DTU Civil Engineering
Department of Civil Engineering

Building Design

Construction of entire buildings
Student projects at the Section for Building Design

Version February 2013

Preface

The Section for Building Design deals with construction of entire buildings considering relevant functional requirements and sustainable issues simultaneously.
The goal is to provide quality of life including applicability, comfort, experience, sustainability, and safety. The research comprises design and operation of buildings concerning load-bearing structures, building physics, architecture, and safety with respect to fire and terror, and the process of design and methods for that for example digital building information models.
A special attention is given to the development of building design methods for the early phases of the design process, where the most important decisions are made.
All areas of research seek to implement their solutions in practise through dissemination and co-operation with clients, architects, consultants, contractors, and manufacturers, and in specific cases, a basis for acceptance is established for the authorities. This means that research, innovation, dissemination, and public sector consultancy constitutes an obvious flow of the sections work.

Courses

11010	Building technology	Christian Rønne
11020	Fire Safety in buildings	Grunde Jomaas
11022	Fire dynamics	Anne Dederichs
11023	Structural Fire Safety Design	Kristian Dahl Hertz, Luisa Giuliani
11031	Bygnings Informations Medellering (BIM)	Flemming Vestergaard, Hans Peter Nielsen
11034	Videregående Bygnings Informations Medellering (BIM)	Flemming Vestergaard, Hans Peter Nielsen, Jan Karlshøj
11035	Videregående BIM for bygningsdesign	Flemming Vestergaard, Lotte Bjerregaard Jensen, Jan Karlshøj
11050	Super-light structures	Kristian Dahl Hertz, Anne Bagger
11066	Building Renovation and Rebuilding	Søren Peter Bjarløv
11080	Advanced Building Design	Jan Karlshøj, Anne Dederichs, Søren Peter Bjarløv
11320	Konstruktionsanalyse af bygninger	Jacob Wittrup Schmidt, Jesper Frøbert Jensen
11691	Fagprojekt - Bachelor i Byggeteknologi	Søren Peter Bjarløv, Claus Simonsen
11701	DesignBuild	Claus Simonsen, Flemming Vestergaard, Anne Hesselgren
11703	Digitale bygningsmodeller	Flemming Vestergaard

11715	Technical Drawing and CAD	Flemming Vestergaard, Hans Peter Nielsen, Anne Hesselgren, Anders Mejlhede Jensen
11742	Design and Construction of Buildings	Finn Larsen
11900	Building component design	Anja Bache
11904	Introduktion tl Architectural Engineering	Christian Rønne
11913	CAD, sketching and 3D-modelling	Hans Peter Nielsen
11915	Baggrund for Architectural Engineering 1	Lotte Bjerregaard Jensen
11924	Boligbyggeri og bygningsde-sign	Lotte Bjerregaard Jensen
11932	Byens rum, den store kon-struktion	Lotte Bjerregaard Jensen
11933	Systematical planning with CAD-system and Visualization	Hans Peter Nielsen
11935	Baggrund for Architectural Engineering 2	Lotte Bjerregaard Jensen
11945	Bæredygtigt bygningsdesign	Lotte Bjerregaard Jensen
11969	Valgfri projektopgave	Lotte Bjerregaard Jensen
11970	Valgfri projektopgave 2	Lotte Bjerregaard Jensen
11993	Arkitektur og teknologi	Lotte Bjerregaard Jensen
11994	Ingeniørdesign I byskala	Lotte Bjerregaard Jensen

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Student projects – Building Design

Contents

Team: Det Digitale Byggeri og IFC

Background

Det Digitale Byggeri har sat fokus på en større nyttiggørelse af informations- og kommunikationsteknologi i den danske byggesektor. Det er kendt at det manglende digitale sammenspil betyder at data må genindtastes igen og igen, og at teknologiens potentiale ikke udnyttes optimalt med et betydeligt tab til følge i byggesektoren. Det Digitale Byggeri har valgt at byggeriets parter skal satse på brug af Industry Foundation Classes (IFC) som udvekslingsformat af BIM-information.

IFC er implementeret i en lang række programmer, som anvendes i den danske byggesektor. For at få det fulde udbytte af IFC er der en række forhold som skal være i orden, da både indholdet, teknikken og arbejdsmetoden skal være på plads for en succesfuld anvendelse.

Projekt 1: Test af IFC interfaces

Sammenlign to programmers evne til at håndtere import og eksport af IFC-data, så mest mulig information overføres korrekt. Resultaterne kan sammenlignes og evt. indgå i den internationale testdatabase i Tyskland. I testen skal der gennemføres sammenlignelige afprøvninger i de to programmer baseret på egne eller eksisterende testmodeller. Man bør påregne af resultaterne af testen publiceres via Internet efter at softwareleverandørerne har haft en mulighed for at fjerne eventuelle faktuelle fejl.

Projekt 2: Vejledning i modelopbygning under hensynstagen til IFC baseret dataudveksling

Opbyg en vejledning som beskriver hvilke forholdsregler man skal gøre sig i forbindelse med modellering af bygninger og deres bestanddele for bedst muligt at kunne udveksle dem via IFC. Det kan fx betyde at navne, egenskaber og beskrivelser skal stå i bestemte felter og at man skal vælge nogle komponenttyper i programmet frem for andre. Vejledningerne bør hovedsageligt udarbejdes til programmer som benyttes i Danmark, men der kan endvidere indgå programmer, som har vist sig at have særligt gode kvaliteter i forhold til IFC baseret dataudveksling.

Projekt 3: IFC baseret byggeprogram

De danske bygherrer har endnu ikke taget BIM-model baserede byggeprogrammer til sig, men blandt andet Statsbygg i Norge har udbudt større byggeprojekter, hvor bygherren har udleveret en "krav BIM-model" til de bydende som indeholdte krav til arealerne af rummene, navngivning af disse mv.

Opgaven i dette projekt er at omforme et eksisterende statsligt byggeprogram til en krav BIM-model, og efterfølgende vurdere hvordan krav BIM-modellen vil kunne bruges af de bydende, samt ikke mindst hvilke fordele princippet vil kunne medfører for bygherren selv.

Projekt 4: IFC baseret mængdeudtagning og kalkulation

Flere af kalkulationsprogrammerne på det danske marked er i stand til at importere data i IFC-format. Det er målet i projektet at afprøve funktionaliteten af disse interfaces i forbindelse med kalkulationer på et tidligt niveau i projekteringsforløbet efterfulgt af en mere detaljeret kalkulation i projekteringsforløbet. Det vil endvidere være hensigtsmæssigt at gennemføre en tilbudskalkulation baseret på et udvalg af bygningsdele, der nedbrydes til komponenter. Projekter kan bygge videre på allerede gennemførte eksamensprojekter.

Projekt 5: IFC baseret energiberegning

På energiområdet findes der adskillige energianalyseprogrammer, som er i stand til at importere BIM-modeller, som grundlag for energiberegninger. Nogle af disse programmer benyttes på det danske marked, men det vil være naturligt at se på programmer som endnu ikke har fået en udbredelse på det danske marked. Energiberegningsprogrammer BE06 har en særstatus i det danske bygningsreglement. BE06 er dog ikke IFC-kompatibelt, men der eksisterer tredjepartsprogrammer som er i stand til at overføre BIM-data til BE06 via gbXML. gbXML er et format specifikt til at overføre informationer til energianalyser.

Projekt 6: Kobling mellem modeller for bygninger og omgivelserne

I samarbejde med Bentley Systems ønskes det at blive vurderet i hvilket omfang, det er muligt at udnytte simple repræsentationer af bygninger i kombination med GIS-data. Kombinationen kan fx benyttes i forbindelse med brand og beredskabsopgaver, hvor det er vigtigt at kunne sætte bygningen ind i en bymæssig kontekst.

Projekt 7: IFC baseret overgang til drift

BIM-modeller indeholder mange informationer, som kan være nyttige i eller ved overgangen til driftssituationen. Det er derfor nærliggende at undersøge i hvilket omfang de eksisterende programmer på markedet er i stand til at udnytte informationer fra projekterings- og udførelsesfasernes BIM-modeller i forbindelsen med driften. I dette projekt vil der blive fokuseret på eksisterende programmer, som er i stand til at importere IFC-data til FM/drift-programmer. Projektet vil blive gennemført i samarbejde med DTU Campus Service, som har flere igangværende og planlagte byggeri på Campus.

Projekt 8: BIM og brand

Det ønskes undersøgt i hvilket omfang det er muligt, at udnytte bygningsinformationsmodellering i kombination med analyser og simulering i relation til brand. Det ønskes specielt vurderet i hvilket omfang om IFC kan bruges til overførsel af informationer fra bygningsinformationsmodeller til brandanalyser eller simuleringer, og om brandtekniske data kan føres tilbage til bygningsinformationsmodellerne. Afhængig af den studerendes interesse kan der specifikt ses på brandudvikling, røgudvikling, evakuering, konstruktionsbrandberegninger eller overholdelse af krav fra bygningsreglementet.

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Fire safety design

Type of projects
M.Sc. thesis, 30 ECTS points

Prerequisites
110221 – Fire dynamics
11124 - CFD on buildings (optional)

Project 1: Modeling of fire in large compartments

Background and motivation
Large compartments have been often required in industrial hall and public buildings and, nowadays, open spaces are frequently a desired feature for office premises as well. Nevertheless, prescriptive design and verification methods for structural fire safety can only be applied to compartments not exceeding specific dimensions. In particular, according to the Eurocodes [1], compartments should not exceed 500 m2 of floor area and 4 m of height.

These limitations are based on the fact that simplified analytical fire models, such as parametric fires, are based on the assumption of a uniform distribution of temperature along the compartments. This is a sensible assumption for small compartments, where a uniform and relatively high fuel load density and a significant thermal feedback from the wall are likely to trigger a flashover. However, the occurrence of a flashover is unlikely in large compartments, where the need of free stream of people or goods require a low density of furniture and encumbering materials and where the enclosure has lower influence on the fire development.

In particular, the low fuel load density can lead to two opposite situations:

i. A local concentration of the fuel load, which can be piled up in a relatively small portion of the compartment, leaving the rest of the compartment free potentially free from combustible materials (warehouse, industrial hall).
ii.) A more homogenous distribution of the combustible materials, spread along one direction of the compartment or along both. The high spread of the fuel combined with the low amount of fuel per unit area could then lead to a mild but very long fire, which slowly travels across the compartment [2].

In both cases, the use of a parametric fire could lead to an unsafe design, either because the duration of the fire would be underestimated (ii) or because the temperatures of unprotected elements above the flame would be underestimated (i). In the latter circumstance, the use of a localized fire model (Alpert) could be more appropriate to assess the temperature of the element impinged by the flame. However this necessarily requires the assumption of a pre-determined location for the fire and to a possible underestimation of the elements outside the fire area.

Ensuring the fire safety of large compartments represents therefore a challenge for architects and structural engineers and further research effort should be devoted to investigate the fire development in large compartments and to identify the parameters that play a key role there.

Purpose and method

A first aim of this thesis is to review current available design methodology for the fire design of structural elements in large compartments and highlight limits and potentiality of these methods. In particular, pre- and post-flashover fires will be considered and recent studies proposing simplified methodologies [3] [4] will be discussed.

A second aim of the thesis is to identify the main parameters deemed to affect the development of the fire in large compartments. In this respect, the effect of uniform and non-uniform distribution of the fuel load will be in particular investigated.

To this aims, a steel industrial building, devoted to the storage of goods, will be taken as case study. Thanks to the symmetry of the compartment, the building is suitable to the adoption of both simplified methods and CFD simulations, so that the results of the different calculations can be compared. Furthermore, previous studies carried out on the same structure [5] [6] will allow for a validation of the numerical model.

The CFD model will be implemented in FDS (NIST) and will considered a fire involving wooden of differently distributed in the premises. The results in term of temperatures of the hot gasses and of the steel elements composing the structural system will be presented and compared with those obtained by simplified models.

Problematic issues of the CFD modeling concerning the presence of uncertainties, the objectivity of the solution, and the reduction of computational onus will be highlighted and discussed.

Keywords
Large compartments, Design fires, Pre- and post-flashover models, CFD simulations, fuel-staking, fuel spread, flashover, travelling fires.

Essential literature

[1] EN 1991-1-1 (2002). Eurocode 1: Actions on structures - Part 1-2: General actions Actions on structures exposed to fire.

[2] Stern-Gottfried, J, Rein, G. (2012), Travelling fires for structural design – Part I: Literature review, Fire Safety Journal, 54, pp. 74-85.

[3] Hertz, K. (2012). Parametric Fires for Structural Design. Fire Technology, 48(4), 807-823.

[4] Law, A., Stern-Gottfried, G., Gillie, M., Rein, G. (2010). The influence of traveling fires on a concrete frame, Engineering Structures, 33, pp. 1635-1642.

[5] Gentili, F., Giuliani, L., Bontempi, F. (in press). Effects of combustible stacking in large compartments. Journal of Structural Fire Engineering.

[6] EUR 24222 EN (2010). Fire safety of industrial hall – A valorization project, Directorate-General for Research and Innovation, European Commission.

[7] NIST (200). Fire Dynamics Simulator (Version 5) - User guide - Special Publication, Washington, US.

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Structural fire safety

Type of projects
M.Sc. thesis, 30-60 ECTS points

Prerequisites
11023 - Structural fire safety design or
11020 - Building Fire Safety;
11311 or 11746 - Concrete structures (Prj. 2-3-4)
11371 – Advanced FE Method (Prj. 1-3-4)

Project 1: Fire-induced mechanisms of steel frames: sway and non-sway collapses

Background and motivation
Behavior of steel structure in fire is dominated by the effects of material degradation, eigenstresses induced by hindered thermal expansion and large deflections and runaway resulting from the action of imposed load on the weakened structure [1].

If the consideration of material degradation is -even with some differences- well established in all fire verifications, the effects of eigenstresses and large deflections are mostly completely disregarded in usual prescriptive-based codes, due to the difficulties of being integrated in simple verification methods. In particular, according to the Eurocodes [2] the effect of hindered thermal expansion can be neglected in the verification of single elements when standard curve is used as design fire.

The counteracting effects of thermal expansion and large displacements play however a key role in the assessment of the progressive collapse susceptibility and of the type of collapse mode of the structure. With respect to the collapse mode of a steel frame in particular, two basic failure mechanisms can be identified (Figure 1): i) a sway collapse, where one (or more) columns are pushed outwards by the thermal expansion, and ii) a non-sway collapse, where the effect of large deflection on the beams are prevailing on the effect of thermal expansion and cause an inwards movement of the columns. The first collapse mode is particularly dangerous, since, it may cause additional injuries and damages on people and properties on the outside.

The understanding of the response to fire and fire effects of the structural system as a whole and the identification of possible collapse modes are essential in the framework of a performance-based fire design (PBFD), where the response of the whole structure is of interest, as well as for compliance with the requisite of structural integrity. The requirement of structural integrity is referred to the ability of the structural system of suffering a proportionate, limited damage when hit by accidental actions, such as impacts, blast and fire and is nowadays a requirement of several structural codes worldwide [3][4].

These consideration are even more relevant in case of unaccounted failures, e.g. due to human errors in the design or execution phase, or of rare but severe events like an arson, or a fire after an explosion or an earthquake, which cannot be contemplated in the usual design.

Purpose and method

Aim of this project is to investigate how the organization of the structural elements of a steel frame, namely the relative stiffness of beams and columns and the type of element connections influences both the resistance of the frame to fire and the collapse mode.

At first, the basic fire-induced failure mechanism of beams and columns are considered, with particular respect to thermal buckling, loss of support (bowing), catenary effect, and thermal degradation. The effect of different loading conditions and restrain grade is investigated and discussed. Then the behavior of column-beam structure is considered with respect to sway and no-sway failure modes and it is expected that a parameter or a set of parameters can be identified, capable of predicting the failure modes.

The investigations are carried out with a finite element code, capable of accounting for the thermoplastic behavior of the steel and for the geometrical nonlinearities. The models of the frames are progressively built up from simpler models, such as a single element free to expand or totally restrained, which can be validated by analytical calculations and literature data as well [5] [6] [7]. Then parametric studies are conducted on single elements by varying the loads and the restrain grade, and on frames, where different relative stiffness's of beams and columns are considered [8].

By definition of a proper force- or displacement-based collapse criterion, a collapse mode can be associated to each structural configuration and design boundaries separating a non-sway from a sway collapse can be identified.

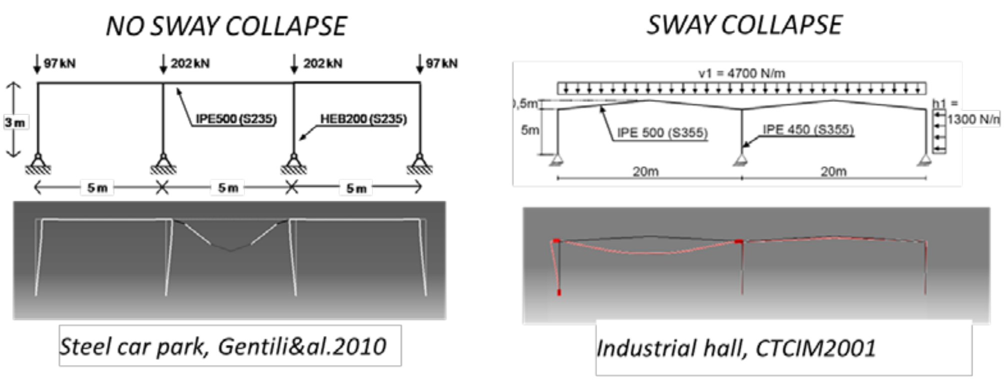

Figure 1: sway (right) and non-sway (left) collapse of steel frames

Essential references

[1] O. Pettersson, S.E. Magnusson, J. Thor: "Fire Engineering design of steel structures", Bulletin 52 1976, Sweden

[2] EN 1993-1-2:2005 Eurocode 3: Design of steel structures - Part 1-2: General rules - Structural fire design

[3] EN 1991-1-7 (2006). Eurocode 1: Actions on structures, Part 1-7: General actions - Accidental actions, Comité Européen de Normalisation (CEN)

[4] DS-INF 146, Robustness - Background and principles - Information, Danish Standard Association, 2003

[5] A. S. Usmani, J. M. Rotter, S. Lamont, A. M. Sanad and M. Gillie (2001). Fundamental principles of structural behavior under thermal effects, Fire Safety Journal, Volume 36, Issue 8, pp. 721-744

[6] Yin, Y.Z., Wang, Y.C. (2004). A numerical study of large deflection behaviour of restrained steel beams at elevated temperatures, Journal of Constructional Research, 60, pp. 1029-1047.

[7] Gillie, M. (2009). Analysis of heated structures: Nature and modeling benchmarks, Fire Safety Journal, 44, pp.673-680.

[8] Giuliani, L., Budny, I. (2012). Different design approaches to structural fire safety. Journal of Lifecycle and Performance Engineering, vol. 1,Special issue on Fire Safety Design and Robustness Considerations in Structural Engineering, (in press)

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Project 2: Comparison of design methods for fire design of concrete structures

11023 - Structural fire safety design OR

Background and motivation

In the last years, national codes of most European countries have been substituted by the adoption of Eurocodes, which should harmonized the different national regulations and represent the best European consensus on design rules for structures subjected to fire. Nevertheless different philosophies and approaches to fire safety led to difficulties in the harmonization process and in the practice design procedures followed by engineers of different countries are often different.

A significant difference introduced by the Eurocodes in the Danish action code [1] is marked, for example, by the definition of design situation for fire, which is now considered within the framework of accidental design situation [2], together with other exceptional actions such as blasts and impacts. The consideration of fire as an exceptional rare event has a repercussion on the safety coefficients to be used for loads [3] and materials [4] (e.g. frequent value of action and characteristic strength of materials), as well as on the verifications formats [4] [5] [6] [7].

Another main difference can be found in the implicit aims of distinct prescriptive codes, which can be focused on the safety of people or on the structural behavior of the construction. In the first case, a time resistance for structural elements can be fixed on the basis of the evacuation time (as Eurocodes typically requires) while in the second case a more refined modeling of the fire action can be required, which better represent a natural fire and accounts for the cooling phase (as usually done in Denmark). The consideration of the cooling phase can be particularly important for concrete sections, which often exhibit a lower resistance when the concrete core is the hottest, which typically occurs several hours after the fire.

However, due to the higher severity of nominal fire curves that may counterpoise to the longer duration of fully developed fires, it can be difficult to a-priori evaluate which design is the safest one. A comparison has been previously done in the framework of a thesis project here at DTU, with respect to steel structure only [8]. A similar punctual comparison between the different simplified design method for concrete structures would be therefore of interest [9].

Purpose and method

Aim of this thesis is to evaluate and compare different design methods for concrete structures under fire, with particular reference to different fire modeling (e.g. standard and parametric curves), thermal analysis (simplified analytical models or more advanced thermal maps) and different verification formats (tabular data, different design methods for column and beams, etc.).

A concrete structure, taken as case study, will be designed according to the above mentioned design methods and the resulting differences in term of costs and safety coefficients will be evaluated and discussed.

Essential references

[1] DS410 (1999). Code for Actions on structures, Danish Standards.

[2] EN 1990:2002 Eurocode - Basis of structural design

[3] EN 1991-1-2:2002 Eurocode 1: Actions on structures - Part 1-2: General actions - Actions on structures exposed to fire

[4] EN 1992-1-2:2004 Eurocode 2: Design of concrete structures - Part 1-2: General rules - Structural fire design

[5] Hertz, K. (1999). Analyses of Concrete Structures Exposed to Fire: U-050. Lyngby: Department of Buildings And Energy, Technical University of Denmark.

[6] EN 1993-1-2:2005 Eurocode 3: Design of steel structures - Part 1-2: General rules - Structural fire design

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[9] Hertz, K. (2000). A Survey of a System of Methods for Fire Safety Design of Traditional Concrete Constructions, in proc. of the First International Workshop on Structures in Fire. (pp. 283-292), Liege, Belgium.

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Project 3: Performances and damages of R.C. elements in fire

Background

Reinforced concrete structures are expected to perform well in case of fire due to the thermal properties of concrete and the protection offered to the reinforcement by the concrete cover. This is only partially true, as witnessed by several examples of fire-induced collapse of concrete buildings. The WTC7 of NY in 2001 (NIST NCSTAR 1A, 2008), the Windsor Tower of Madrid in 2005 (NILIM, 2005), and the Architectural faculty building of Delft University in 2009 (Meacham, et al., 2009) are just few recent examples of a disproportionate structural response to fire of concrete buildings.

These events showed the importance of a more careful consideration of the effects of a fire on concrete structures and renewed the attention to the advanced modeling and investigation of the behavior of concrete structural system during and after a fire event.

In this respect, it’s worth recalling that, contrarily to structural steel, which generally regains the original mechanical properties after cooling, ordinary concrete suffers permanent damages when heated over 300°C: at this temperature micro-cracks develop as a consequence of the material dehydration and the thermal expansion of the aggregates, so that the loss of mechanical properties becomes permanent (Hertz, 2005). Therefore, even in case a concrete structure survives a fire without major or local collapses, the costs for repairing concrete elements damaged by fire may be significant. For this reason, in addition to the evaluation of the response during a fire, the residual performances concrete elements after a fire are also important criteria to be considered in view of an efficient and sustainable design of concrete structures (ISO 15392, 2008) (Shipp, 2007).

Even if the need of assessing and classify the damage level of a structure after is recognized by most researchers and practitioners operating in the field (Guo&Shi, 2011) (Jayasree et al., 2011), no indications are found in the codes on the methods and procedures. Different parameters are considered in literature as indicators of the severity of the fire damage, which refer either to the condition of concrete or steel at a fiber level (e.g. the temperature of the reinforcement, the cracking of concrete, etc.) or take into account the overall bearing capacity of the element at a sectional or global level.

All this parameters are generally referred to the time of maximum fire exposure considered, i.e. in a hot condition, when the steel is the hottest and the concrete is mostly undamaged. However this situation doesn’t represent the permanent damages after the fire is extinguished, nor always account for the highest reduction of the element performances. This is the case for example of most tall concrete section, where the strength reduction of the concrete core that occurs in the cold condition may be more significant that the steel strength reduction in the hot condition.

Purpose and method

This project is aimed at reviewing current methods and indicators used for assessing the performances and residual damage of concrete elements during and after a fire event. The limit and potentiality of each method should be discussed. A new procedure based on previous methods should be outlined, capable of assessing the structural vulnerability of a concrete element to fire with respect to both the hot and cold condition and the permanent residual damage of the element.

The method will be applied to few concrete elements, used as case studies. The elements will be modeled with a finite element code. Particular attention will be given to modeling issues such as the thermal degradation of concrete and the representation of the cold condition and permanent damages.

The response of the element to the same fire will be evaluated in term of performances and damage during and after the fire.

Keywords

Structural fire safety; R.C. elements in fire; FE modeling of R.C. in fire; residual damage; hot and cold condition; structural vulnerability index.

Essential literature

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ISO 15392. (2008). Sustainability in building construction - General principles. International Standard Organization.

Guo, Z., Shi, X. (2011). Experiment and calculation of reinforced concrete at elevated temperatures. Elsevier, US.

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Meacham, B., Engelhardt, M., & Kodur, V. (2009). Collection of Data on Fire and Collapse, Faculty of Architecture Building, Delft University of Technology. Honolulu, Hawaii.

NILIM. (2005). Report on the Windsor Building Fire in Madrid, Spain. Japan: National Institute for Land and Infrastructure Management (NILIM).

NIST NCSTAR 1A. (2008, August). Final Report on the Collapse of World Trade Centre Building 7- Federal Building and Fire Safety Investigation of the World Trade Centre Disaster. Washington, D.C.: National Institute of Standards and Technology and National Construction Safety Team Act Report 1A.

Shipp, M. (2007). Fire as a sustainability issue. Constructing the Future, 31.

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Project 4: Structural integrity of hollow core slabs in fire subjected to bending

Background and motivation

Recently, several cases of major fire-induced collapses of concrete buildings [1] [2] [3] have focused the attention of structural engineers to the behavior of concrete structures in fire and have in particular highlighted the key role played by deck slabs in the response to fire of the whole building.

A failure of a slab element during fire may be responsible of a vertical propagation of both the fire and the damages. The propagation of the fire is a consequence of the loss of compartmentalization consequent to the slab failure, while the vertical propagation of the damages may be triggered by the impact of a collapsing slab on the floor underneath or by a possible instability of the walls consequent to the loss of horizontal restrain. Usual fire design procedures don’t account for either of the two events, whose occurrence can therefore be very critical for high-rise building especially and possibly lead to a progressive or disproportionate collapse of the structure.

Furthermore, fire verifications are carried out under the assumption of perfectly integer elements, as concomitant or concurrent critical events are not considered in accidental design situations [4] [5]. Nevertheless, opening of cracks and localized damages are plausible to occur in the bottom part of concrete slabs, where high temperatures can rapidly be reached during a fire. This situation can be detrimental for hollow core slab, where the loss of integrity of the bottom flange would open the cavity and expose the inner part of the slab to the heat. This would lead to a much faster decay of the performance of the slab and in a possible unexpected early failure of the element in bending.

A proper representation of hollow core slab response in case of fire is therefore of great importance in view of a safe and sustainable design of buildings [6]. This is especially true considering that, being lighter than other deck solution, these types of floor-decks are frequently found in tall buildings and their employment is of great interest nowadays, in consideration of the savings they allow in term of material costs and CO_2 production [7].

Purpose and method

Aim of this project is to highlight possible shortcoming in the current design of RC slabs, with particular reference to the vulnerability to fire (intended as sensitivity of the element to the fire action) and the element robustness (intended as sensitivity of the slab to a local damage).

The thermal and structural response of a hollow core slab will be investigated in relation to the effects of crack openings and possible local damages in the bottom flange of the decks below the cavities. Investigations will take input from the results of previous studies and tests available in literature and will possibly be based on the results of two fire tests that will be carried out next year on hollow core slabs in bending. The results of the tests will be used to validate numerical finite element models (ABQUS or DIANA), which will be employed to predict the response of the slabs under different conditions of load, exposure, and boundaries.

Keywords
Structural fire safety, hollow core slabs in fire, FE modeling, loss of integrity, bending failure

Essential literature

[1] Meacham, B., Engelhardt, M., & Kodur, V. (2009). Collection of Data on Fire and Collapse, Faculty of Architecture Building, Delft University of Technology. Honolulu, Hawaii.

[2] NILIM. (2005). Report on the Windsor Building Fire in Madrid, Spain. Japan: National Institute for Land and Infrastructure Management (NILIM).

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[4] EN 1990:2002 Eurocode - Basis of structural design, Comité Européen de Normalisation (CEN).

[5] EN 1991-1-7 (2006). Eurocode 1: Actions on structures, Part 1-7: General actions - Accidental actions, Comité Européen de Normalisation (CEN).

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[7] Hertz, K. D., & Bagger, A. (2011). CO2 emissions from Super-light Structures.In: Proceedings of the International Association for Shell and Spatial Structures (IABSE-IASS) Symposium 2011 “Taller, Longer Lighter”.

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Structural integrity against exceptional actions

Type of projects

M.Sc. thesis, 30 ECTS points

ERASMUS EXCHANGE POSSIBLE[1] *(SAPIENZA, ITALY)*

Prerequisites

11743 - Soil mechanichs (or equivalent)

11305 - Elementmetoden (or equivalent)

Project 1: Soil structure interaction in OWT collisions

Background and motivation

Renewable energy sources are an attractive alternative when it comes to decreasing the undesirable environmental consequences of the more traditional fossil fuel energy sources. Hence the future growth of offshore wind power capacity is expected to be significant in most of the European countries. Vessel impact is one of the load cases which should be accounted for according to design codes [1]. Collisions are considered either in ultimate limit state or in accidental limit state, requiring adequate load carrying capacity after the collision and non-collapse of the wind turbine, at each limit state respectively. The risks associated with a potential failure include loss of energy production, loss of investment, injuries or fatalities and environmental damages [2]. Reducing the aforementioned risks may be achieved either by controlling the probability of occurrence of the collision events or by mitigating the related consequences. The current study focuses on the evaluation of the distress induced in a wind turbine by a ship collision, thus providing an insight on the potential damage mitigation measures and their applicability. This problem has been only recently examined by finite element analyses for different types of foundation, indicating that monopile system is probably the least hazardous [3].

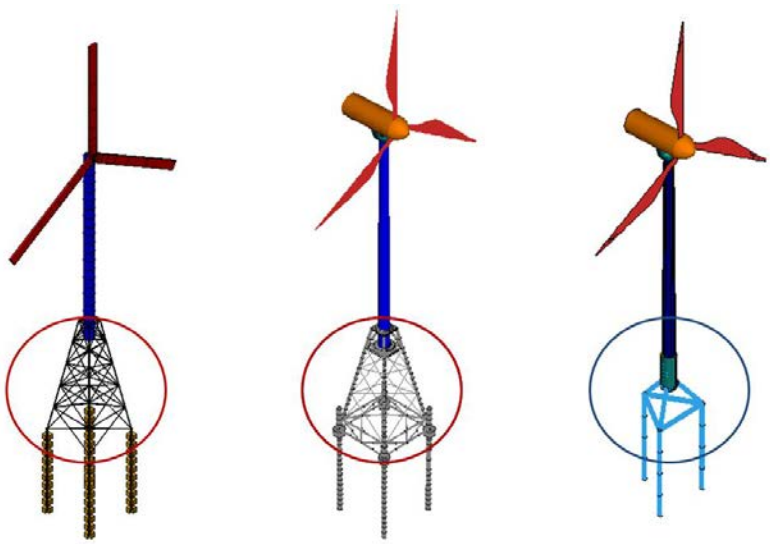
Purpose and method

Aim of the project is to investigate the role of the site conditions, namely the foundation soil properties, on the response of the structural system to the impact.

Different types of foundation should be investigated in order to assess the hazard potential with respect to the stiffness of the soil.

The grade of significance of impact load case in the overall structural safety of the OWT should be evaluated and discussed in the framework of the design of mitigation measures.

The investigations are carried on with the avail of a finite element program (such as Ansys, Abaqus or Strand7). A model should be developed, capable of simulating the behavior of the integrated system (wind turbine – foundation – surrounding soil).
The OWT model will be validated against results available in literature and previous results of dynamic investigation on similar systems and then different soil condition will be considered. Particular attention should be paid to the modeling of appropriate interface conditions, depending on the type of foundation considered.
Uncertainties related to load amplitude, load velocity and soil conditions should be properly taken into account and their effect on the structural performances of the OWT and the robustness of the turbine-soil system should be highlighted.



Different OWT systems

Keywords

Offshore wind turbines (OWT), impact load, structural integrity, structural robustness, soil structure interaction, finite element model (FEM), nonlinear dynamic analysis.

Additional information

[1] The project or part of the project can be developed at the School of Engineering of Sapienza University of Rome, in Italy. Participation in the ERASMUS program is required in this case: application deadline for departures in the winter semester in spring term. Knowledge of Italian is NOT necessary. Free enrollment in Italian language courses is however offered to incoming students who apply.

Essential references

[1] DNV-OS-J101. (2004). Design of Offshore Wind Turbines. Det Norskes Veritas, Norway.

[2] Den Boon, H., Just, H., Hansen, P.F., Ravn, E.S., Frouws, K., Otto, S., Dalhoff, P., Stein, J., Van der Tak, C., and Van Rooij, J., (2004). Reduction of ship collision risks for offshore wind farms -SAFESHIP. Proceedings of European Wind Energy Conference, EWEC, London, UK.

[3] Biehl, F. (2009). Kollisionssicherheit von Offshore-Windenergieanlagen. Stahlbau, Volume 78, Issue 6, June 2009 (in German)

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Project 2: Progressive collapse susceptibility of a long suspension bridge

Background and motivation

Long span bridges are complex structural systems, which may be susceptible to a disproportionate response in case of local failures. Current codes prescribe that disproportionate collapse of structures should be avoided, even in case of rare unexpected circumstances [1] [2], but guidelines and provisions are mostly addressed to the design of buildings [3]. Bridges however represent strategic infrastructures, whose failure typically has repercussion on the whole urban environment and consequences associated to the inoperability of the structure and the cost for repair are very high. Major structural damages of bridges should therefore be avoided even in the unlikely case of extreme wind, terroristic actions, design errors or other unexpected events, which cannot be taken in to account within an ordinary design.

In particular, current regulations for cable-stayed bridges prescribe that the structural integrity should be maintained in case of a detachment or failure of one cable [5] [6]. Leaving aside the causes of the initial failure, this provision focuses on the organization of the elements within the structural system of the bridge, which should be able to maintain the collapse localized. This can be achieved by following two opposite strategies: the first strategies is aimed at creating a redundant system capable of redistributing the stresses caused by the damage over the highest number of elements, so that each element is not overloaded and no further failures occurs; the second strategies is aimed at lowering the redundancy of the system in few pre-determined points, where the transmission of overstresses is hindered and the collapse will come to an halt.

Progressive collapse in bridges, which are characterized by a horizontal load transfer system, may progress along the deck or along the suspension system. Previous studies have highlighted these failure modalities for cable-stayed bridges [7] [8] and for suspension bridges; however possible countermeasures have never been investigated in detail.

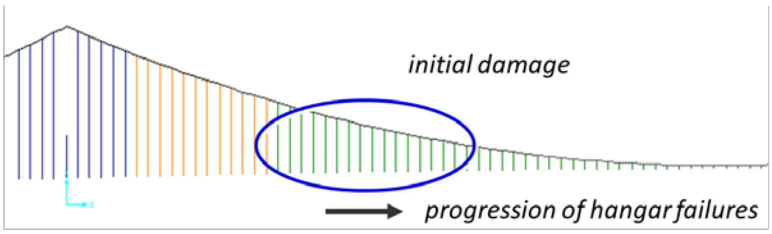
In case of a suspension bridge in particular, the initial failure of one or more hangers causes a dynamic overloading of the hangers immediately adjacent to the failed ones and a moment overloading of the part of the deck left unsupported. Depending on which of the two type of overloading can trigger a failure, a different progression of damages may follow. A deeper understanding of these collapse mechanisms seems therefore of great interest in order to identify suitable and most effective countermeasures to the progressive collapse susceptibility of suspension bridges.

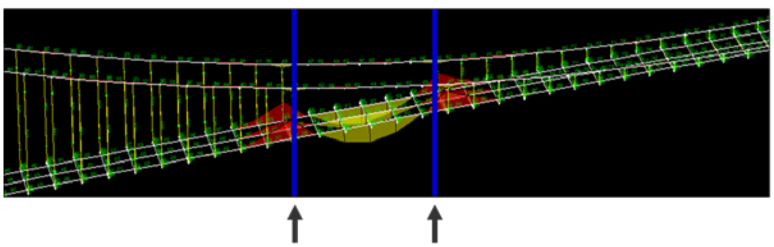
Purpose and method

Aim of this project is to investigate the sensitivity of a long suspension bridge to possible local failures triggered in the suspension system. In particular, a preliminary project done few years ago for the Messina Strait Bridge will be taken as case study and a possible progression of the collapse will be investigated with respect to the entity and the location of the initial damage.

Critical aspects of the structural design such as most dangerous damage type and locations should be highlighted and possible countermeasures for ensuring a standstill of a possible progressive collapse should be investigated. For example, if a possible propagation of the collapse along the suspension system is found, a collapse standstill at some pre-determined hangar locations of the bridge could be envisaged. This could be achieved either by strengthening some hangers or by creating some disconnecting joints along the deck. The effect of these or further similar provisions should be investigated and the different countermeasures should be compared and discussed.

The project will move from previous studies carried out on the same structures [9] and will avail dynamic non-linear FE investigations in order to identify and follow possible progression or standstill of the failures. The FE model will be validated against results of previous studies and will account for mechanical and geometrical nonlinearities, as well as for the dynamic effects of the abrupt failures.





Keywords

Long suspension bridge; progressive collapse susceptibility; collapse propagation; suspension system, hanger strengthening, deck detachment, collapse standstill.

Essential references

[1] EN 1991-1-7 (2006). Eurocode 1: Actions on structures, Part 1-7: General actions - Accidental actions, Comité Européen de Normalisation (CEN).

[2] DS-INF 146, Robustness - Background and principles - Information, Danish Standard Association, 2003

[3] ASCE 7-98 C1.4"Minimum design loads for buildings and other structures", Commentary C1.4: General structural integrity

[4] UFC 4-023-03: “Design of Buildings to Resist Progressive Collapse”, Unified Facilities Criteria, United States Department of Defense, Washington, D.C., 14 July 2009.

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[6] PTI (Post-Tensioning Institute) 2001. Recommendations for stay cable design, testing and installation. 4th edition, Cable-Stayed Bridges Committee. Phoenix: PTI.

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[8] Yan D., Chang C. (2006). Vulnerability of long-span cable-stayed bridges under terrorist event, proc. of the Int. Conference on Bridge Engineering - Challenges in the 21st century, Hong Kong.

[9] Giuliani L., Bontempi F.: “Dynamic analysis for structural robustness evaluation”, proc. of the 4th Int. conference on Bridge Maintenance, Safety and Management (IABMAS’08), Seoul, Korea, 13-17 July 2008

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Evacuation in case of fire

Background

Prescriptive fire safety codes have been developing ever since they were first created and they mainly base on bitter experience from previous fire accidents. The prescriptive codes have requirements concerning e.g. fire safety installations, distance to the nearest exit and width of evacuation routes.

To meet the needs and demands on constructing larger and more complex buildings as well as buildings with untraditional design, several countries have introduced performance based fire safety codes in the last decades. Denmark implemented the codes in 2004 meaning that instead of meeting the requirements stated in the prescriptive codes it is permitted to use calculations and simulations to prove that a building is sufficiently safe, when it comes to fire and evacuation. The calculations involve computations on the dynamic of the fire, fire resistance of the construction and evacuation times. The available safe egress time (ASET) is based on the properties of the fire e.g.

the heat release rate and gives the timeframe on when critical conditions occur. Whereas the required safe egress time (RSET) estimates the time needed to complete an evacuation and is based on e.g. the warning method and system, human behavior and movement characteristics. Comparisons of these two time components are essential in order to prove the safety level.

Topics

There are a number of project opportunities within the field of fire and evacuation. Type and subject of a potential project depends on the student´s interest and competence as well as other ongoing projects. There are no ready to go project descriptions but some ideas can be seen below.

- Project involving evacuation experiment(s) focusing on a special building type, population or part of the evacuation process. This would include use of the portable evacuation lab.
- Project involving evacuation simulations with one or more computer software and comparing the results with experimental data, if available.
- Project involving comparison of different measurement and camera techniques used during evacuation experiments. This would include use of the portable evacuation lab.
- Project involving one or more buildings comparing ASET and RSET and possibly combining with evacuation experiments.
- There is also a possibility of being involved in a larger ongoing research project where a part of the project could be assigned to a thesis.

Keywords: Evacuation, fire safety, evacuation simulation

If you are interested in some of the above mentioned topics you are welcome to contact:

Associate Professor Anne S. Dederichs, B:118, R:262, and@byg.dtu.dk
Ph.D. student Aldis Run Larusdottir, B:118, R:260, allar@byg.dtu.dk
Ph.D. student Janne Gress Sørensen, B:118, R:260, jags@byg.dtu.dk

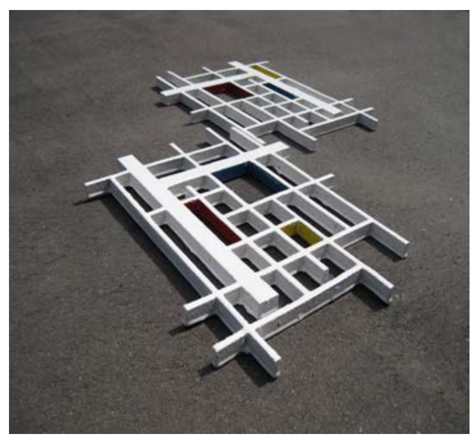
Material design component design

CERAMIC GLAZED CONCRETE AS ART, DESIGN AND ARCHITECTURE

Tests and design of materials, processes, facades and lasting shutterings for buildingindustry. A fund-financed project at Buildingdesign in Collaboration with: C.F. Møllers Tegnstue, Gottlieb Paludan Arkitekter, Densit Aps, Confac, Danmarks designskole med flere.

Er du interesseret i materialer og de muligheder, der er for at designe dem til ny perfomance, kombineret med design af processer relateret til industrien og design af bygningskomponenter, er det her måske noget for dig.

I projektet transformeres nye betonteknologier fra varmformgivningsindustri og designes via materialeteknologiske koncepter, til ny performance, nye mekaniske, æstetiske, stoflige og taktile egenskaber, som afsøges i henholdsvis kunst, design og arkitektur, som keramisk glaseret beton.



Der søges studerende til at lave tekniske test af de mekaniske egenskaber for de redesignede materialer samt beregning af bæredygtighedsaspekter som udgangspunkt for dit design af en facade eller evt. en blivende forskalling. Der indgår fire typer af facader: Den selvbærende, den som indgår i sandwichkonstruktionen, samt halvfabrikatafacaden, der udgør en kasse, som insitu, udstøbes med anden betontype på byggepladsen.

I marts og april 2011 udfolder jeg de 4 typer facader på Statens Værksteder for Kunst og håndværk, Gammel Dok, i samarbejde med internationale keramikere, fra henholdsvis England og Tasmaniaen. Du kan evt. deltage her i workshopsbaserede forløb, ligesom også Danmarks Designskole er inde over.

Du opnår en bred viden om kompositmaterialer og mulighed for design af materialer. Ligesom du lærer at lave forsøgsopstillinger til at afprøve og

verificiere eller falsificere din hypotese. Du lærer også den synteseskabende brede designproces, hvor du tager afsæt i blandt andet den viden du har erhvervet ved forsøg. Du vil efterfølgende kunne agere selvstændigt i brandfeltet mellem design af nye materialer og hvordan de skal bearbejdes og anvendes i byggeri.

Kontakt: Lektor Anja Margrethe Bache

Building Renovation – Transparent shelters and fire hazards

The growing focus on CO_2 emissions' impact on the global climate leads to an increasingly stronger need to reduce the current energy consumption. Approximately 40% of energy consumption in Denmark today is used for heating and operation of existing buildings and it is thus an important area to address. Focus on reducing energy consumption by major renovation and refurbishment projects are expected to be increased in future years in the form of stricter regulations and requirements. Based on this idea, there is a need to develop new products and methods that improve quality and efficiency of building renovations.

In connection with the renovation of existing buildings it is often a dilemma between the relatively high energy consumption of the existing buildings and the architectural value of the exterior of the building. Many existing buildings have some architectural values you do not want to cover in insulation with plaster or insulation covered by different plate materials.

The creation of a transparent shelter over a group of buildings or a transparent covering of a single building is a challenge in many ways. The architecture and the construction, the relation to the existing buildings, the indoor climate with control of heat and cold, ventilation and pollution, the sound, and the fire protection are all elements which should be dealt with in the creation of a transparent shelter.

A transparent shelter will affect the way hot gasses and smoke move away from a fire and will influence the pattern of smoke movement and fire spread as well as evacuation of people and fire brigade intervention.

This project will focus on the aspects related to the building design and the fire protection. The project will include a description of matters to be solved when a transparent shelter is used for multi-storey dwellings, and a proposal for a design model will be drafted and applied on a case scenario.

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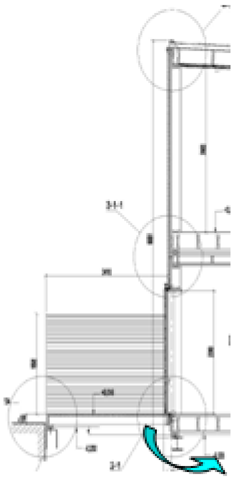
Søren Peter Bjarløv, spb@byg.dtu.dk, mobile: 40384258

Associate Professor, Architect. Field of works: Building techniques, building renovation, high-rise building design etc. Research: Building renovation in Greenland, Ventilation of cold attics.

Annemarie Poulsen, amp@byg.dtu.dk

Annemarie is currently a PhD student at the Fire Group at BYG. She has a background as a fire engineering working with fire testing, consultancy and development of fire regulations and standard.

The new generation of crawl spaces – Building technics and vapor



Dansk:
I de seneste 10 år har der været en række konkrete udspil, der med afsæt i udenlandske erfaringer rettede sig mod at udvikle en dansk model for præfabrikerede billige boliger.
Der har været fokus på, at familier med almindelige indtægter har haft svært ved at bosætte sig i de større byer på grund af stigende huspriser.

De igangsatte initiativer har haft forskellige aktører, der er gået til opgaven på forskellig vis – både byggeteknisk og organisatorisk. Der er særligt tre aktører, der har været fremherskende indenfor dette område; det er BoKlok, som er et samarbejde mellem Ikea og Skanska; det er De Forenede Ejendomsselskaber, Bedre Billiger Boliger; og det er Fonden for Billigere Boliger.

Etablering af fundament og krybekælder for volumenelementerne har krævet nytænkning og kræver yderligere nytænkning fremover. Krybekælderen er nødvendig ved anvendelsen af volumenelementer. Der har tidligere været store problemer med fugt og krybekældre, og indledende målingsresultater fra den nye generation krybekældre indikerer at det er der stadig.

Der er adgang til temperatur og fugtmålinger i krybekældre til 6 forskellige nyere krybekældre hvor der er trykt nogle vejledende aflæsninger i forbindelse med rapporten: Blev de billigere boliger bedre? Evaluering af teknik og produktion. Link:
http://orbit.dtu.dk/Person,contextNavigationMenu.link.sdirect?sp=SPublications

De vejledende målinger der er anvendt i rapporten er kun målt over en kort periode. Der foreligger nu data over ca. 1 år der kan danne grundlag for en kvalificeret vurdering af de forskellige krybekældres performens og dermed mulighed for, på et videns baseret grundlag at designe krybekældre der er egnet til f.eks. de moderne isoleringstykkelser der kræves i dag.

English:
In the past 10 years there have been some concrete proposal, which, based on foreign experience was aimed at developing a Danish model for prefabricated low cost housing.

There has been a focus on ensuring that families with general revenue have had difficulties to settle in large cities due to rising house prices.

The initiatives have had different players who have gone to the task in different ways – both in a technical and organizational way. There are especially three players that have been prevalent in this area, it is BoKlok, which is a collaboration between Ikea and Skanska, it is the "De Forenede Ejendomsselskaber" with Better Cheaper Housing, and it is "Fonden for Billigere Boliger".

Establishment of foundation and crawl space for volume elements has required new thinking and requires more thinking ahead. Crawl space is necessary in the application of volume elements. There used to be great problems with moisture and crawl spaces, and preliminary measurement results from the new generation of crawl spaces indicates that it is still there.

There is access to temperature and moisture measurements in 6 different newer crawl spaces. Some illustrative readings are printed in the report: Were they cheaper homes better? Evaluation of technique and production. Link:
http://orbit.dtu.dk/Person,contextNavigationMenu.link.sdirect?sp=SPublications

The indicative measurements used in this report are only measured over a short period. There are now data of approx. 1 year as the basis for an assessment of the performing of various crawl spaces' and we are now able, in a knowledge-based approach, to design crawl spaces that are suitable e.g. to insulation layers as it is required today.



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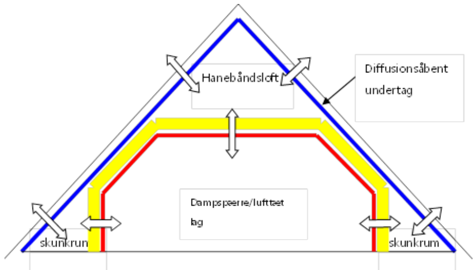
Associate Professor, Architect. Field of works: Building techniques, building renovation, high-rise building design etc. Research: Building renovation in Greenland. Ventilation of cold attics. Crawl spaces.

Data Handling in relation to the research project – Ventilation Conditions in Cold Eaves and Upper Attics

Attempts to efficiently insulate the building envelope have occasionally been hampered by unforeseen obstacles and in order to overcome these new challenges, it has been – and in the future, will be –necessary to develop new technologies and techniques. One of the obstacles encountered while striving to lower the energy consumption, is the mould growth and wood rot found in some of buildings that have been constructed with cold attics.

A cold attic is an attic space where the loft, but not the roof, has been insulated, leaving the attic cooler than the below living areas. Moisture from the conditioned living areas diffuse into the unconditioned attic environment. Travelling through the ceiling insulation, the air cools and as a result, relative humidities rise; in some cases the relative humidities become large enough to cause mould growth and wood rot in the attic.

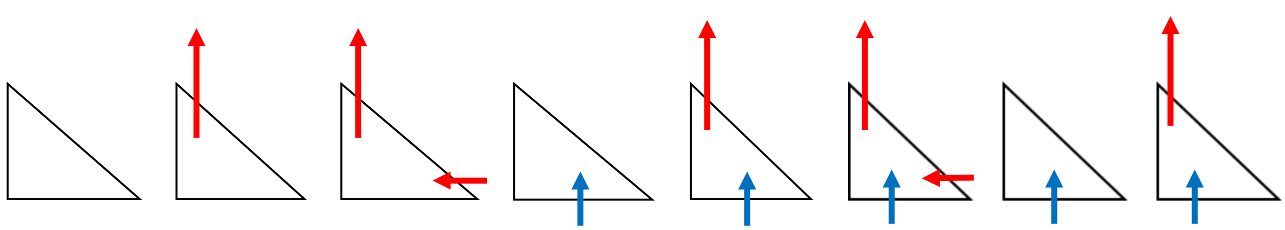


Principles of cold eaves and upper attics

Course Description

The special course will be part of the on-going research project '*Ventilation Conditions in Eaves and Upper Attics in Structures with Vapour-Open Roofing Underlays*'. The project is investigating how different ventilation techniques affect the overall physical environment in cold attic spaces, specifically the enclosed spaces under the eaves and over the collar beams, with vapour-open roofing underlays.

The project is investigating a claim brought forward in a BYG-ERFA informational sheet that states that if a vapour-open roofing underlay is used, then an enclosed space under the eaves with a distance no greater than 1 meter from the outside of the roofing construction to the outside of the interior warm wall (bordering a warm/occupied space in the attic) does not need to be ventilated in order to avoid mould growth and wood rot related problems. The experimental setup of the project has been designed to test the empirically derived design advice set forth in the BYG-ERFA sheet. However, it is planned to extrapolate from the end results and draw more general conclusions. The research project has now been running for more than two years.



Principles of infiltration and ventilation in cold eaves of the experimental model on the experimental site of DTU

The student(s) who decide to follow this special course will be asked to help examine the gathered data. There is comprehensive data on both the weather outside and the hygrothermal conditions inside the experimental setup. The main aim of the exercise is to analyse the data and see if it is possible to find hidden and/or statistically significant correlations between the different variables. In order to do this, it is expected that the student(s) has a rudimentary knowledge of building physics and statistics – with emphasis on building physics. The understanding of building physics will let the student(s) know where to look for correlations and the statistical skills will help them establish the correlations. The student(s) will have a high degree of autonomy and they will decide for themselves how to handle the data.

Contact: Søren Peter Bjarløv, spb@byg.dtu.dk or Christopher John Johnston, cjjo@byg.dtu.dk

Kerto-træ element konstruktion til Roskilde festival

I januar 2012 byggede studerende en mock-up af solar decathlon huset til Madrid.

Disse Kerto træ elementer kan samles igen til en pavillon, men skal tilføjes et eller flere elementer, så de gøres stabile rent statisk og passer til en funktion på Roskilde festival.

Kontakt: Lotte Bjerregaard Jensen, lbj@byg.dtu.dk eller Henrik Almegaard, hal@byg.dtu.dk

Nul-energi bryggeri

Studerende fra DTU Fødevareinstitut og Systembiologi har udviklet et mikro bryggeri. Det har eksisteret med succes et par år som et portabelt udstyr og som en installation i instituttets pilot plant.

Nu vil de gerne have en inspirerende lille bygning til bryggeriet, hvor energien til øl-produktionen er grøn og indarbejdet i bygningsdesignet.

Kontakt: Lotte Bjerregaard Jensen, lbj@byg.dtu.dk eller Timothy John Hobley, tjho@food.dtu.dk

Nye designmetoder til energirenoveringsforslag

Kan nye teknisk-videnskabeligt informerede design metoder skabe energirenoverings-forslag som ikke er en automatik-agtig udskiftning af vinduer og påfyld af isolering? Via kortlægning af sol- og dagslyspotentialet for bygninger i Albertslund (solar mapping) , samt indledende simulering af indeklimaforhold i den eksisterende bygning udvikles strategier for energirenovering som forbedrer energibalancen og indeklimaet - med mindst muligt energi forbrug.

En række bygninger i regi af gate 21/plan C kan være bærere af design forslagene.

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In-Situ Burning of Oil Spills

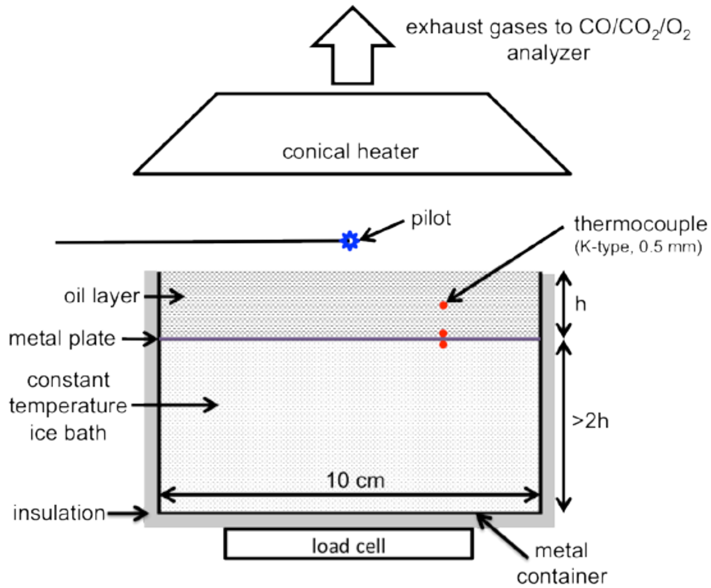
Background:

Several Arctic council reports conclude that oil spills are the most significant threat to the arctic ecosystem. Studies have shown that in-situ burning (ISB) on water can remove more than 90 % of the oil, and is as such the most promising technology for an efficient response to oil spills in the arctic region. However, few studies have been undertaken on the influence of ice on the ignition and burning behavior of oils and on the environmental impact of the residues. This study will therefore include both the "fire science" and the "environmental science" aspects of ISB in cold climates.

Project:

The primary objectives are to evaluate the ignition mechanisms and the burning rate of oils on ice and to assess the environmental impact of the residues (e.g. on microorganisms, wildlife). The results will improve the strategies and the net environmental benefit of, and thereby the success of, oil clean-up after an accidental spill.

Location:
DTU Fire Laboratory, Building 122



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