

Technical University of Denmark



BYG•DTU Annual Report 2005

Kristensen, Kasper Kjeldgaard; Borchersen, Egil; Møller, Jacob Steen; Ottosen, Lisbeth M.; Jensen, Karsten Ingerslev; Koch, Christian; Leth, Caspar Thrane; Poulsen, Peter Noe; Nielsen, Susanne Balslev; Rode, Carsten; Kristiansen, Kristian; Emmitt, Stephen

Publication date:
2006

Document Version
Publisher's PDF, also known as Version of record

[Link back to DTU Orbit](#)

Citation (APA):
Kristensen, K. K., Borchersen, E., Møller, J. S., Ottosen, L. M., Jensen, K. I., Koch, C., ... Emmitt, S. (2006). BYG•DTU Annual Report 2005. Kgs. Lyngby: DTU Byg, Danmarks Tekniske Universitet.

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BYG•DTU
Annual Report 2005

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Printed in Denmark by Gullanders
Bogtrykkeri A/S
ISSN: 1601-8605 (SR 06-05)

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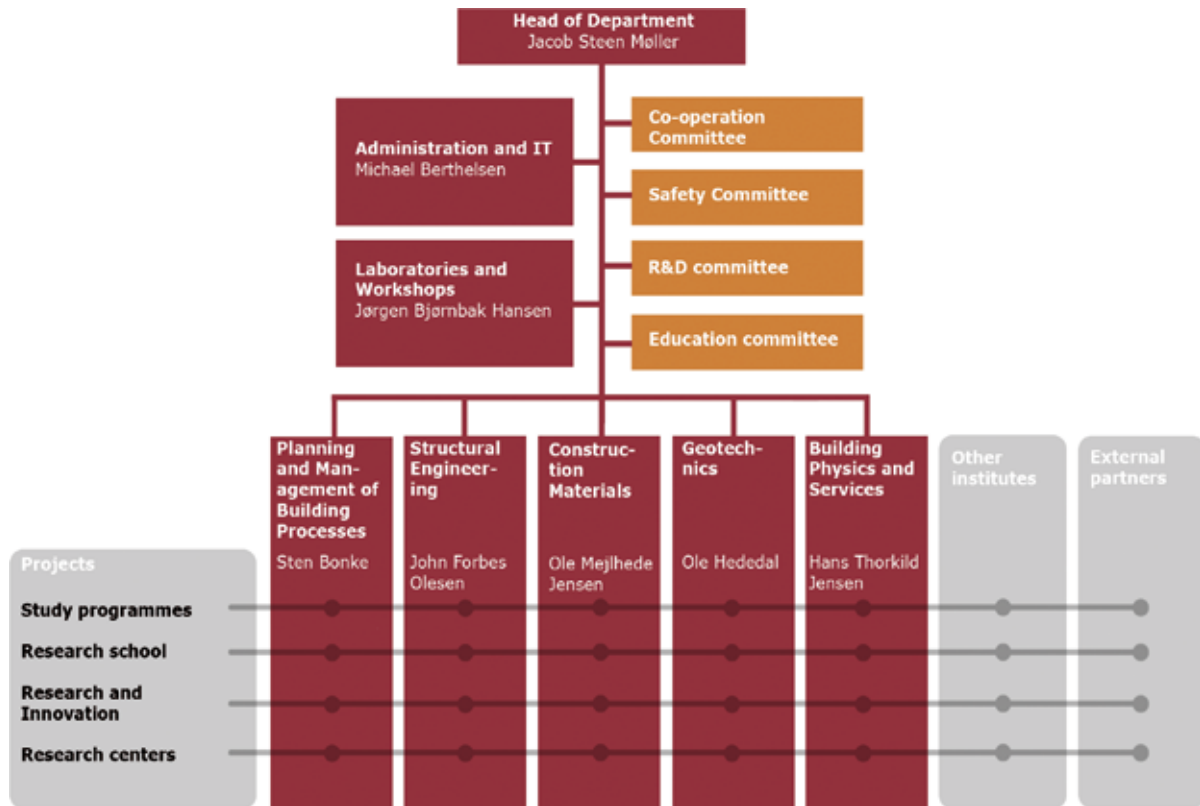
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Organisation



Study Programmes and Programme managers:

- Civil Engineer (B.Eng.). Associate professor Ole Mærsk-Møller.
- Architectural Engineering (B.Eng.). Associate professor Kirsten Christensen.
- Building Technology (B.Sc.). Professor Henrik Stang.
- Arctic Technology (B.Eng.). In Greenland, Associate professor Egil Borchersen. In Denmark, Associate professor Ole Mærsk-Møller.
- Civil Engineer (M.Sc.). Associate professor Kristian Hertz.

Department of Civil Engineering hosts the following centers:

- IRS@BYG, The International Research School for Civil Engineering. Professor Stephen Emmitt.
- ARTEK, Arctic Technology Centre. Professor Arne Villumsen.
- C•PROSAM, Centre for Protective Structures and Materials. M.Sc. Civil Engineer Benjamin Riisgaard.

The Advisory Board:

- Executive director Mette Lis Andersen, Københavns Kommunes Bygge- og Teknikforvaltning
- Development director Thomas Heldgaard, Rockwool A/S
- Executive director Peter Lundhus, Femern Bælt A/S - Sund og Bælt Partner A/S
- Executive director Klaus H. Ostenfeld, COWI A/S
- Senior advisor Jørgen Vorsholt, E. Pihl & Søn A.S

From the Head of Department

The Department of Civil Engineering, BYG•DTU, unites the technical disciplines, which are applied in the building design, construction and operation process.

The Department focuses on: Planning and Management of Building Processes, Structural Engineering, Construction Materials, Geotechnics, and Building Physics and Services. In 2005 a section was established for each focus area. The Department has further strengthened these areas through strategic recruitment, renewal of laboratories and further development of the research organization and yearly planning cycle.

As part of the fundamental reorganization and strategy renewal that took place in 2002-03 BYG•DTU was the first Department at DTU to establish an external Advisory Board. In 2005 DTU's new by-laws were approved, and now Advisory Boards are established at all DTU Departments. Research, Education and Innovation in Civil Engineering at a technical university thrives on close collaboration with industry. Thus the headline for BYG•DTU in 2005 has been a further development of the strong relations with industry partners.

Education

In 2004 DTU adopted the Bologna Declaration on the European Space for Higher Education, thus all the Department's Civil and Architectural Engineering education programs were revised during 2005 and now follow the Bachelor/Master structure. The revision is based on new competence descriptions, which were developed in dialogue with industry partners and employers.

A new Department Study Board (studienævn) was elected and Study Program Managers (ud-

dannelsesledere) were appointed. The Program Managers have a leading role in the ongoing development of the study programs.

Civil and Architectural Engineering are attractive fields for future students. In 2005 we experienced a general increase in admission to all our education programs (see key figures).

The Department employs a large number of external associate professors with their primary employment in industry, and we have reorganized the practical engineering training program (see feature article).

Research

There is a strong need for research based innovation in the building sector. BYG•DTU aims at supporting this via basic research and industry collaboration.

In spite of the large exchange in staff and very large teaching load BYG•DTU researchers published 61 peer reviewed scientific papers in 2005. This is a consolidation compared to 2004 and in accordance with the planned output.

BYG•DTU together with the Danish Building Research institute (SBI) and Technological Institute (TI) manages the Danish section of European Construction Technology Platform (ECTP). The ECTP-Denmark maintains a network of 30 companies and institutions. The network has interacted with the Danish Research Foundations and EU in discussions on future priority areas.

The International Research School for Civil Engineering, IRS@BYG, was successful in attracting funds from the Ministry of Research and a number of Ph.D. projects with industry started. In general, the recruitment of industry funded Ph.D.s has been satisfactory.



Head of Department
MSc (Civil Engineering) Jacob
Steen Møller

The Research School has established an agreement with RILEM (International Union of Laboratories and Experts in Construction Materials, Systems, and Structures) through which our PhD courses are advertised and endorsed. The international perspective will be further expanded via two new Marie Curie programs in cement based materials and solar heating.

Two conferences were conducted by the Department: The Knud Højgaard Conference on Advanced Cement-based Materials – Research and Teaching, and the CIBW096 (International Council for Building, Work Group 96) Conference on Architectural Management.

Innovation

Innovation at BYG•DTU comprises activities directed towards direct economic value generation together with external partners. This is done through patenting, collaborative research and networks, commercial testing and consultancy, and continued education programs.

In 2005 BYG•DTU researchers registered two proposals for patenting with DTU's patent office. A business plan is currently being developed for one patent; however, commercialization of ideas has been hampered due to lack

of funds for establishing proof of concept prototypes and tests.

Via ECTP-Denmark BYG•DTU initiated and is now leading a high tech network on integrated low energy solutions for the building sector supported by Danish national research grants (Højteknologisk Netværk for Integreerede Lavenergiløsninger på Bygningsområdet). The network includes nearly all major players in Denmark in the field of energy and buildings.

The continued education programs include the Master in Fire Safety and the Master in Management in Construction (see feature article). Both programs have run repeatedly and a stable future admission is forecasted.

Staff development

The generational change continued in 2005 and resulted in a significant strengthening of the scientific groups.

Three faculty professors were employed within structural engineering: Björn Täljsten (Structural Performance), Jeppe Jönsson (Design of Civil Engineering Structures), and Henrik Stang (Integrated Structural and Materials Modelling)

In addition, Facilities Management, Architectural Engineering, Building Services and Concrete Research were strengthened through strategic recruitment of new faculty.

Technical Resources

The Department has completed a full renewal of the laboratories for construction materials and a number of much needed investments in process ventilation and building adjustments for the structural and building services laboratory.

There exists a large need for investments in laboratory renewal and equipment. The basic DTU

grant cannot sustain the large stock of equipment needed to maintain the experimentally based research and education, thus the Department continuously is seeking external grants.

In 2005 BYG•DTU together with the Department of Mechanical Engineering was successful in attracting major grants for advanced photo-grammetry equipment for deformation monitoring.

Outlook

The steadily increasing internationalization of education and research is the most important challenge for BYG•DTU, thus the Department will give priority to international activities within Education, Research and Innovation.

In education a major challenge is to establish attractive international opportunities for student exchange. In research we must become further integrated in the international community through staff exchange, international research projects and PhD education. In innovation our activities should be expanded with international partners.

A recent report on globalization from the Danish Government states that major increases in public research funding will be established over the coming few years. It remains to be seen to what degree these funds will be available for civil engineering research, and if the building industry is willing to establish matching funding.

In any case BYG•DTU is well prepared. Civil Engineering is about creating.

First Candidate in Arctic Technology

The first Bachelor of Engineering in Arctic Technology graduated in June 2005

Now four years after start in Sisimiut, Greenland of the B.Eng. Education in Arctic Technology, the primary objective, graduation of bachelors from Greenland, was achieved. Each year 7-8 students from Greenland and 2-4 students from Denmark start in Sisimiut. Until now 52 students have been enrolled, and 35 are still active.

Greenland/Denmark

The education is unusual compared to other B.Eng. educations at DTU. The first 3 terms take place in Greenland, at the Building and Construction School in Sisimiut. Teachers from DTU are travelling to Sisimiut and are lecturing 2-week courses. The fourth and fifth terms are at DTU in Lyngby, and after that parts may take place somewhere in Arctic or at DTU. The prescribed period of study is 4 years, six months more than the ordinary B.Eng. studies at DTU. The extra time is used for specialization on different arctic subjects.

The education is a combination of the regular civil engineering courses with a dedicated arctic approach. The Arctic is unusual in a lot of ways. One is the ground. Foundations or roadbeds in areas with permafrost may be destroyed due to thawing and freezing parts of the soil. This is just one of the many challenges the new Arctic engineers will be equipped to handle.

The very first Arctic candidate

Ujarak Rosing Petersen became the first candidate in Arctic Technology graduated as B.Eng. The examination took place 24th of June in the Arctic Technology Centre in Lyngby. Ujarak defined the style for the new education with the grade 10 for his final thesis "Waterpower in Tasersuaq". He started at his new job in Inuplan, a leading consulting engineering firm in Greenland, just weeks after he received his diploma.



Dean of Studies Gunnar Mohr congratulates Ujarak with his new degree



Arctic Technology students in front of the place of their studies in Greenland, the The Building & Construction School in Sisimiut

First Graduates from the Master Programme in Construction Management

To become a master

The Master Programme in Construction Management is a postgraduate programme. It started in January 2003 with 15 participants coming from all sides of the construction industry: contractors, architectural firms, client organisations, local municipalities, technical schools and consulting engineers with equally varied educational backgrounds: engineers, architects, constructing architects and social sciences.

To qualify, at least 2 years of working experience is needed. The programme is half time or less. The participants continue working full time in their normal jobs.

Total study time is 60 ects points. The final dissertation is 15 points, and 45 points are covered by nine courses in:

- Trends in Construction Industry
- Innovation in Construction

- User orientation in Construction
- Change management
- Project management
- Project economy
- Facilities Management
- Partnering
- Lean Construction

Throughout the four semesters a wide range of international lecturers and prominent individuals from the Danish building industry have been giving guest lectures. The first graduates have among others experienced: professor Graham Winch, Manchester University, director John Olie, Joint Origin, Holland, professor Tore Haugen, Norway, professor Carl Haas, University of Texas, professor Stuart Green, Reading University and professor Lauri Koskela, Reading University.

The final dissertations from the first group of graduates covered a wide range of subjects such as: Lean Construction, Innovation

and Learning in Construction Industry, Risk management in Contracting, Value in Construction and Management of Complex, Technologically Advanced Projects in Construction.

More than satisfied

The programme has been evaluated, and the participants express more than plain satisfaction. The integration of their practical insights acquired through many years of working experience with the more theoretical knowledge of their teachers has challenged them personally and professionally. A year after graduation the former participants say that they feel they have learned a lot and that the programme was a great experience. Some of the graduates have moved on to better jobs others feel that their jobs have been enriched.

The Master programme in Construction Management wishes to play its part in pushing the Danish construction industry towards excellence. With the first graduates of 2005 a first step has been taken.



Teachers and students from the graduation party for the new Masters in Construction Management

Engineering Training in the B.Eng. Programme

Focus on interplay with companies to ensure the best engineering training

To develop professional skills in the field of practical civil engineering the studies "diplom B" and "diplom" Architectural Engineering includes a semester of engineering training. This is a very exciting period for the students and has always been appreciated by the students and also by the companies. The course "Engineering Training" has been a part of the 3½ year of curriculum for B.Eng. in Civil Engineering in 40 years and this experience has been very useful in the development of our students. However BYG•DTU wants to play a more active role in creating a dialogue with the companies that employ a trainee. Furthermore BYG•DTU wants to keep a stable and growing network of companies that are keen to employ our students in their practice period.

Elements of training

The core elements of a training period are as follow. It is the students who must find their own employment; however BYG•DTU

will announce all expressions of interests from contractors, consulting engineers, and architect firms or other companies and institutions working within the building sector. In the beginning of the trainee period, BYG•DTU organizes a half day meeting where the students present to each other their company and what they do. This is a very constructive day and the students inspire and support each other to be more responsible for their outcome of the trainee period. Later in the training period a teacher from BYG•DTU will visit the student and the company to discuss the status of the training period, the experiences so far, eventual problems, expectations and plans for the remaining period. These visits will have high priority in the future, because the face to face meeting is important to create a common understanding of how to make the best out of this training period for this student in this company. At these meetings the BYG-teacher will also gain knowledge about the company and their interest in trainee employment. This

can help us improve our way of organizing engineer training and build long term relations with the company. Possible side effects are the personal connections which can lead to other collaborations within teaching, research and innovation.

The future

So far our experience is that some companies would also like to share experiences with others in the same situation on how to create a good practice period. This is why we plan to expand our trainee activities with meetings for the company contact persons and the teachers from BYG•DTU to exchange experiences, view-points and possible actions in order to ensure the best practice periods.



Assistant Professor Susanne Balslev Nielsen from the section for Planning and Management of Building Processes is the new coordinator for BYG•DTU's trainee service.

In 2005 116 students took part in the programme. The largest group of students were taken by building contractor, consulting engineering companies and architectural companies.

A trainee session last 20 weeks and starts either at the 1st of February or the 1st of August.



One of this years students in Engineering Training

International Research School for Civil Engineering at BYG•DTU

A Home for the PhD students to grow and achieve

The proposal to establish a PhD School was submitted and approved by DTU in the autumn of 2004. The International Research School for Civil Engineering at BYG•DTU (IRS@BYG) was then formed on the 1st January 2005 to provide a home for the Department's PhD students.

We created this PhD School to help facilitate knowledge transfer and share best practice within a dynamic, friendly and student centred environment.

IRS@BYG is here to offer and arrange a variety of activities to help, assist and enhance the research experience of the PhD students. These activities range from, for example, presentations to industry and research communities through to periods of study as visiting researchers in other countries. Activities are supported by modern facilities, including state of the art laboratories and well equipped offices.

The primary aim is to provide a stimulating PhD environment that helps you to achieve world class

scientific research and disseminate your findings effectively.

The school has an international approach to teaching and research and welcome students of all nationalities to experience the high quality research environment.

What we do

PhD projects are centred on (but not exclusive to) a number of focus research areas. These are:

- Building physics and services
- Construction Materials
- Geotechnics
- Planning and management of building processes
- Structural engineering

The working language for the management of the International Research School for Civil Engineering at BYG•DTU is English. Students may choose to write their doctoral thesis in Danish or in English.

Individual activities (such as PhD courses, research projects etc.) are organised and managed by academics within the Department. These individual activities are

co-ordinated by the International Research School for Civil Engineering at BYG•DTU.

The PhD Day

Part of the stimulating environment is gained by having established a tradition - the PhD Day where students presents their work to their peers and industry/academic partners. The PhD day is organised by our doctoral students and has proved to be a popular and rewarding event, both for the students presenting their work and for those who come to listen and participate in the debate.

The PhD day is held twice a year, thus all PhD students will have the opportunity to present their work at least once during their studies. Visiting PhD students are also invited to talk about their work during their stay in the Department.



A group of PhD students in one of the open offices



Professor Stephen Emmitt from the section for Planning and Management of Building Processes is the coordinator at The International Research School for Civil Engineering at BYG•DTU.

At the end of 2005 40 PhD students were registered under the IRS@BYG. Two PhD days were held and 10 students successful completed their PhD.

Removal of Salt and Water from Masonry

Rising dampness in brick masonry is a large problem in Denmark due to increasing moisture and salt concentrations in the walls.

According to "The Building Damage Fund" rising dampness is among the 10 most frequent damages in connection to building repair.

At present, two groups of methods are used to preventing rising dampness: mechanical methods and injection. The principle of both is to prevent rising dampness with a horizontal damp-proof layer. In the mechanical methods a layer of typically steel is placed in joints and in the injection methods the damp-proof layer is obtained chemically by filling water-proof material in holes and this material must distribute from the holes to the area between them by capillary transport to obtain the damp-proof layer.

A new electrochemical method developed

In this method an electric DC field is applied to the masonry wall, and in the electric field it is possible to control both water and ion movement within the masonry. Thus both water and salt removal can be obtained. The method has several advantages; primarily no holes are made in the masonry since the electrodes are placed on the surface and further the removal of salts decreases the hygroscopic moisture content, and the risk for salt-induced decay is eliminated.

In laboratory



The electrodes in the pilot-plants have been constructed as cheap and simple as

scale very promising results have been obtained with the electrochemical method. Water has been removed from water saturated bricks to a water content of about 1%. Salts such as NaCl and Ca(NO₃)₂ have been removed from concentrations that according to the Austrian ÖNORM B3355-1 (there is no Danish norm) were so high that active salt removal is advised, to concentrations where there is no risk from the salts.

Pilot scale experiments have been initiated at two places in older buildings. One pilot scale experiment is placed outdoors at Kavalergården, Bernstorff Castle and the other is placed indoor in a private basement. In the basement the primary goal is drying of the masonry whereas both water and salt removal is in focus at Kavalergården. The concentration of salts is very high in the latter and the masonry appears wet due to the high hygroscopic moisture content. In this case the problem could not be solved with a horizontal damp-proof layer, which would not remove the salts.

In both of the pilot plants, the electrodes are placed on the same side of the masonry. This is an advantage in e.g. situations with cavity wall or in situations with salt induced decay. Another possibility could be to place the positive electrodes indoor and the negative electrodes outdoor (the water moves from the positive electrode towards the negative). However, such an electrode arrangement has not been tested yet.

possible. They consist of a bar of reinforcement steel placed in a layer of carbonate rich clay. When the electric field is applied to the steel it is important that the products from the processes occurring at the surface of the electrodes cannot enter the masonry, and this is prohibited by the clay.

Both pilot-plants are running at present, and the preliminary results have been very promising. In the basement water has been collected underneath the negative electrode, and at Kavalergården very high salt concentrations have been found in the clay around the electrodes showing efficient salt removal. Further the outdoor pilot plant has been running during January and February at temperatures below 0°C without any problems.



Associate professor Lisbeth M. Ottosen is conducting her research in the section for Construction Materials.

This section is the base for BYG-DTU's activities in the fields of construction materials, with vital importance to the function and performance of structures. The area has its strong professional tradition and identity and it is through the interaction with the other professional areas in BYG-DTU the importance of construction materials becomes clear.

Smart Windows

Smart windows, second generation liquid crystal glazings – where nanotechnology meets fenestration

Push a button and your glazing switches from transparent to reflective or translucent. So thanks to applied nanotechnology in glazings, you can dumb your curtains and Venetian blinds.

Ordinary windows and glazings have constant optical proper-



ties, whereas so-called smart or dynamic windows can switch between three optical modes:

- 1) a reflective mode limiting the overheating
- 2) a transparent mode with an excellent transparency
- 3) a scattering mode with translucency.

Smart windows can be widely applied within the building field and e.g. the automotive one. These new glazing components are very interesting due to the fact that they soon can be manufactured with controllable daylight and solar energy transmittances. Hereby, the quality of life can be improved as well as the energy consumption for lighting, heating and cooling can be reduced even further.

Liquid crystal (LC) glazings are available on the market today, e.g. Priva-Lite from Saint Gobain. These glazings can switch from translucent to transparent when a small electric current is applied. When the current is cut off, the glazing switches back to translucent. However, these glazings are the first generation LC glazings, and the solar and daylight modulations are negligible. The second generation LC glazings

Top) A SmartWin II prototype without voltage, i.e. in reflective mode.

Middle) The active area is divided into five sections, which can be controlled individually. Only the stripe in the middle has an applied voltage and hence it is transparent.

Bottom) The opposite situation of the previous image; only the stripe in the middle is without voltage.

can switch fast between three different modes and with high modulations regarding daylight and solar energy, and thus solar shading with no mechanically moving parts are obtained.

BYG.DTU was manager of an EU FP5, EESD project: New Liquid Crystal SmartWindow and Its Production Process – SmartWin II – contract ENK6-CT-2001-00549, which was finished in 2005. Within this project, second generation LC glazings, which only require a voltage or a voltage pulse for switching between the three modes, were developed. Furthermore, pre-industrial manufacturing methods and equipment were developed for technical glazing prototypes up to a size of 1 m².



Associate professor Karsten Ingerslev Jensen is conducting his research in the section for Building Physics and Services.

This section takes a holistic approach to the building envelope and installations as the basis for creating buildings with a good indoor climate and low energy consumption. It deals with the technical, social and environmental problems that require a development towards sustainable building design based on energy conservation and sustainable energy systems.

Learning from Failures in Construction Operations

Better coordination between the parties in construction can save billions

Poor quality has been a long-term feature and debate in Danish construction. Especially the final quality vis-à-vis the client has been in focus. The last wave of reforms from the state as a response to this commenced in 2000, but still in 2006 failures cost the industry and its clients paramount sums.

An empirical study of failures and their causes has been carried out by researchers at the Section for Planning and Management of Building Processes. The observation period was three month covering the assembly phase.

Failures broken down in percent

In each case the analyses showed a mixture of causes, and it was not possible to assign single causes to the single cases. More specifically, 14 % of the failures had exclusively distal causes, and 19 % exclusively proximal causes, whereas 67% had mixtures of those. In the vast majority of our cases a series of "subsequent" actors as well as one originator were involved in the generation of the failure on the site. It was found that 56% of the failures were predictable on the basis of existing knowledge on the site.



A coordination failure between the HWS team and the architect led to the installation of radiators not fitting the previous made holes. This resulted in a lot of rework.

There is thus a large room for improvement.

Of the total failures the organisational causes were the most prevalent. Of the organisational the following causes scored the highest: Problems with communication and cooperation 61%, design activities 45%, production planning and control 42%, project review meetings 36%, production work 34%, process and product control 29%, weather and theft 20%, and access to skilled workforce 15%. Although organisational factors played the most important role, we found failures related to all kinds of interaction between the actors in the project. It involves formal organisational elements such as meetings as well as informal interaction. Communication and cooperation are central activities in a multi-actor project, and speculatively it could be added, that the found level of problems is less alarming since it should be compared to the amount of communication and cooperation carried out in the project.

Apart from the organisational factors, the analysis covered technological and individual factors as well. The technological failures relate to 37% of the observed failures. They relate to issues like purchasing of material, equipment, which had not been properly cleaned, and features of the product like a too broad plinth. The individual factors were found at 40% of the failures. They relate to competence (24%), erroneous acts (18%), avoided acts (11%), and hindrance due to limited resources (53%). Indirectly, it follows from these figures

that focusing on the individual would have less impact in terms of improvement.

After the failures occurred the actors put various measures in place to repair the damage, and the analysis shows that only 7-8% of the failures affected the final quality. The consequences and costs involved thus relate to man-hours and materials used to obtain an acceptable final result. The losers in this game are the participating companies who obtain less surplus.

Cost equal 8%

The total amount of observed failures in the study was 160. This equals to a calculated cost of 80.800 euro and 8% of the production costs. The study has shown that the main focus on improvements can be on operational quality, developing procedures that prevent reworking and thus bring down this amount.



Associate professor Christian Koch is conducting his research in the Section for Planning and Management of Building Processes.

This section has as its prime goal through research and education to contribute to the transition of the building industry from a reactive, problem-strained state towards an innovative and customer oriented production field.

Modelling of Reinforced Concrete applying Fracture Mechanics – XFEM

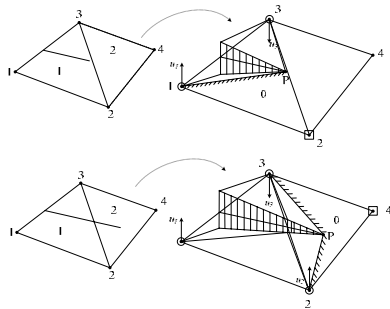
Throughout the last century intense research has been carried out regarding methods to determine the ultimate strength of reinforced concrete structures. We are now moving further and deeper.

Today, methods for estimating the ultimate strength of most reinforced concrete structures are well documented. Most of these methods, however, require the use of empirical factors and do not consider phenomena such as size effects and reinforcement arrangement in a fully consistent way.

The predictive capability of the existing methods of analysis is limited for reinforced concrete structures in the serviceability limit state. Complete models for this state require prediction of the complex cracking, which takes place in the concrete during loading.

Understanding cracks

Modelling of cracks in concrete has been a focus area in the research community since the mid seventies. Detailed information about cracking and crack propagation is particularly important



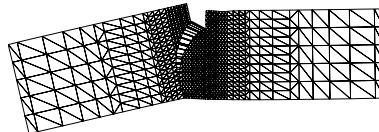
Propagation of a crack across an element boundary. Upper figures illustrate situations just before the crack reaches the element boundary, while the lower figures illustrate the case where a crack continues into a new element.

with respect to durability and service life prediction.

An optimal designed reinforced concrete structure relies heavily on extended knowledge of the complex mechanical interaction between concrete and reinforcement and on methods for modelling reinforced concrete structures in serviceability state.

Today, several commercial Finite Element Method (FEM) codes have interface elements suitable for concrete cracking and discrete elements for smeared cracking based on the concept of a crack band. The use of interface elements for crack modelling, however, requires the crack path to be known beforehand, while crack modelling applying the smeared approach is not well suited for modelling of localized crack growth.

One of the promising new approaches for modelling of localized crack growth within the framework of finite elements is the eXtended Finite Element Method also now as XFEM. In XFEM the traditional continuous displacement field of an element is enriched with a discontinuous displacement field allowing a crack to develop within the interior of the element.

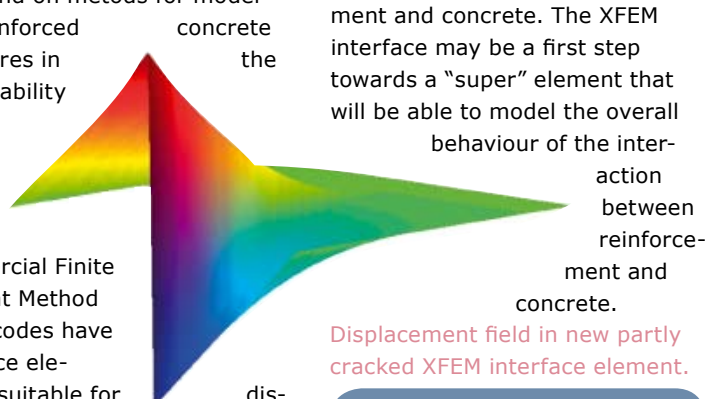


Crack propagation in four point shear beam modelled applying XFEM.

XFEM at BYG•DTU

So far at BYG•DTU new XFEM elements have been developed for modelling of crack propagation in the bulk concrete, and good results have been obtained applying those elements. More lately, work has been carried out in the development of a new interface element suitable for modelling of the bond zone between reinforcement and concrete. The XFEM interface may be a first step towards a “super” element that will be able to model the overall behaviour of the interaction between reinforcement and concrete.

Displacement field in new partly cracked XFEM interface element.



PhD student Jesper L. Asferg is conducting his research in the section for Structural Engineering.

The field covers the overall design of the structure and particular design aspects including the demonstration of strength, durability, etc. with regard to the loads and effects on the structure from, e.g. climate, wear and breakdown processes. It is central to the technical sciences of civil engineering in general, and they are primarily based on the fundamental sciences of mechanics and physics.

Research Geotechnics

A proper foundation for a large farm of offshore wind turbines

BYG•DTU has recently started a PhD project sponsored by the Danish Research Council on "Modelling of laterally loaded pile in sand subject to cyclic loading", where models of piles will be tested in the geotechnical centrifuge at BYG•DTU – the only facility of its kind in Scandinavia.

Centrifuge testing is a physical modelling technique that is well-suited for doing scale models of geotechnical structures. The properties of soil are in general dependent on the actual stress level. Therefore, if it is necessary to perform realistic tests on a geotechnical structure, there will often only be two options: Full scale testing or scale testing in a centrifuge. Since geotechnical structures are often very large, full scale testing is complex, tedious and - most importantly - very costly.

In the geotechnical centrifuge we are able to scale the model. The correct stress level is obtained by increasing the gravity, meaning that length is equally scaled. Hereby a 30 m long pile may be reduced to 30 cm in case the centrifuge can generate a gravitational acceleration of 100g. Such models are evidently much

easier to handle and less complex, hence also less costly.

Centrifuge modelling is a means to gain insight into the soil-structure interaction of geotechnical structures under well-controlled conditions. The method thereby provides a valuable input to the development of other types of models – theoretical or numerical - since it may reveal important mechanisms that need to be incorporated in the theoretical or numerical model.

From small to large scale

The current PhD study on laterally loaded piles is motivated by the need for establishment of large offshore wind farms with wind turbines founded on single large diameter piles – monopiles. The industry has recognized the importance of understanding the long term effect of cyclic loading on such foundations. The aim of the project is therefore to provide better understanding of the performance of piles subjected to cyclic loading. The PhD project involves aspects on sample preparation, verification of specimen properties, analysis of pile loaded in one and two horizontal directions with cyclic loads.

At present, we are redesigning existing equipment and controls for the sample preparation and two-directional loading of the pile.

Initial tests showing very promising results have been made with respect to standardisation of preparation method for sand specimen and verification by use of a small scale cone penetrometer.



Pictures from test in centrifuge with small scale Cone Penetrometer.



PhD student Caspar Thrane Leth is conducting his research in the section for Geotechnics.

This section deals with the foundation of structures. The foundation of a structure is determining for its load bearing capacity and hereby a central element in the load-bearing construction. Furthermore, the deformation of the foundation is a key element in the total performance of the structure. The area covers rock and soil properties as well as the shape and size of the foundation, its load-bearing capacity and deformation during daily use.



Beam centrifuge at BYG•DTU

Low Energy House in Sisimiut, Greenland

In April 2005 BYG•DTU and Centre for Arctic Technology inaugurated a new low-energy house in Sisimiut, Greenland.

The low-energy house in Sisimiut is designed to test and demonstrated state of the art low-energy technology in an arctic climate with the purpose of inspiring a general development of sustainable buildings in Greenland.



Floor plan of the low-energy house

Building the house became a reality with a generous donation from the Villum Kann Rasmussen Foundation of 5 million DKK. The Municipality of Sisimiut provided the serviced building plot.

In connection with this donation it was an objective, that the project should involve as much Greenlandic labour as possible. Therefore Rambøll Greenland was selected as principal consultant and has had the job of tendering among local contractors to carry out the turnkey contract. A local contractor, Arctic Sanasut ApS, was chosen, and they have built the house to great satisfaction.

Sisimiut is located just north of the Polar Circle and has mean average temperatures of around 5 to 6° C in the summer and -10 to -15° C in the winter months.

Low energy?

The definition of a low-energy house is that the house consumes only half the energy permitted in the building code, which for this project has been understood as the requirements of the coming building code of Greenland. Thus, the objective was to build a house with an annual energy consumption for heating of not more than

80 kWh/m².

The house is approximately 200 m² and is built as a double house with common boiler room and entrance hall.

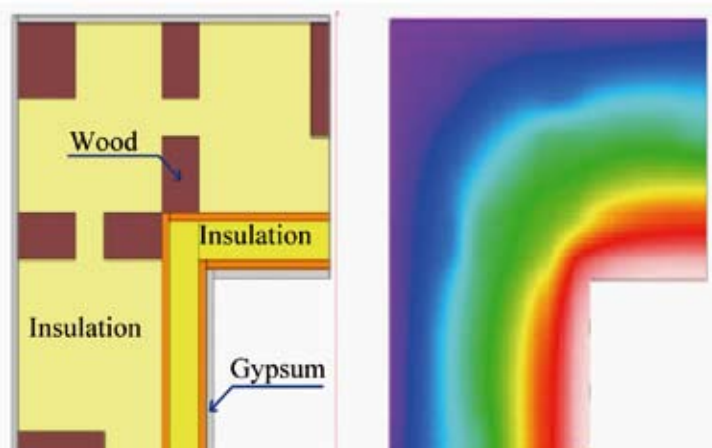
The means to reduce the energy consumption in

comparison with common Greenlandic houses has been to use extra insulation in exterior walls (300 mm) and in the floor and roof (350 mm). The house has a ventilation system with a heat

exchanger with an efficiency of 90% that uses the warm exhaust air to heat up the cold inlet air. Furthermore, improved windows are installed with low energy glazing using 3 layers of glass. A solar collector is installed on the roof to heat water for domestic use. In addition, the house is orientated to exploit the light, and it has a geometry which optimizes the daylight.

Many of the chosen solutions have required new developments or use of technologies not applied to date in Greenland. For instance the heat recovery system had to be constructed with intermittent changing of the pathways for the air flows so that blockage of the ducts by freezing of the humid exhaust air could be prevented. This solution was developed and tested first in the laboratories of BYG•DTU. Another solution, which until now has not been used in Greenland, is the heating of the house by a floor heating system.

The heat loss due to thermal transmittance through the building envelope constructions is reduced by use of increased insulation thickness and wood profiles with minimum thermal bridge effect.



Heat loss: Simulation model of the outer wall corner. To the right a temperature plot

Solar collectors

The solar panels installed on the low-energy house are flat plate collectors which are oriented south-east and tilted 70° from horizontal to have the optimal



The solar collectors on the low-energy house

position in relation to the sun. The solar collectors have a total surface area of 8 m² and the system is able to produce around 1,600 kWh/year. This covers more than 60 % of the hot water consumption of the house.

The windows

Three types of glazing units are tested in the low-energy house. Sealed units comprise two or three layers of glass with either vacuum in between or with a gas-filling of argon or krypton. In the case of double-layered sealed units, a third layer of glass with low emission coating completes the window.

Moisture conditions

The outdoor air in Greenland is generally very dry because it is so cold that the air is unable to hold much moisture. However, because of high indoor humidity production and minimal ventilation (to avoid draft), it is not unlikely to see moisture problems in Greenlandic homes. It has been important to demonstrate that it was possible to construct a low-energy house without moisture problems in the indoor air or in the constructions. Therefore, the house has been instrumented with a number of humidity sen-

sors positioned in potential critical places. The sensors have not shown any gravely high moisture levels, and the building has continually dried out even more since it was created.

Measurements of energy performance

The house is equipped with energy-meters, which are available for on-line viewing on the Internet. The data can be found on the address: <http://www.energyguard.dk/> (Brugernavn = DTU & Password = sisimiut).

The energy consumption for space heating during the first year of operation of the house has been around 28,000 kWh. This is not quite as low as anticipated but still less than the permitted consumption according to the coming Greenlandic building code. The extra energy consumption can partly be explained by necessary tuning of the advanced systems during the first year, and by the fact that the indoor temperature has been slightly warmer than assumed.

Closure and follow-up

In connection with the inauguration ceremony in April 2005 an international symposium was held in Sisimiut about low-energy buildings in arctic climates. Proceedings from this symposium can be found on the homepage for the low-energy house: <http://www.arktiskcenter.gl/Artek-Lowenergy/>. It is anticipated that the symposium along with the house itself will serve as good inspiration for future developments of sustainable buildings in arctic climates, and in Greenland in particular. The achievements of the house will help Greenlandic legislators, local builders and the Building and Construction School of Sisimiut to set new standards for achievable low-energy solutions in buildings in cold climates.

The low-energy house is now inhabited by a Greenlandic family. The performance of the house will be followed and reported by researchers and students from BYG•DTU and Centre for Arctic Technology for a five year period.



The inauguration of the Low Energy House in Sisimiut in April 2005

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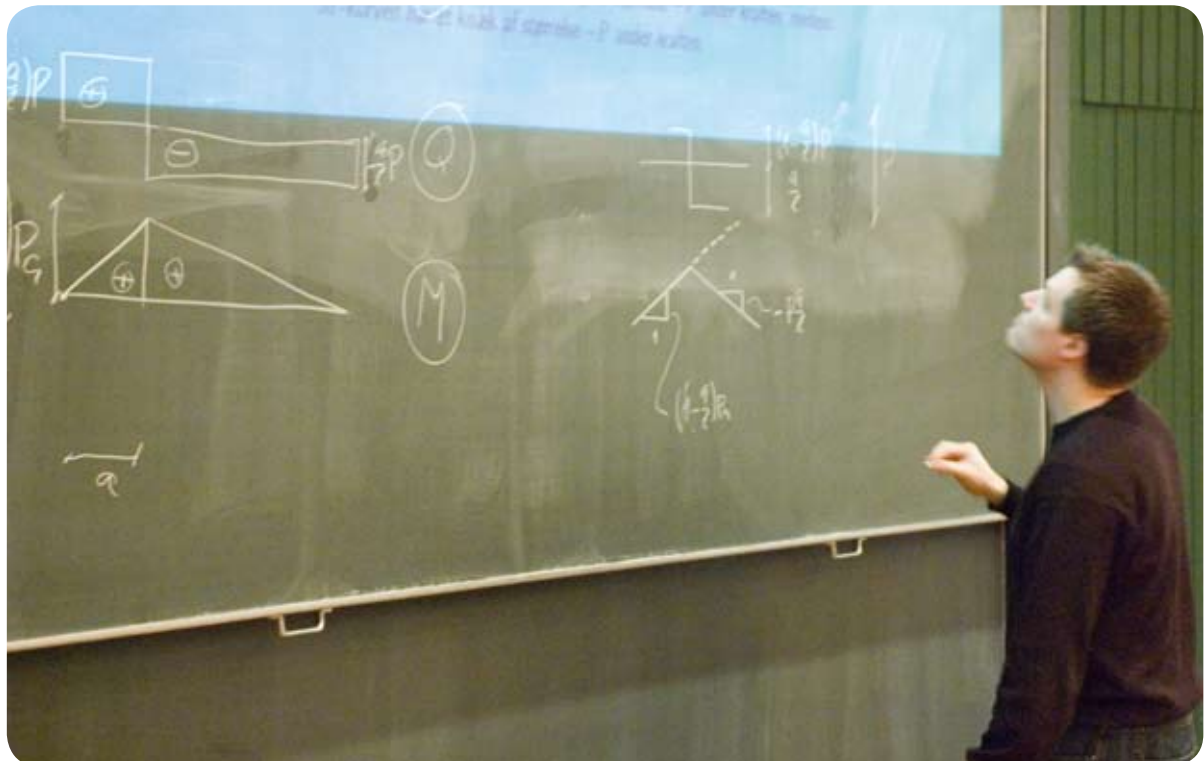
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Henrik Stang and Mette Geiker: Suspension of clay in water

Christos Georgakis: Liquid Dampers or spherical Tuned Liquid Dampers.

DTU chose to adopt the later.

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The Little Belt 2004 - Fyns Amt, Sønderjyllands Amt, Vejle Amt, 2005 (pp. 97) ISBN : 87-7343-603-8

Vogelius, Peter

Nye informations- og kommunikationssystemer på byggepladsen : Evaluering af et pilotprojekt med internetopkoblede, håndholdte terminaler på byggepladsen ISBN : 87-7877-184-6 In: BYG Rapport ; R-116

Reports

PhD theses

Ferreira, Célia Maria Dias

Removal of Heavy Metals from Municipal Solid Waste Incinerator Fly Ash by an Electrolytic Process
Ottosen, Lisbeth M.

Findsen, Karsten

Murede skivers styrke - murværk påvirket til plane spændingstilstande
Nielsen, Mogens Peter

Gudmand-Høyer, Tim

Instability of Concrete Slabs
Nielsen, Mogens Peter

Hansen, Lars Zenke

Unreinforced Masonry Walls, Transversely and Axially Loaded
Nielsen, Mogens Peter

Lykke, Miriam Mølgaard

Displacement of Oil by Waterflooding in Fractured Chalk
Foged, Niels Nielsen

Nystrøm, Gunvor Marie

Electrolytic Removal of Heavy Metals from Contaminated Harbour Sediments
Ottosen, Lisbeth M.

MSc theses

Abdelrasul, Hasanin S.

Urban quality-experiences from Denmark transferred to Iraq and vice versa
Elle, Morten

Akram, Zobia, Yasser Qaddoura

Design of school building
Kjærbye, Per

Andersen, Ann-Louise, Dorte Nygaard Pedersen

Drainage of soil in the Arctic
Villumsen, Arne

Andersen, Caroline H.H.

Earth pressure on walls – variation with time
Krogsbøll, Anette

Andersen, Claus Wessel, Jakob Blichert-Toft

Integrated design with focus on indoor climate and energy performance
Svendsen, Svend

Andersen, Susanne Førgaard

Pedestrian bridge at Kvæsthusbroen
Gimsing, Niels J. and Poulsen, Peter Noe

Barandalla, Daniel Garcia

Monitoring of a solar combisystem prototype
Furbo, Simon and Thür, Alexander

Bech, Kristian Alberg

Cyclic loading of sand
Krogsbøll, Anette and Hededal, Ole

Bech, Ronni and Anders Dragsted

External fire spread
Sørensen, Lars Schiøtt

Bech, Ronnie, Anders Dragsted

External fire spread
Sørensen, Lars Schiøtt

Bisgaard, Ann

Moisture buffer capacity of buildings
Rode, Carsten

Blichert, Christian

Deformation of fire exposed concrete
Hertz, Kristian

Bøhm, Anja Hillmann

Cement-based materials, microstructure property relationships
Geiker, Mette and Kjeldsen, Ane Mette

Christensen, Rasmus M.

Bolted endplate connection of tubes
Poulsen, Peter Noe

Christiansen, Ulla

Stabilizing wood frame walls in multistorey housing
Kjærbye, Per, Hoffmeyer, Preben and Egerup, Arne

Cravo, Antonio M.

Design and analysis of a sustainable building in Portugal with solar heating system
Furbo, Simon

Fabricius, Jesper Sværke and Admir Mehic

Innovative liquid dampers for the passive vibration control of structures
Georgakis, Christos

Fino, João and Mahomed Y. Gani

Design and analysis of a sustainable building in Portugal
Svendsen, Svend

Hansen, Mark Normann, Rasmus Knudsen

Movable bridge between Amaliehaven and the Opera
Gimsing, Niels J. and Skettrup, Erik

Haukohl, Jens Christian, Martin Hoff Jørgensen

Pedestrian bridge across the harbour of Copenhagen
Olesen, John Forbes and Poulsen, Peter Noe

Henningsen, Søren

Limestone parameters at elevated temperature and consequences for the district heating tunnel
Foged, Niels

Henriksen, Jørgen Bryn

Design of new Fossum bridge
Poulsen, Peter Noe and Gimsing, Niels J.

Højman, Anders

Risk analysis of Fisketorvet Shopping Center
Sørensen, Lars Schjøtt

Hvidberg-Hansen, Anna

Development of a tensile membrane structure
Reitzel, Erik, Aagard and Gimsing, Niels J.

Jacobsen, Mads

Friction dampers for structures
Nielsen, Leif Otto and Mualla, Imad

Jebjerg, Christian P.

Heighten of existing buildings
Engelmark, Jesper and Larsen, Henning

Jensen, Christian, Jesper Ring Christensen

Stability problems in wind turbine towers
Agerskov, Henning and Bonke, Sten

Jensen, Mads Nicolai, Jesper Vinholt

Structural analysis of Boase-project
Gimsing, Niels J. and Gath, Jesper

Jensen, Mikkel Vibæk

Self compacting concrete
Geiker, Mette

Jensen, Thomas Søby

Flange connections in wind turbine towers
Poulsen, Peter Noe and Agerskov, Henning

Jóhannesdóttir, Fjóra

Production of concrete in Greenland
Villumsen, Arne, Geiker, Mette

Jørgensen, Anders Stuhr

Carrying capacity of Greenlandic Roads and Airfields
Villumsen, Arne

Jørgensen, Jørgen Højbjerg

A solidwood building system
Hoffmeyer, Preben

Kalbakk, Thale

Implementation of the RTB (Clean-Dry-Build) concept
Bonke, Sten

Kold, Dorte

Cable-stayed bridge with composite deck
Poulsen, Peter Noe and Gimsing, Niels J.

Larsen, Casper Schultz and Morten Schultz

Cross level organizationally efficiency for Danish constructors
Koch, Christian

Larsen, Charlotte

Movable pedestrian bridge across shipping lane
Gimsing, Niels J. and Poulsen, Peter Noe

Lauritzen, Mads

The suppliers role in constructions
Bonke, Sten and Christensen, Knud

Levi, Vibeke

Strength parameters for typical Danish soils
Krogsbøll, Anette and Christensen, Helle

Lyby, Karsten

Pedestrian bridge at Odense station
Gimsing, Niels J. and Olesen, John Forbes

Madelung, Thomas and Hans Færck Jensen

Steel chimney
Johnsen, Finn

Marciniak, Darek

Analysis of factors regarding office location by companies in Malmø
Elle, Morten

Meincke, Joan Alexander, Henrik Pahl

Deformation properties of till
Foged, Niels

Mikkelsen, Henrik Nordentoft

Public participation in urban development
Elle, Morten

Møller, Karen Louise

Design of roof over atrium
Poulsen, Peter Noe and Gath, Jesper

Møller, Steffen C.

Overall economy in the construction industry
Vestergaard, Flemming

Mortensen, Henrik

Geotechnical properties of melted – earlier frozen silt and clay deposite in Sisimut
Foged, Niels and Clausen, Helle

Munck, Peter Martin, Kasper Køppen

Bolted connections in structural glass
Stang, Henrik

Nguyen, Anh Duy and Mesut Ocak

Design of industrial building
Kjærbye, Per O.

Nielsen, Jacob Ringsholt and Søren Egholm Hansen

Seismic analysis
Jönsson, Jeppe and Nielsen, Mogens Peter

Nielsen, Jacob

Intelligent buildings – with and without technology
Rode, Carsten, Nielsen and Toke Rammer

Nielsen, Jens Henrik

Lean construction and work and environment
Poulsen, Peter Noe

Nielsen, Lene Markvad

Feasibility study – post-tensioning of concrete structures with CFRP tendons
Hoffmann, Birgitte

Nielsen, Tryggvi

Calculation of performance of solar shadings
Svendsen, Svend, Nielsen and Toke Rammer

Normann, Jesper

Carbon fibre cable-stayed bridges
Georgakis, Christos, Poulsen, Peter Noe and Gimsing, Niels J.

Ómarsson, Sturlaugur Aron, Hákon Örn Ómarsson

Strenhtening with CFRP sheets
Nielsen, M.P. and Thorsen, Torsten

Özdikmen, Dide Bøggild

An Urban Renewal in Ankara: G.O.P.
Elle, Morten

Pedersen, Lars and Simon Præst Holm

Analysis of cable stay bridge with one sided harp stag arrangement and truss pylon
Poulsen, Peter Noe and Gimsing, Niels J.

Petersen, Gry

Acid-enhanced desorption of Pb during elektrodialytic soil remediation
Ottosen, Lisbeth M. and Jensen, Pernille E.

Petersen, Steffen and Christian Anker Hviid

Method for optimization of new houses to low energy level
Svendsen, Svend

Rasmussen, Martin

Electrochemical repair methods
Geiker, Mette and Ottosen, Lisbeth M.

Rasmussen, Martin, Anders Kudsk

Quality of work offerings
Bonke, Sten and Rasmussen, Finn F.

Risvig, Søren

Thind-walled beams
Jönsson, Jeppe and Nielsen, Leif Otto

Santana, Benjamin D.

Voltex-induced motion of boxgirder bridges
Georgakis, Christos

Sea, Samuel Cordova

Design of Church in Bøler
Kjærbye, Per O.

Skov-Larsen, Niels Clemens

Creativity as a theme in urban planning
Nielsen, Susanne B. and Agger, Annika

Søren Risvig

Thind-walled beams
Jönsson, Jeppe and Nielsen, Leif Otto

Sørensen, Anne

NATM Tunneling
Hededal, Ole and Krogsbøll, Anette

Sveinsson, Sigurour S.

Lean construction and work and environment
Pedersen, Elsebet F.

Thangarajah, Srirengan and von Holstein, Steffen J.

Parametre excitation of the great belt suspensen bridge hangers
Georgakis, Christos

Ureta, Maite B.

Thermosyphon solar charging unit
Furbo, Simon and Thür, Alexander

Vienberg, Trine Hee

Bathrooms in older houses
Engelmark, Jesper

Ick, Mirko

Planning in Consulting Engineering – Communities of Practice as Knowledge
 Arena
Koch, Christian and Hansen, Per Richard

Zass, Katrin

First functionally tests of the prototype of a new developed solar combisystem
Furbo, Simon and Thür, Alexander

B.Eng. theses

Akkas, Yakup

Roof diaphragms of plywood, nail to 45mm rafter
Traberg, Søren

Alm, Anne Birkedal and Johansen, Søren Udengaard

New roof structure
Kjærbye, Per

Andersen, Louise Toftebjerg

Material Science
Thorsen, Torsten

Andersen, Marie-Louise N. and Rauø, Hanna

Material Science
Thorsen, Torsten

Berard, Ole Bengt and Hansen, Morten Hahn

Small and medium size companies use of IT
Vestergaard, Flemming

Bossow, Brian and Jensen, Lars Mikael

Energy savings in building 118
Christensen, Kaj and Nielsen, Toke Rammer

Christensen, Knud

Examination of underroof membrane
Kjærbye, Per and Andersen, Jens

Christensen, Peter Mainz and Helmer, Lars

Explosionfire
Sørensen, Lars Schiøtt

Christiansen, Toni Mühlestein and Kastbjerg, Nicolas Michael

Design of housing
Kjærbye, Per

Ferdinandsen, Rikke Amalie and Henriks, Mette

Wasted time in construction site work
Bonke, Sten

Frederiksen, Ronnie R. H. and Hoffmann, Nicolai H.

Effect of entrained air on chloride ingress into concrete
Geiker, Mette

Hanjani, Melissa Jamali and Schwarz, Frank

External wall structures
Kjærbye, Per

Hansen, Peter Mose

Restoration of bay-structures
Kjærbye, Per

Hansen, Morten Ingemann

Urban Planning at the water-front
Christensen, Kirsten and Elle, Morten

Haugaard-Jensen, Lars Peter

Professional development of projectmanagement competences in a construction company
Christensen, Knud

Hejnfelt, Thomas and Øksengaard, Rene

Lateral buckling of steel beams
Olesen, John Forbes, Olsen, Poul Colberg and Jønsson, Jeppe

Højgaard, Bardur and Madsen, Anders Møller

Repairs of concrete bridge with latexmodified concrete
Stang, Henrik, and Jensen, Ole Mejlhede

Jensen, Marie Nygaard

Utilization of project experience
Christensen, Knud

Jensen, Simon Rich and Jacobsen, Morten Brogaard

Moisture in wooden windows
Hoffmeyer, Preben

Jensen, Mette Hegelund and Bjørnlun, Lars Bo

Project Web
Koch, Christjan and Christensen, Knud

Jørgensen, Anne Marie and Laustsen, Sara

University construction
Holck, Niels and Egerup, Arne

Knudsen, Jakob Lindsted and Christoffersen, Morten

Dowel joint in timber framing
Traberg, Søren and Clorius, Christian

Kruse, Lars and Christensen, Anders Mygind

Logistics – planning and management
Bonke, Sten

Kryger, Morten

Fire design of timber buildings
Kjærbye, Per

Mørch, Søren and Yang, Yuan-Yuan

Interaction between structure and foundation
Fuglsang, Leif and Holck, Niels

Morelli, Martin and Bennedsen, Nicolai

Development of Leca from Greenland clay
Villumsen, Arne

Nørrelund, Claus D. and Rosenkjær, Peter

SCC (Self Compacting Concrete)
Thorsen, Torsten

Olsen, Pia Kaaber and Jørgensen, Trine Gotha

A renovation project by stages
Bonke, Sten and Kjærbye, Per Oluf

Pedersen, Brian and Hansen, Anders

SCC
Thorsen, Torsten

Pedersen, Frank Schou Kruse and Buch, Bjørn

Process management in small and medium sized construction companies
Christensen, Knud

Petersen, Ujarak Rosing

Hydro power dam at Tasersnaq, Greenland
Villumsen, Arne

Poulsen, Kim Thomas and Høiagaard, Tobias

Strengthening existing steel constructions by use of carbon fibers
Thorsen, Torsten and Poulsen, Ervin

Rasmussen, Finn Fischer, Haugaard, Mikkel and Petersen, Jacob Dyrby

Construction project in a third world country
Bonke, Steen

Rasmussen, Thomas

Cost of construction for road to Sarfanguaq, Grønland
Villumsen, Arne

Volsing, Kristoffer and Jørgensen, Nicolaj Mac

Energy renovation of one family house
Svendsen, Svend and Tommerup, Henrik



Staff

On 31. December 2005

		2005	2004	2003
Scientific	Professor	9	11	12
	Associate Professor	38	44	45
	Assistant Professor	15	15	13
	Other VIP	6	4	2
	PhD students	44	40	42
	Total	112	114	114
Technical and Administrative	Academic	11	10	10
	Clerical	12	12	12
	Technician	22	22	23
	Other TAP	5	4	4
	Total	50	48	49
Total department staff		162	162	163

Education

STÅ ¹ – total		508	519	469
Projects	BEng (diplom)	62	82	73
	PMP/BSc (midterm)	36	56	25
	MSc (civil)	92	74	60
Admission	BEng (Civil Engineering) - summer	63	58	88
	BEng (Civil Engineering) - winter	30	32	32
	BEng (Architectural Engineering)	52	42	49
	BEng (Arctic Technology)	9	8	12
	BSc (Building Technology)	72	60	60

Research

Refereed papers	Total	61	63	44
	Of these in ISI	43	37	N.A.
PhD		8	10	7
Doctoral		1	0	0

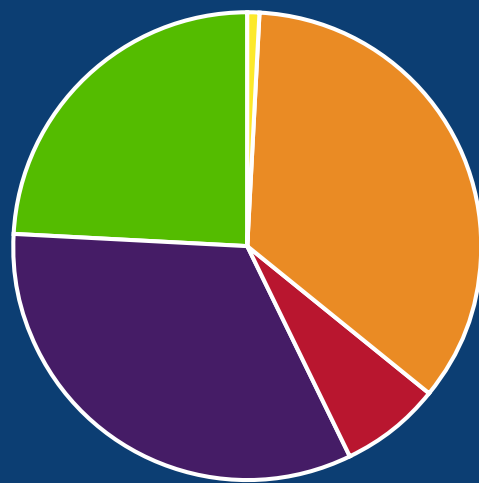
Finances

Finances in 1.000 DKK

Revenues	DTU-grant	53.184	52.523	51.189
	External revenue	30.862	28.563	26.191
	Total	84.046	81.094	77.380
Expenditures	Wages	62.725	62.917	61.927
	Other expenses	19.628	16.445	14.688
Total		82.353	79.362	76.615
Result		1.693	1.732	765
Available amount	January 1	6.264	4.532	3.767
Carried forward	December 31	7.957	6.264	4.532

1 1 STÅ is one student annual work (1 STÅ=60 points/student)

Turnover 2005



Innovation	1%
Education	35%
PhD scholarships	7%
Faculty reasearch	33%
External Financed reasearch	24%

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