire, earthquakes and explosions
- New possibilities for architectural expression

Of course, the lightness means that you can design longer spans and higher buildings. But the application of ultra lightweight concrete weighing only 600 kg per cubic metre to fill out the shape also means that the moulds for casting can be made much lighter, cheaper and of quite different materials and shapes as those used for ordinary concrete. In addition, the pearl-chain reinforcement, which is a spine of strong concrete blocks placed on a prestressed wire, makes it cheaper to produce structures like beams and shells of any curved shape. This, combined with the fact that arches usually are optimal shapes for forces, means that it is now often affordable to use curved arches and vaults instead of straight rectangular structures. The new technology therefore opens the door to a wealth of new possibilities for architects, liberating buildings from the many tight constrains that previously have hindered natural shapes in building design. This pushes the standard for what constitutes a resource-economic building.



Pi-Omega precast beam system

Research, development

A research and development centre for super-light structures is being established at DTU Civil Engineering, where several aspects of the technology will be developed further. A PhD study with Grontmij Carl Bro and DTU Electrical Engineering is investigating the sound-damping of super-light deck structures, where the stiffness of a vaulted super-light structure is taken into consideration, allowing a considerable weight reduction compared to traditional massive or hollow-core decks.

Other projects deal with the development of new, light self-levelling foam concretes for casting out the ultra-light moulds, the development of new pearl-chain structures and their pre-stressing techniques, investigating the interaction between light and strong concrete counteracting deflections, investigating optimal design by means of the new technology, and investigating the new possibilities for architectural design.

Super-light structures with pearl-chains offers a multitude of advantages for “tailor-made” structures cast on the building site, allowing impressive, unique and optimized shapes to be made much cheaper than previously. This might cause a revolution in architecture, where the designs are no longer subject to economical constraints. However, super-light technology also means a renewal for prefabricated structures. New factory-produced building systems are being designed by Kristian Hertz based on the super-light technology for all kinds of buildings. The Pi-Omega system, for example, consists of vaulted slab- and beam-elements. Other new building systems are designed for large halls with span-widths of 40-400 m, including a standard arch hall for industry, storage, or sport. Ongoing projects seek to develop low-bridge-systems and tunnel elements with optimal usage of the structural materials.

Commercialization

A marketing company, Abeo, will be established in cooperation with partners from International Business at Copenhagen Business School selling licenses for the technology and the building systems. A number of actual building projects are now implementing the technology, architects have adopted the new possibilities in their visionary designs, suppliers of building materials are making new standard products which facilitate industrial and customized applications, full prefabricated building systems are ready for production, and recently, new investors have decided to open a Chinese office of the marketing company.

For more information, please visit www.super-light.dk

Arctic oil spills **fought with fire**

The Arctic Technology Centre, together with the Norwegian research institute SINTEF, tested alternative oil spill response methods in the Barents Sea. The results indicated that in situ burning is very effective

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The Arctic contains approximately 25% of remaining undiscovered global oil and gas resources. While the region presents a significant development opportunity for the oil and gas industry, this development will take place in a very harsh environment. As such, there is a need to conduct extensive research into ways to develop this important resource in a manner that protects the ecosystem, and addresses the concerns of local inhabitants. Consequently, the independent Norwegian research organization SINTEF has established a Joint Industry Project, "Oil in ice", that examined various methods for cleaning up oil spills on ice. Experiments on burning accidently spilled oil on spot – a method known as in situ burning – was included in the project and so far the results are promising. This JIP is funded by the Norwegian Research Counsil and the six oil companies Agip, ConocoPhilips, Chevron, Shell, Statoil and Total.

PhD student Janne Fritt-Rasmussen from the Arctic Technology Centre at DTU Civil Engineering is writing her thesis on in situ burning of oil spills in the Arctic in cooperation with SINTEF as part of the "Oil in ice" project, and she participated in the final field experiment in the Barents Sea north of Norway in spring 2009.

Fire in the Barents Sea

In May 2009, the research vessel Lance left Longyearbyen on Svalbard heading for the marginal ice zone in the Barents Sea northeast of Hopen. The purpose of the journey was to perform various experiments with oil spill response in ice. The experimental area was found after three days in the choppy Barents Sea: 70-90% ice coverage and minimal activity from birds and mammals.

Two experiments were conducted; a long-term experiment focusing on the weathering of oil and a large-scale burning experiment. Seven cubic metres of crude oil were released for the long-term experiment. The oil slick was closely monitored for the eight days the experiment lasted, and samples for various physical and

Burning of experimental oil spill in the Barents Sea and small- scale burning. Photo: Janne Fritt-Rasmussen

Research vessel Lance in the marginal ice zone in the Barents Sea, west of Svalbard. Photo: Janne Fritt-Rasmussen

chemical analyses and small-scale burning were taken regularly. The experiments showed that the oil was ignitable for five days after it had been released. The second experiment involved 2 m_3 of crude oil weathered for 10 hours between the ice floes before the oil was ignited and successfully burned. Prior to the fieldwork, several laboratory experiments had been performed which involved burning oils with different degrees of weathering (evaporation/water content) in a specially designed set-up, which imitates real life in 125 ml size. To confirm the laboratory experiments it was necessary to make comparisons with real data. The experiments in the Barents Sea were thus unique experiments in order to verify the many studies in the laboratory. This was fully accomplished.

Why in situ burning?

In situ burning is an effective and simple method with considerable potential, especially in Arctic conditions due to:

- Low emulsification. The ice dampens the wave movement resulting in slow water uptake (emulsification). High water content normally makes ignition impossible.
- Low temperature. Oil evaporation is reduced due to the low temperatures. Thus more ignitable compounds are present in the oil.
- Ice. A crucial parameter for successful burning is a connected oil layer with a certain thickness. Broken sea ice reduces the oil spreading compared to open sea and thereby contributes to better conditions for in situ burning.

Some research has been performed over the last 30-40 years, even so there is a need for more knowledge about burning oil. In particular, more knowledge about the time window for in situ burning of weathered oil. This is precisely what Janne Fritt-Rasmussen's PhD project and field experiments in the Barents Sea have contributed to.

New Professor **in Building Physics**

By instituting a new professorship in building physics, the Department of Civil Engineering aspires to play a leading role in the development of high-performance buildings for the future

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A new highly energy-efficient dormitory building currently being constructed in extreme climate conditions at Sisimiut, Greenland. Illustration: tnt-nuuk a/s

We spend 90% of our time in buildings, and 40% of national energy consumption is related to the operation of buildings – heating, ventilation, lighting etc. The buildings themselves, as well as the activities which are carried out in buildings, represent important expenditures for our society, businesses and for ourselves as private people. In consequence, it is of paramount importance that our buildings are energy-efficient, healthy to stay in and durable. And obviously they also should be aesthetically and functionally optimal for our use.

A theme of broad interest

Building physics is the science that studies different phenomena in conjunction with the aim to achieve the optimal building solution for the future's new and renovated existing buildings. In order to strengthen the research in building physics and put the scientific field into focus, the Department of Civil Engineering has instituted a new professorship in building physics. Carsten Rode MSc, PhD in civil engineering, was appointed new professor in November 2009 and the department thereby aspires to playing a leading role in the development of high-performance buildings for the future. Research in building physics is executed by developing computational models and making laboratory and field investigations of building materials, building structures and whole buildings. As such, it is a science that combines many ongoing research fields at the Department of Civil Engineering as well as being a theme of interest to building industry consultants and manufacturers and to building owners, users and authorities with whom the department has close collaboration.

New challenges in future

Climate change incurs new challenges when buildings need to be able to sustain more extreme exposures while still remaining durable, efficient and comfortable. Therefore, we need highly insulated building structures, advanced fenestration products and efficient methods to heat and ventilate our buildings, as well as preferably passive methods to keep the building from becoming too warm. Fortunately, new building products are being produced, but we must know and understand their properties well and use the products in the most appropriate way when determining how they tie in with other parts of the building. We insulate our buildings better, which is generally considered an advantage, but the exterior shell of well-insulated buildings becomes colder and must be protected from damage due to moisture or frost which in the past were avoided only at the expense of high energy consumption. While we should thrive in energy-efficient buildings, biological and some chemical processes should not be allowed to develop and we must therefore prevent the conditions that lead to their proliferation. The new professorship will now be implemented to provide the highly efficient, comfortable and durable buildings we need for the future.

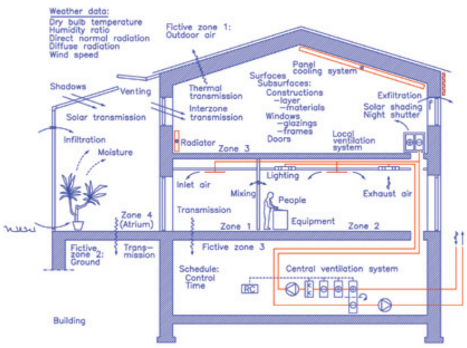

Illustration of the many building objects and services which are considered in advanced building simulations. Illustration: SBi, the Danish Building Research Institute

Carsten Rode (born 1963) qualified at the Technical University of Denmark and has been an associate professor with the Department of Civil Engineering since 1996. He has previously worked for the Danish Building Research Institute and he has a very well-developed network with contacts in the building industry and colleagues on the international research scene. He is currently chairman of the International Association of Building Physics. He is a very active educator who teaches all levels of the engineering studies from first semester B.Eng. classes to PhD students. He is also head of the Section for Building Physics and Services, and a member of the Academic Council of DTU.

Research into human quality of life in cities

A collaboration between DTU Civil Engineering and architectural firms aims towards a universal method to evaluate urban space quality based on measurable parameters. The objective is to create an optimum environment

Axeltorv in the city of Copenhagen – a wide open space and therefore exposed to urban wind. Photo: Miriam Ann Hellmann and Victor August Aalund-Olsen

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Study of the ground-near wind conditions on Axeltorv in Copenhagen performed in the wind tunnel at DTU Civil Engineering. Miriam Ann Hellmann and Victor August Aalund-Olsen, students in Architectural Engineering, conducted their BSc project within the framework of a research collaboration between DTU Civil Engineering and Gehl Architects. Photo: Holger H. Koss

Mission

One research activity at DTU Civil Engineering focuses on the evaluation of urban space quality. The majority of activities performed by people in cities take place in urban areas. From sitting at an outdoor café or strolling through a shopping zone or just a brisk walk from one spot to another, all such activities in open public areas are significantly affected by the quality of the ambient environment. For this reason architects, developers, city planners and municipalities seek to create optimal environments. Even though efforts at finding ideal solutions have been documented over the last many years, few scientifically based methods have been developed. Individual aspects of climatic conditions affecting city life have been researched, such as predicting pedestrian wind comfort in urban areas. Using the latest technologies and methods in simulating urban environments, our research concentrates on the development of a holist approach combining wind, air temperature, humidity and quality, sun radiation and noise nuisance in the evaluation of urban space quality. As mentioned, the approach will be based on measurable quantities. Non-measurable influences on city life relate, for example, to architectural aesthetics. Our mission is to translate experience and knowledge in urban design collected from antiquity to today into universal criteria that can be investigated with modern natural science and serve as a guide to the "Ideal City".

Design tools for the future

A widely used criterion in the evaluation of urban space quality is the assessment of pedestrian wind comfort. Both the function of the space and the dominating climatic condition, namely wind, are combined in this approach. In order to predict the local ground-near airflow conditions, the overall urban wind needs to be simulated. Wind tunnel testing techniques have been developed in recent decades as proven methods of investigating the ground-near wind in detail. Wind tunnel testing has been used traditionally in many new development projects both for studying the wind environment and the imposed wind loads on the new building structure. In particular, simulating urban wind is a complex task requiring a suitable test facility or immense computational power.

The fast developments in computational power and user-friendly software in Computational Fluid Dynamics (CFD) are finding an increasing number of applications in research and engineering. Paralleled with wind tunnel testing, CFD makes it possible to include additional climatic parameters in the simulation of urban climate. A newly started PhD project at DTU Civil Engineering on "Integration of CFD in structural and architectural wind engineering" will focus on the simulation of urban climate. The research work currently undertaken by Nina Gall Jørgensen combines numerical and experimental simulations, e.g. in the wind tunnel at DTU Civil Engineering, as well as measurements of environmental conditions in nature.

Research to improve city life

Presently, half the world's population lives in urban areas. In industrialised countries, the percentage of urbanised population in 2006 was on average 76%. Against this, Denmark is with 86% one of the most urbanised countries. According to the UN report on world population, the trend of increasing urbanisation will continue worldwide and challenge city planners to cope with future demands. As a consequence, urban space will play a far more central role for human activities in cities and thus increase focus on the quality of the urban space.

This issue is being intensely discussed within the scientific community in wind and environmental engineering. In this connection we are involved in international research collaborations and networks. Furthermore, collaboration with architects provides input for the non-measurable aspects, namely architecture and aesthetics. For example, a collaboration project with Gehl Architects on subjective and objective evaluation methods of urban space quality was conducted last year within the framework of this research.

DTU takes the temperature of **indoor air in schools**

DTU Civil Engineering participated in last year's Danish Science Festival by testing the indoor environment in 330 schools. The results showed that the environment in Danish schools is much poorer than that of schools in our neighbouring countries

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Tomorrows researchers measuring CO_2 in their classroom. Pupils from Amager Fælled Skole. Photo: Carsten Andersen/Dansk Naturvidenskabsformidling

Student performance depends on both the ability to concentrate while in class and on the level of school attendance; factors which are closely related with the indoor environment in schools. Recent studies at the Technical University of Denmark, DTU have shown that poor indoor environment in schools has an unfavourable impact on student performance, as the pupils performed approximately 15% worse in classrooms with poor indoor environment compared to classrooms with good indoor environment. Earlier studies in Denmark and abroad have indicated that ventilation in schools is often inadequate. So what is the status of the indoor environment in Danish schools today?

Every year, Danish Science Communication arranges the Danish Science Festival to promote a wider and deeper understanding of science and technology in Denmark. One of the activities of this festival is a mass experiment involving schoolchildren. In 2009, the idea was raised of letting students in 1,000 classes measure some important indoor climate parameters in their classrooms.

Classrooms are characterised by a high occupant density, and ventilation is therefore needed to dilute and remove human bioeffluents. The concentration of CO_2 is a simple measure of how well a room is ventilated in relation to the number of occupants. Normally the indoor CO_2 concentration varies between 400 and 2500 ppm (parts per million), and in some cases it rises up to 5000 ppm. The outdoor CO_2 concentration is approximately 385 ppm.

Regulations and recommendations

The Danish Building Regulations 2008 (BR08) prescribes that new schools must have a balanced ventilation system that provides a volume flow rate of 0.4 l/s per m2 floor area and 5 l/s per person in the classroom. This corresponds to a CO_2 concentration of approximately 1200 ppm. The Danish Working Environment Authority (WEA) aimed at employees in Denmark recommends that the indoor CO_2 concentration should not exceed 1000 ppm, and if it exceeds 2000 ppm for more than short periods during a day, the ventilation is inadequate.

Methods

It was decided to let the schoolchildren themselves perform measurements of the CO_2 concentration and temperature in the classroom. A simple method was used for measuring CO_2 concentrations, consisting of a measuring tube and a syringe, as shown in the photo above. Furthermore, the schoolchildren determined the amount of mould in the classroom, but this is not described further here. Similar experiments were performed simultaneously in Sweden and Norway, using the same measuring equipment. After the data was sorted, there was usable CO_2 data from 743 of the participating classes in 330 different schools. This means that there were results from 74% of the participating classes, and that 13% of all schools in Denmark provided data for this study. In Sweden, 238 classes in 135 schools reported their results, and in Norway 448 classes in 170 schools participated.

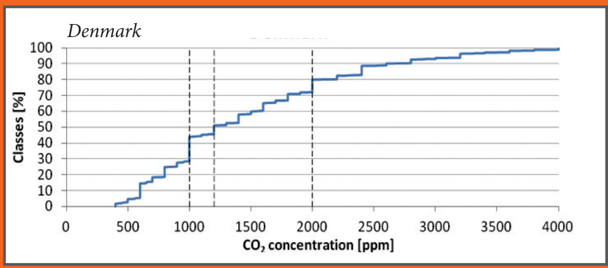

Fig. 1 Cumulated distribution of CO_2 concentrations

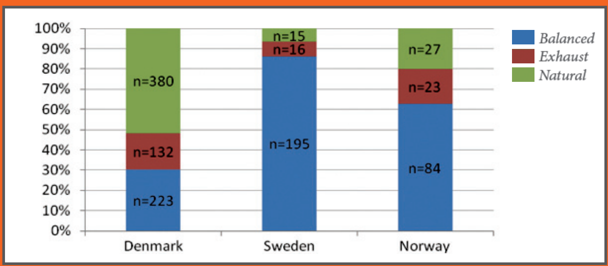

Fig. 2 Type of ventilation found in the participating schools

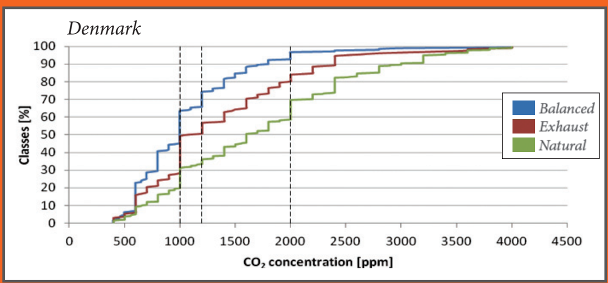

Fig. 3 Accumulated distribution of CO_2 concentrations from the three different types of ventilation

Engaged purpils from Amager Fælled Skole looking at the first results of the measurements of the CO_2 concentration and temperature in their classroom. Photo: Carsten Andersen/Dansk Naturvidenskabsformidling

Results

The results showed that the indoor environment in Danish schools was poor. 56% of all the participating classes reported CO_2 concentrations higher than 1000 ppm (see fig. 1). The results from the mass study in Sweden and Norway were 16% and 21%, respectively, which showed that our neighbouring countries had a substantially better indoor environment in their schools. One explanation for this can be found in the type of ventilation used. As seen in fig. 2, less than half of the participating Danish schools had mechanical ventilation, whereas more than 90% in Sweden and almost 80% in Norway had mechanical ventilation. In general, classrooms with balanced ventilation are better ventilated than those with natural ventilation. This is illustrated in fig. 3, showing cumulated distribution of CO_2 concentrations in Danish Schools for the different types of ventilation.

As expected, larger room volume per person was shown to influence the CO_2 concentration in the classrooms positively. So was the construction year of the schools, since there was a significant tendency that newer schools had lower average CO_2 concentrations than older schools.

Reflections

This was in many ways unusual research. The fact that fast feedback to the schools was very important meant that we received the data on a Wednesday and handed in our feedback report on the following Friday. This was a challenge. The following Monday it made headlines in the national news. Also the fact that it was schoolchildren of various ages that were making the measurements could certainly make many experienced researchers more than a bit nervous. But the experimental work was designed to work under these conditions, and the reward was, besides the interesting results, the joy of having had approximately 20,000 schoolchildren engaged in the assessment of their own indoor environment. We have since continued our research on indoor environments in schools by making long(er) term measurements in a representative sample of 100 Danish schools using more advanced equipment.

Two students, Henriette Ryssing Menå and Eva Maria Larsen, analyzed the data as part of their MSc Project. The examiner of the MSc Project Lars D. Christoffersen, Head of Research, Alectia states: This kind of science really provides knowledge and attention. After conducting the experiment, 20,000 pupils are now aware that we actually do influence the environment. And it encourages conscientious decision-makers to take action. As consultants, we can appreciate these results as they qualify and support sustainable development.

The Arctic Engineering programme **– a success story**

Interest in the Arctic Engineering programme has increased greatly in recent years. Between 18 and 20 students have been enrolled each year for the last three years. Three-quarters of theses students have come from Greenland

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Greenland – and the rest of the Arctic – offers major technological challenges, and there is a considerable need for people with special knowledge about arctic conditions. Topics such as mining, energy supply, and the maintenance of infrastructure in the Arctic are examples of areas that require specialised technological solutions. Since 2001, students studying engineering have been able to enrol in "Arctic Engineering" that takes place partly in Sisimiut, the second-largest town in Greenland, and partly at DTU in Lyngby. Arctic Technology is a four-year engineering programme taught in Danish. Most of the students are from Denmark or Greenland. At present it is possible to specialize in building and construction, environment and planning, or geology and natural resources. A specialization that will make it possible to become a high-school teacher in mathematics, physics or chemistry in Greenland is currently being developed.

Interest in this education was limited at first and only 8-10 students were enrolled each year. It was not economically viable to run these courses with such low numbers. However, the Greenland government provides economic subsidies for DTU to perform university education in the country. Interest has increased greatly in recent years. Between 18 and 20 students have been enrolled each year for the last three years. About three-quarters of these have been from Greenland, and about a fourth are women. A total of 114 students have been enrolled since the beginning of 2001. Some of these have dropped out, but the retention rate is increasing towards the average for DTU as a whole.

The main criterion for success is naturally the number of graduates. After the initial low numbers it is very satisfactory that we have now (15 February 2010) reached a total of 22 engineering graduates, eight of whom finished last year. We are proud that so many have chosen this programme and that so many have qualified as arctic engineers. It is also very satisfying that we now have the first PhD student with an arctic engineering background.

Jobs for all – also in the future?

So far our graduates have been very successful at finding jobs. The current reorganization of Greenland society towards improvements in the fields of sustainability, infrastructure, environmental aware-

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Polar Oil, Maniitsoq

Jeanette Birkholm
Sweden

Inooraq Brandt, civilingeniør,
Industrial PhD Student, Asiaq

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Ramböll, Sisimiut

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The picture gallery identifies the graduates as of 15th February 2010 and provides information as to their profession or further education after finishing their engineering degree. Photo: Fartato Olsen

ness, utilization of natural resources and the renovation of housing, does not imply a shortage of jobs for our graduates.

With its location in the far north, Greenland is a good place from which to provide engineering know-how to the rest of the Arctic. It is something of a challenge for Greenland industry to live up to the slogan "Arctic technology that has been developed and tested in Greenland must be exported to the rest of the Arctic" – this was how the task was formulated several years ago when the Arctic Technology Centre, ARTEK, was established.

Other participants on Arctic courses

ARTEK also offers project-orientated courses for "ordinary" DTU students that involve three weeks of fieldwork in the summer period. From February 2010 it is possible to spend the spring period in Greenland during the "International Semester", and in 2010 we are holding a "Summer University" in Greenland – an approx. three-week summer course.

The 'PhD of the year at DTU Byg' for 2009 is proudly awarded to Jens Henrik Nielsen for his thesis 'Tempered glass - bolted connections and related problems'. The assessment committee praised the high scientific quality of the work, combining novel experimental techniques with advanced numerical modelling.

The committee moreover applauded the research production resulting from Jens' thesis: Four papers were are submitted to international journals, three of which have already been published. Finally, Jens' thesis is well written, with figures and tables of high quality.

Tempered glass for structural use

The use of glass in modern facades ("Den Norske Opera & Ballett" located at the Oslo habour). Photo: Jens Henrik Nielsen

A numerical model for predicting the residual stress in tempered glass has been developed and validated in a PhD project at DTU Civil Engineering. The model can be used for optimizing the tempering process in order to improve the quality of the tempered glass

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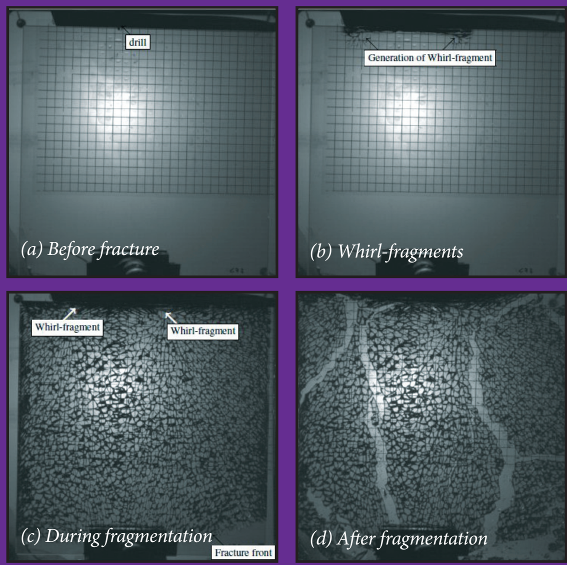

Fig. 2 Fragmentation of tempered glass. Fracture initiated by drilling

Archaeologists date man-made glass back to the old Mesopotamian period (about 5000 BC). Around 100 AD transparent pieces of glass were used for windows by the Romans. After that the process has been refined considerably to increase the transparency and properties of glass. Even though glass has been used for many years, it has not been used for structural load-carrying purposes until recently. Utilizing the strength of glass in load-carrying structural elements is attaining an increasing interest among e.g. architects, and glass is widely used in modern buildings, e.g. Den Norske Opera & Ballet.

Due to the high brittleness of glass, surface flaws govern its tensile strength, making it relatively low and unreliable. Furthermore, the tensile strength is also found to be dependent on the loading time.

In order to increase the tensile strength and minimize the time-dependency of the strength, glass can be tempered. Tempered glass is produced by rapid cooling from above the glass transition temperature (about 575°C). This process induces a self equilibrated residual stress state in the glass where the surface is in compression. Such a process might increase the apparent strength 4-5 times and practically eliminate the time dependency. However, the apparent strength is due to the residual stresses and these stresses will be spatially dependent, see fig. 1.

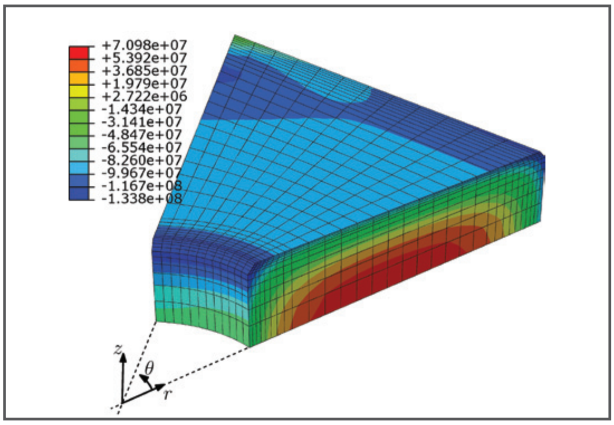

Fig. 1 Contour plot showing the tangential stresses in a square plate with a centrally located hole. Only 1/16 of the geometry is shown

Numerical model

During the work at DTU Civil Engineering, a numerical model capable of predicting the stress state in an arbitrary geometry of glass has been developed. Such a tool can be used for predicting the apparent strength of tempered glass at e.g holes, which is of great use when designing bolted joints in tempered glass. The model is capable of predicting the transient stresses at the tempering which can be used for optimizing the tempering process in order to improve the quality of the tempered glass.

A new hypothesis

The failure in tempered glass is very characteristic due to the sudden release of the residual stresses. This causes the tempered glass to fragmentize completely. Part of the PhD project has investigated this phenomenon by using high-speed cameras, and captured images to determine the velocity of the fragmentation and a never before reported phenomenon, namely the so-called whirl-fragments as shown in fig. 2. Images were also captured through the narrow side of the glass and revealed that the shape of the in-plane fragmentation front, which corrected a hypothesis from 1962 based on investigating the fragments from the failure, see fig. 3. These investigations were also used for setting up a hypothesis for the development of the fragmentation. Tempered glass is increasingly used for load-carrying purposes; however, such structures are most often over-dimensioned due to the uncertainties about the properties of tempered glass. The work at DTU Civil Engineering can be used by architects and engineers for gaining important knowledge of behaviour of tempered glass in order to design safe sustainable structures

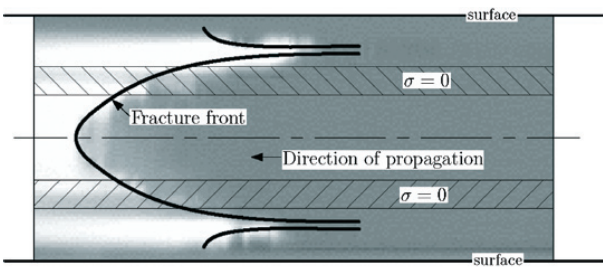

Fig. 3 Shape of the in-plane fragmentation front

Focus on engineering competences

A survey among newly graduated engineers from DTU and their employers indicates general satisfaction with the teaching and education at DTU Civil Engineering

Students at DTU Civil Engineering practice engineering during their studies and combine theory and practice in many ways. Photo: Mikkel Adsbøl

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Most young engineers graduated from DTU Civil Engineering and their employers are satisfied with the education and the engineering competences they bring with them into their first job as an engineer. That is the main result of a survey conducted in 2009.

In spring 2009, Learning Lab DTU carried out a survey for the department. Questionnaires were sent to all the engineers that received a degree in civil engineering from DTU Civil Engineering in 2004 or 2005, and to as many employers as possible. As a follow-up and in order to present the results, a seminar for employers was arranged in May 2009.

The main aim of the survey and the seminar was to obtain answers to the following questions:

- Do new engineers from DTU Civil Engineering have the required skills in order to perform their first job as an engineer?
- Which skills should they bring with them from the university and which skills are better developed within the scope of theirfirst job?

Room for improvement

The newly graduated engineers as well as the employers had a positive impression in general of the competences that civil engineers from DTU have brought into their first job. About three quarters of the engineers answering the questionnaire indicated that they were able to meet the requirements of their first job. However, all agreed that newly graduated engineers need to continuously improve their qualifications while working, and that being able to and interested in learning more are among the most important requirements. The department is interested in a dialogue with the stakeholders of the educations, and the continuously ongoing revision of our educations and the teaching methods should hopefully tie in with the interests of employers and society in general.

A total of 329 employers and 310 young engineers (161 BSc Engineering, and 149 MSc Civil Engineering) received a questionnaire. Approximately 15% responded to the questionnaire. This is a quite poor response rate, but since the results were in accordance with similar surveys conducted previously among other groups of engineers and employers, we believe that the results are valid nevertheless.

Important skills

The focus in the questionnaires was on which engineering competences are expected in addition to the strictly technical knowledge. In other words, the skills and attitudes that make the engineer able to work in cooperation with others, in a responsible manner, and under many different conditions. Examples of the most important skills indicated by the survey include:

- Engineering reasoning and problem-solving
- Personal skills (creativity, curiosity, flexibility, open-minded attitude etc.)
- Communication skills (teamwork, oral and written communication etc.)
- System-oriented analyses (over all solutions, perspective etc.)

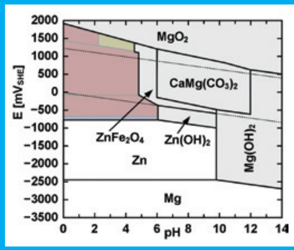
In 2008 a new teaching concept was implemented for students on the bachelor of engineering programmes at DTU. The concept is called CDIO (Conceive, Design, Implement, Operate). It is based on the principle that engineering is problem-solving, and basically consists of four phases represented by the letters CDIO. The most important point is that students should practise engineering during their studies, and thereby develop their skills within engineering. The purpose of the new study programme is to integrate all the competences mentioned in the survey in the curriculum for the new generation of engineers. The outcome of the survey and the seminar confirms that the new study programme seems to be heading in the right direction.

Tailoring the concrete-steel system for improved corrosion resistance

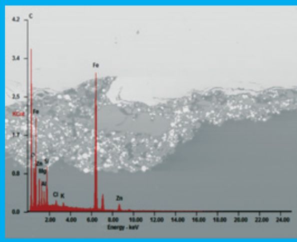
A thermodynamic basis for describing corrosion processes was established in a recent PhD project at DTU Civil Engineering. This provides a promising tool for the evaluation of available and the development of new corrosion countermeasures

Concrete structure face durability challenges in the harsh marine environment. Construction of Helgeland Bridge, Leirfjorden, Norway." Photo: COWI A/S

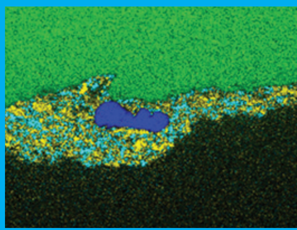
Investigations on a magnesium doped zinc silicate primer applied to the surface of carbon steel reinforcement.



Superimposed multi-element Pourbaix diagrams of Mg-Ca-C-H2O, Zn-Fe-Cl-H2O, and Fe-Cl-H2O systems.



EDS spectrum superimposed on corresponding BS image of Mg grain in Zn silicate primer on carbon steel surface.



EDS mapping of Mg grain in Zn silicate primer on carbon steel surface.

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Reinforced concrete is the most widely used construction material for bridges, tunnels and other civil structures. Large sums are used to ensure the durability of the concrete structures, especially to protect them against reinforcement corrosion.
Several strategies to counteract reinforcement corrosion have been proposed. However, only a few methods – such as using stainless steels and cathodic protection – are considered to be effective. And these cannot always be justified for economical or technical reasons. Thus, there is still a demand for effective and cost-efficient corrosion countermeasures.
The lack of performance of some countermeasures can be explained by conceptual weaknesses from a thermodynamic perspective, as the descriptions of both the corrosion mechanisms and the protection mechanisms are inconsistent or incomplete.

From thermodynamics to effective countermeasures

A consistent thermodynamic basis for describing the corrosion of steel in concrete was established to provide a tool for the evaluation of available and the development of new corrosion countermeasures. The work covered: a) the adaptation of thermodynamic principles to the area of reinforcement corrosion, b) a thermodynamically consistent description of the diverse corrosion states of steel in concrete, c) the assessment of available countermeasures, and d) the development of theoretical concepts for new, effective and cost-efficient countermeasures. In addition, two principles for implementing the developed concepts were proposed.
The two proposed principles are founded on the use of ordinary carbon steel reinforcement and can be applied to both new and existing structures. The first principle is based on a tailored surface modification of the steel reinforcement, whereas the second principle employs new concepts for sacrificial anodes.
Obtaining targeted low corrosion potential is the primary aim of both principles. The materials concept of the first principle also enables concrete-steel interface improvement by electrochemical densification during the setting of concrete as well as the formation of pore-blockers at later stages. These actions are immobilised in the materials concept for the second principle to provide a low resistance anode-concrete interface for a high current output.

New and inexpensive materials concepts

The materials concepts employ small portions of magnesium and zinc in combination with supplementary inexpensive compounds, which are both chemically and electrochemically active. The principle-specific features are achieved by tailored proportioning of the materials and customised production processes.
By means of these low-cost solutions, carbon steel reinforcement is kept at the targeted low corrosion potentials, while hydrogen evolution or any other undesired interference between the introduced materials concepts and the concrete-steel system are prevented. This way, the corrosion protection of reinforcement in carbonated or chloride-contaminated concrete can be improved in a cost-efficient manner.

Solar collectors being tested at the Department of Civil Engineering. Photo: Jianhua Fan

Development and lifetime of solar collectors

A cooperation between Arcon Solvarme A/S and DTU Civil Engineering has resulted in improved efficiency of solar collectors for solar heating plants and an estimated life span of the collectors of about 30 years

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One of the most attractive types of solar heating systems in Denmark is solar heating plants supplying a town or a part of a town with heat by means of district heating networks. In these systems a solar collector field produces heat in sunny periods. During the period 2002-2007, Arcon Solvarme A/S developed their so-called HT solar collector for solar heating plants in cooperation with the Department of Civil Engineering. Arcon Solvarme A/S has produced solar collectors for about half of all the solar heating plants worldwide.

The changes applied during the development were:
- Insulation material changed from Isover glass wool to Rockwool Industribatts 80
- Absorber emittance changed from 0.12 to 0.06
- Glass cover changed from AFG Solite to AFG Solatex
- Glass surfaces supplied with an antireflection treatment by Sunarc Technology A/S
- Improved installation of Teflon foil to increase durability and decrease thermal bridges
- Improved edge insulation

Improvements

The design changes mentioned above resulted in strongly improved collector efficiency. The annual thermal performance determined using weather data from the Danish Design Reference Year appear from table 1. From 2002 to 2007, the thermal performance of the solar collector increased by 39% for a mean solar collector fluid temperature of 60˚C. The main reasons for the strongly improved thermal performance are the antireflection treatment of the cover glass, the improved absorber and the improved installation of the Teflon foil. The thermal performance increases with increasing solar collector fluid temperature.

Lifetime of solar collector

During 2009, old versions of two HT collectors, one from the solar heating plant in Marstal and one from the solar heating plant in Ottrupgaard, have been investigated. The collectors have been in operation at high temperature levels for 13 and 15 years, respectively. The investigations showed that the efficiency of the collectors has fallen since they were installed. The reduction in annual thermal performance caused by 13-15 years of ageing are about 2% at a temperature level of 40°C, about 10% at a temperature level of 60°C and about 25% at a temperature level of 80°C.

It is estimated that the reduced thermal performance is only caused by the state and installation of the Teflon foil. Apart from the ageing problems with the Teflon foil, which most likely are solved during the above-mentioned development work, the condition of the collectors is remarkable good. The extent of corrosion in the absorber pipes is surprisingly small. Based on the investigations, the lifetime of the collectors is estimated to be about 30 years.

8000 m² solar collector field in Brædstrup. Photo: Jianhua Fan

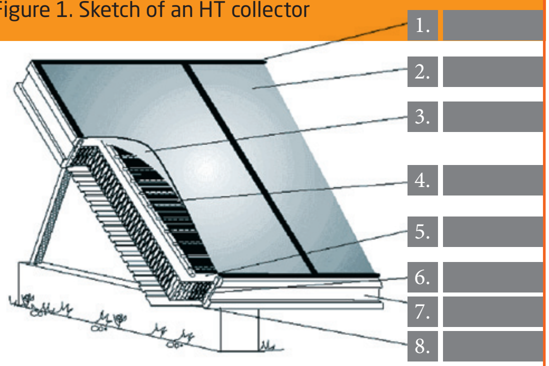
Reference

"Levetid for solfangere i solvarmecentraler". Ziqian Chen, Jianhua Fan, Bengt Perers and Simon Furbo. DTU Byg, report R-210, 2009.

Table 1. Thermal performance of HT collectors

Mean solar collector fluid temperature	*Annual thermal performance of HT collector before 2002*	*Annual thermal performance of 2007 HT collector*	*Improvement in thermal performance of solar collector from 2002 to 2007*
40° C	*485 kWh/m²*	*628 kWh/m²*	*29%*
60° C	*360 kWh/m²*	*501 kWh/m²*	*39%*
80° C	*256 kWh/m²*	*398 kWh/m²*	*55%*
100° C	*172 kWh/m²*	*311 kWh/m²*	*80%*

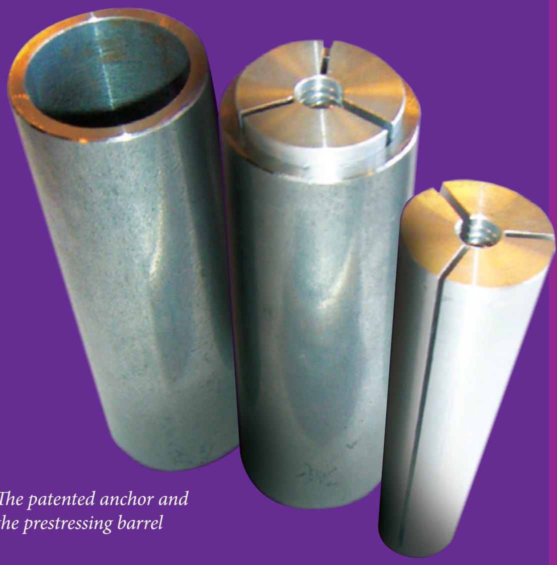
Figure 1. Sketch of an HT collector



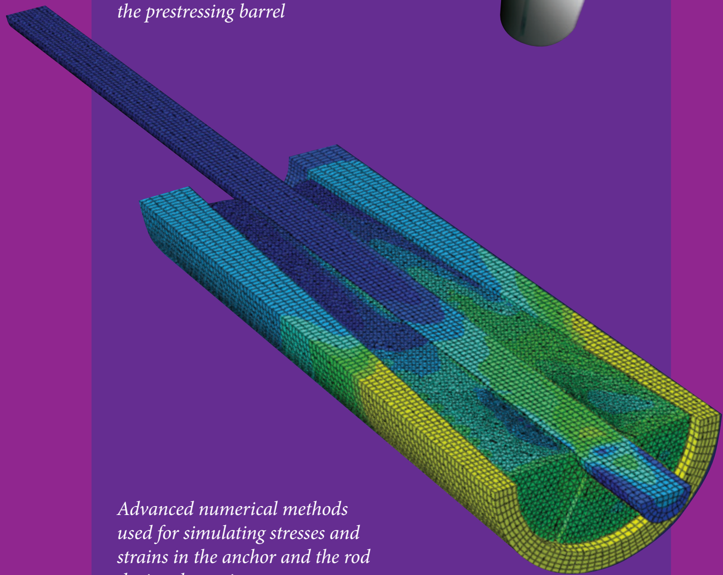
1. *Glass Frame: Top and bottom mouldings made of EPDM rubber*
2. *Glass: 4 mm, non-iron, and non-breakable glass with a fitted back*
3. *Convection Trap: Teflon insulation suspended between glass and absorber*
4. *Absorber: Copper tube/aluminium plate with selective surface*
5. *Vapour and Diffusion Trap: Aluminium foil*
6. *Insulation: 75 mm glass wool*
7. *Sill Profile: Extruding aluminium profiles*
8. *Back: 0.5 mm treaded aluminium sheet*

Patents and teaching **at DTU**

The Department of Civil Engineering has teaching and research in focus. A new patented technique is incorporated in the teaching just as a new patent has been developed during a current PhD programme



The patented anchor and the prestressing barrel



Advanced numerical methods used for simulating stresses and strains in the anchor and the rod during the testing

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The teaching and the research at DTU Civil Engineering focus on high quality, but also on combining theories and testing with a clear link to the performances in practice using actual cases and problems. This approach has in 2009 led to incorporation of a new patented technique in the teaching as well as the development of a new patent during a current PhD programme.

New patents used in teaching

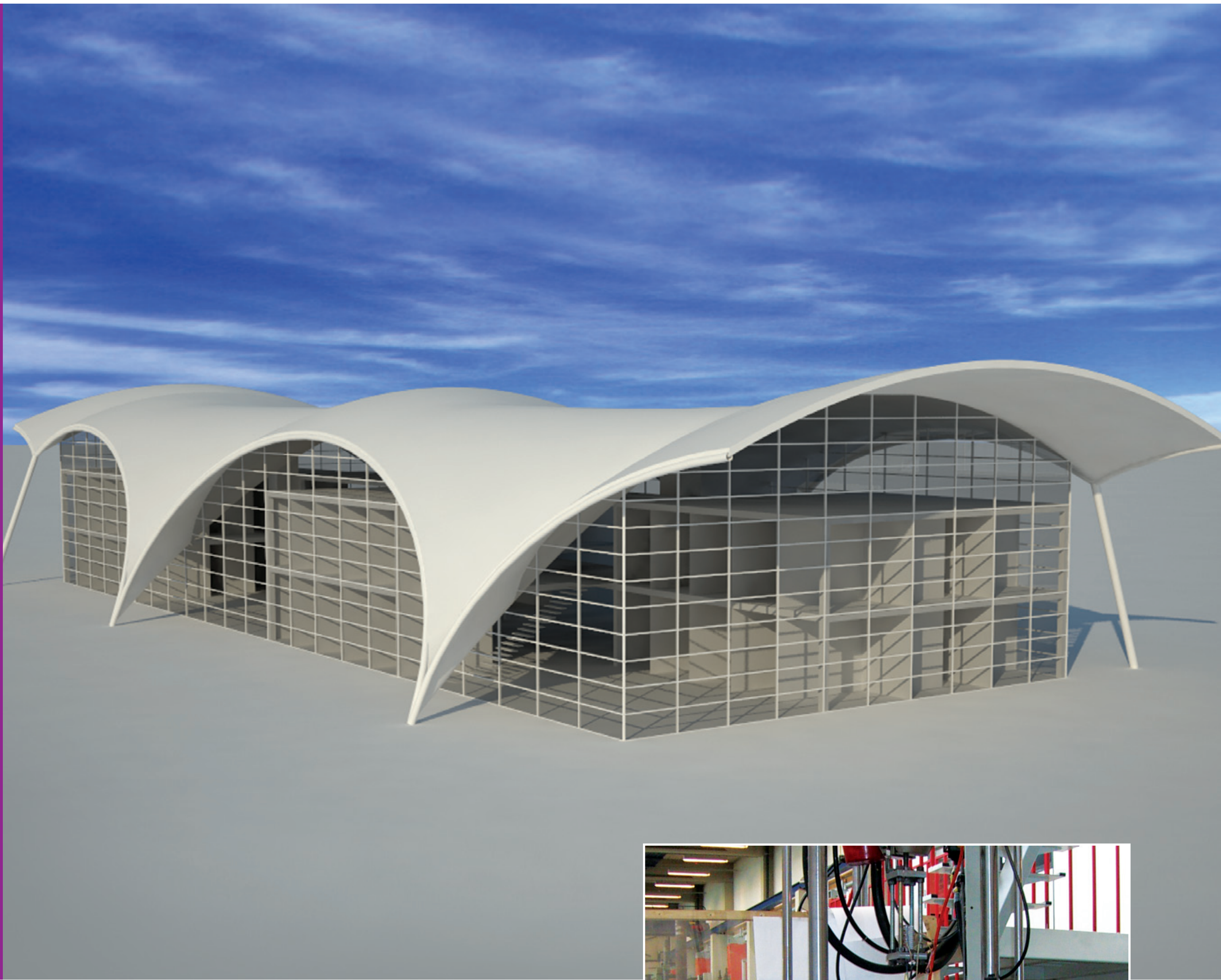
Teaching civil engineering students at the Technical University of Denmark, DTU, includes not only the classic engineering knowledge, but also a teaching of independence and understanding of structures and their design.

It was therefore tempting to use DTU's new patents on Super Light Structures invented by Professor Kristian Hertz, DTU Civil Engineering, in 2007 as a starting point in a problem-based project course 11050 "Super Light Structures", where the students should carry out an individual design of a structure or structural element using the new concept.

This approach provides the students with a good opportunity to develop their skills in project formulation, good engineering design and estimation and also lead to a number of new draft designs for Super Light Structures. Some of these may be implemented in practice as the students' work has been a good source of inspiration for the Centre for Super Light Structures, not only due to their technical qualities, but also through their visualisations of the designs. In ddition, the new technology serves as a subject for developing commercial models in the teaching on the International Business programme at Copenhagen Business School, CBS. A group of students from CBS has in cooperation with DTU won a prize at t he Venture Cup in Applied Technology with their project on Super Light Structures.

An industrial PhD programme

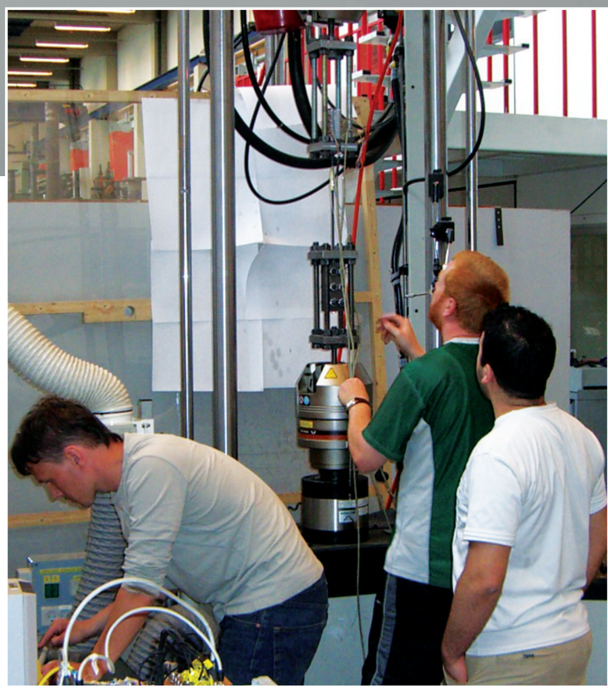
The quality and performance of the infrastructure are vital for the efficiency and competitiveness of society. It requires large investments in the infrastructure, both through new structures, but also by strengthening and upgrading existing structures.



The building is a design proposal based on super light structures for the new building 324 at DTU. The inner parts of the building are designed with the Pi-Omega system and the roof shell incorporates the pearl-chain system. From the Master's thesis: Designing with Super Light Structures, by Andreas Castberg

DTU and the world's leading bridge design company COWI decided therefore in 2007 to initiate an industrial PhD study by Jacob W. Schmidt on the topic of external strengthening of structures with prestressed CFRP (Carbon Fibre Reinforced Polyester) rods, mainly as a mean of strengthening bridges, but also focusing on solutions which could be used in other fields..

The most critical aspect of the external prestressing was quickly identified to be the performance of the anchorage and the study has so far focused on combining good craftsmanship, engineering intuition with clear experimental and theoretical documentation for the design of a new anchoring system. This approach into a new field has lead to over ten papers produced during the project, a number of which may increase during the students' stay at Hong Kong University. The anchoring system developed in the study has already been awarded a Swedish patent, just as an international patent application has been submitted. The patent owners are currently negotiating with producers and contractors for the industrial application of the anchor in practice. Jens Sandager, Head of the Bridge Operation and Maintenance



Testing the new anchor as part of a Master's project at DTU Civil Engineering. Photo: Jacob W. Schmidt

Department at COWI: The industrial PhD cooperation between DTU and COWI A/S provides an excellent basis for developing state-of-the-art technology in connection with strengthening existing concrete bridge structures.

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John Forbes Olesen, Peter Noe Poulsen

Puurand, Maire
Udstillingsbygning i glas
Leif Otto Nielsen, Peter Noe Poulsen

Ingdam, Nichlas
Indflydelse af blandemetode på homogeniteten af stålfibearmeret beton
Mette Rica Geiker, Anders Ole Stubbe Solgaard

Lund, Philip Giødesen
Hydropower Potentials in Southern Greenland
Morten Holtegaard Nielsen

Matthiesen, Bo
Grundvandsundersøgelser i Grønland
Morten Holtegaard Nielsen

Dahl, Rasmus Rokkjær
Grundvandsundersøgelser i Grønland
Morten Holtegaard Nielsen, Rasmus Jakobsen

Madsen, Lars Krogsgaard
Grundvandsundersøgelser i Grønland
Morten Holtegaard Nielsen, Rasmus Jakobsen

Woxholtt-Jensen, Magnus
Temperaturindflydelse på styrke- og deformationsegenskaber for Stevns kalk
Niels Nielsen Foged, Katrine Alling Andreassen

Kannov, Peter Hwan
Overdækning af banegrav ved Vesterport
Per Goltermann, Per Oluf H Kjærbye

Vistisen, Martin
Beregningsprogram for flydelinier i plader
Per Goltermann, Peter Noe Poulsen

Larsen, Alexander Brechling
Projektering af gangbro
Peter Noe Poulsen

Olesen, Lars
Analyse af komposit lavbro til Femern Bælt
Peter Noe Poulsen, Niels Jørgen Gimsing

Vest, Joakim
Analyse af komposit lavbro til Femern Bælt
Peter Noe Poulsen, Niels Jørgen Gimsing

Jensen, Morten Møller
Experimental Evaluations of Rotational Friction Dampers
Sigurdur Ormarsson

Boesen, Thomas
Implementeringsgraden af LEAN i den danske byggesektor
Søren Peter Bjarløv

Madsen, Anders
Implementeringsgraden af LEAN i den danske byggesektor
Søren Peter Bjarløv

Staff

As of December 31 2009		2009	2008	2007	2006	2005	2004
Scientific	Professor	9	7	7	7	9	11
	Associate Professor	42	40	40	46	38	44
	Assistant Professor	7	8	7	10	15	15
	Other VIP	7	9	9	9	6	4
	PhD Students	64	51	42	37	44	40
	Total	129	115	105	109	112	114
Technical and Administrative	Academic	9	9	9	11	11	10
	Clerical	10	11	13	13	12	12
	Technician	25	21	20	18	22	22
	Other	6	9	7	5	5	4
	Total	50	50	49	47	50	48
Total Department Staff		179	165	154	156	162	162

Education

STÅ[1]-total		496	494	514	483	508	519
Projects (students)	MSc	69	74	88	85	92	74
	BSc	20	34	51	31	36	56
	BEng	61	84	119	130	62	82
Admission (students)	BSc (Building Technology)	63	65	58	62	72	60
	BEng (Architectural Engineering)	46	45	47	50	52	42
	BEng (Civil Engineering-summer)	79	82	84	75	63	58
	BEng (Civil Engineering-winter)	31	39	29	38	30	32
	BEng (Arctic Technology)	17	19	18	8	9	8

Research

Refereed papers	Total	53	50	67	45	61	63
	Of these in ISI	46	47	48	30	43	37
PhD theses		8	3	13	5	8	10
Doctoral theses		0	0	0	0	1	0

Finances

Revenues	DTU-grant	70.340	66.718	59.827	56.656	53.184	52.523
	External revenue	44.188	46.489	30.326	31.033	30.862	28.563
	Total	114.528	113.207	90.153	87.689	84.046	81.094
Expenditures	Wages	77.830	68.846	66.782	63.021	62.725	62.917
	Other expenses	34.471	31.933	23.954	26.420	19.628	16.445
Total		112.301	100.779	90.736	89.441	82.353	79.362
Result		2.227	12.428	-583	-1.757	1.693	1.732
Available amount	January 1	9.054	7.839	6.200	7.957	6.264	4.532
Carried forward	December 31	11.281	9.054	5.617	6.200	7.957	6.264

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

Donations

Grundejernes Investeringsfond
Elektrokinetisk injection, 392.000 kr., Sektionen for Byggematerialer

Knud Højgaards Fond
RILEM Doctoral Course - Durability og concrete, 70.000 kr., Section for Construction Materials

Bergiafonden
Saltfjernelse fra gotlandske sandsten, 50.000 kr., Sektionen for Byggematerialer

Knud Højgaards Fond
RILEM Conference, 70.000 kr., Section for Construction Materials

Knud Højgaards Fond
PhD Symposium in Civil Engineering 20-23 June 2010, 286.313 kr., Section for Construction Materials

Otto Mønsteds Fond
Gæsteprofessor Hrnryk A. Sobczuk, 195.000 kr., Sektionen for Bygningsfysik og Installationer

Otto Mønsteds Fond
Gæsteprof Richard Horden, 195.000 kr., Center for Arktisk Teknologi

COWIfonden
Respons fra cyklisk tværbelastning af vindmølle monopælfundament i vandmættet sand, 60.000 kr., Sektionen for Geoteknik

Reinholdt W. Jorck og Hustrus Fond
Award for career achievement and research excellence, 150.000 kr., Christos Georgakis/Section for Structural Engineering

Martha & Paul Kerrn-Jespersens fond
Måling af mørtelfugers forskydningsstyrke, 50.000 kr., Sektionen for Byggematerialer

Hygro Wick-International, ApS.
Bidrag til festligholdelse af 50-året for oprettelsen af Laboratoriet for Varmeisolering, 10.000 kr., Sektionen for Bygningsfysik og Installationer

Varmeisoleringsforeningen
"Projekter eller aktiviteter, der medvirker til udvikling af den ikke-transparente del af klimaskærmen i relation til lavenergibyggeri", 50.000 kr., Sektionen for Bygningsfysik og Installationer

Bjarne Saxhof Fond
Afdelingen for Forskning og Innovation, 1.000.000 kr. ved Carsten Rode

Villum Kann Rasmussen Fonden
Gæsteprofessor Jan Hensen, 1.200.000 kr., Sektionen for Indeklima

Knud Højgaards Fond
Ph.d kursus: Flow of Fresh Cement Based Materials, 81.750 kr., Section for Construction Materials

Fonden Realdania
Research project on ceramic glaze-treated concrete, 940.000 kr., Section for Building Design

Direktør Ib Henriksens Fond
Støtte til køb af stensav til præcisionsskæring, 75.000 kr., Sektionen for Byggematerialer

COWIfoundation
Research on Clark Electroder, 66.000 kr., Section for Construction Materials

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