The effects of wind-driven rain on the hygrothermal conditions behind wooden beam ends and at the interfaces between internal insulation and existing solid masonry

An inevitable measure when energy retrofitting historic buildings in Europe, is the reduction of building envelope heat loss. On preservation-worthy facades where external insulation is not an option, installation of internal insulation is gaining pace. The historic buildings in Denmark are often constructed with solid masonry facades and wooden decks. The internal insulation may, however, entail potential hygrothermal risks in walls and embedded wood. Measures such as vapour barriers and capillary active insulation materials are continuously evolving and the subject of much current research. The hygrothermal conditions are of great importance for the durability of the building constructions, and for the health and wellbeing of occupants. Wind-driven rain (WDR) is a central factor contributing to water penetration and moisture loads of the exterior walls. Numerous studies have shown that WDR loads influence the moisture conditions in masonry walls and embedded wooden beams, and can even affect interior relative humidity. In the present paper WDR loads on existing façades in a cold temperate climate were determined by measurements and compared to a semi-empirical model. Simultaneously, the hygrothermal conditions within internally insulated walls with exposed brick and embedded wooden beams were monitored. Furthermore, numerical simulations were implemented for clarification of WDR impact. Hygrothermal simulations and previous studies, inevitably show that high WDR loads result in higher moisture content behind the interior insulation. Results from the field measurements of WDR however, cannot directly be referred to the moisture content measured in walls behind interior insulation or beam ends. However, fluctuations in external air humidity proved to be influential on conditions in the construction. Implementation of a semi-empirical model for calculations of WDR agreed with previous studies in predictions being too conservative when compared to measured WDR.
Hygrothermal assessment of internally insulated solid masonry walls fitted with exterior hydrophobization and deliberate thermal bridge

Relative humidity (RH) and temperature were measured in several solid masonry walls with embedded wooden beams, fitted with autoclaved aerated concrete (AAC) thermal insulation on the interior surface and exposed to a cool, temperate climate. The field study was based on the use of a 40-feet insulated reefer container reconfigured with eight 1 × 2 m holes containing the solid masonry walls. The study investigated the influence of AAC thermal insulation on the interior side with a combination of exterior hydrophobization and a deliberate thermal bridge in front of the embedded wooden wall plate using a material with higher thermal conductivity. Validated HAM simulations were used to investigate the effect of controlling the indoor humidity, and how this would affect the theoretical risk predictions from the damage models. Experimental findings indicate that hydrophobization of solid masonry walls with internal insulation have both positive and negative effects on the moisture balance of the wall, in relation to moisture-induced damage, and that a deliberate thermal bridge installed in front of the embedded wooden wall plate can reduce the moisture content in the wooden elements. Simulation findings indicate that a combination of exterior hydrophobization and decreased indoor moisture load can reduce the RH to acceptable levels in relation to moisture induced damage at the interface between existing wall and new insulation. No major changes were observed in relation to the risk of frost damage at the exterior surface.

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Hygrothermal assessment of north facing, cold attic spaces under the eaves with varying single sided passive ventilation strategies and infiltration scenarios, in a cool, temperate climate

Relative humidity and temperature were measured in cold attic spaces under the eaves with diffusion-open roofing underlay to investigate different ventilation strategies, the influence of infiltration, and exterior insulated roofing underlay. The project was carried out as a full-scale experimental setup in the cool, temperate climate in Lyngby, Denmark. The objective was to test if the best practice recommendations concerning design of the cold attic space will prevent damaging moisture levels in the attics. Measurements do however indicate that complying with recommendations will not ensure satisfactory moisture levels in the attic spaces. A comparison of the passive ventilation strategies in combination with varying infiltration rates, for attic spaces fitted with diffusion-open roofing underlay, indicate that attic ventilation increases moisture levels. The exterior insulation of the attic space improved the hygrothermal performance.

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Influence of hydrophobation and deliberate thermal bridge on hygrothermal conditions of internally insulated historic solid masonry walls with built-in wood

A large share of the Danish building stock contains historic multi-storey buildings. A considerable energy saving potential exists, achievable through thermal insulation of the façades. Previous research has elucidated problems regarding poor hygrothermal conditions when interior thermal insulation is applied to the façade, but examples exist with positive results.
Eight 1×2m solid masonry test walls with wooden members were installed in an insulated container. The hygrothermal implication of applying 100mm AAC as interior thermal insulation system was investigated with variations including use of hydrophobation and substitution of insulating material with a deliberate thermal bridge.

Relative humidity and temperature were monitored in the walls over 2 years in 10 measurement points. The amount of wind driven rain was monitored with rain gauges and calculated from climate station data. The indoor excess of humidity by volume corresponded to the highest indoor climate class for dwellings.

Damage models indicated risk of mould growth in the insulation/masonry interface, and risk of wooden decay in the wall plate for the reference and insulated case. Hydrophobation of the exterior surface in tempered cold climate reduced the overall relative humidity, although it increased during winter due to a reduced dry-out potential towards the outside.

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Interior insulation—Characterisation of the historic, solid masonry building segment and analysis of the heat saving potential by 1d, 2d, and 3d simulation
When considering interior insulation of historic, multi-storey buildings with solid masonry walls, it is important to focus on two important factors: How big is the building segment to which it can be applied, and what is the significance of how the multi-dimensional geometry of these facades walls is considered in the assessment of the heat saving potential. The findings show that a large proportion of Danish multi-storey dwellings with solid masonry walls, high energy consumption, and uniform characteristics were found to originate from the period 1851–1930. This segment accounts for 25% of all multi-storey apartments in Denmark. It was investigated which relative reduction of the average thermal transmittance could be obtained by interior insulation when simulated in different dimensions, degrees of insulation and thickness. The analysis showed that partial insulation of the spandrels below windows on the 2nd/3rd highest storeys accounted for up to 40% of the average thermal transmittance reduction achievable by fully insulating inside walls, while covering 17% of the space needed in the full insulation strategy. Furthermore, the analysis showed an underestimation of average thermal transmittance by 2-dimensional compared to 3-dimensional simulation by up to 57%, indicating that 3-dimensional analysis is needed to obtain realistic results.

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Interior insulation – Experimental investigation of hygrothermal conditions and damage evaluation of solid masonry façades in a listed building

Exterior walls in historic multi-storey buildings compared to walls in modern buildings have low thermal resistance, resulting in high energy loss and cold surfaces/floors in cold climates. When restrictions regarding alteration of the exterior appearance exist, interior insulation might be the only possibility to increase occupant comfort. This paper describes an investigation of the hygrothermal influence when applying 100 mm of diffusion open interior insulation to a historic multi-storey solid masonry spandrel. The dormitory room with the insulated spandrel had a normal indoor climate with a maximum observed monthly average humidity by volume excess of 3.2 g/m3 during the experiment. Relative humidity and temperature were monitored manually using wooden dowels over 2 years and 8 months in two solid masonry spandrels: one insulated wall and one untreated wall. The investigation showed that installing insulation on a solid masonry spandrel induced hygrothermal changes: Uniformly distributed higher relative humidity and lower temperature throughout the masonry, compared to an un-insulated wall. The relative humidity of the un-insulated masonry wall was in the range 50% on the inside to 60% on the outside, while the insulated wall showed uniformly distributed values around 80%. The risk of moisture-induced damage was evaluated based on mathematical models for mould and decay of wood, visual inspection for frost and mould, and on-site measurements for presence of mould spores. The damage evaluation showed no risk of damage from the changed hygrothermal conditions when applying interior insulation to a solid masonry spandrel.

Long term in situ measurements of hygrothermal conditions at critical points in four cases of internally insulated historic solid masonry walls

In heritage buildings with solid masonry walls, where external insulation is not an option, insulating internally is an alternative way to improve indoor climate and reduce energy consumption and heat loss through external walls. This study
presents results from hygrothermal measurements performed in four different buildings in Denmark where internal insulation has been installed. The buildings are all heritage buildings from 1877–1932 and of solid masonry walls. The insulated façades differ in orientation, surface treatments, location, and insulation system. The insulation materials used are phenolic foam and polyurethane (PUR) foam, with calcium silicate channels in a grid of 40 × 40 mm. Measurement results and hygrothermal assessments indicate that a vapour barrier does not contribute positively to the performance of the system and the more vapour open, the better performance on solid masonry. However, the performance is highly dependent on other parameters like insulation thickness and surface treatment, and above all: the external hygrothermal loads. Therefore, before the application of internal insulation, every case should be carefully assessed in order to find the most suitable solution with regards to both thermal and hygrothermal performance.

Performance of hydrophobized historic solid masonry – Experimental approach
The hygrothermal conditions in historic solid masonry are expected to change for the worse, with the application of internal insulation. Nevertheless, internal insulation plays a role in a holistic energy retrofit of historic buildings. With careful considerations and correct application, hydrophobic treatment may help remedy moisture ingress from external rain loads. This study includes experimental investigations of the effect on hygrothermal performance of various hydrophobization treatments on both brick and air lime mortar. An investigation of water migration through masonry applied with imitated climatic loads is also reported. The study showed a larger efficiency of hydrophobization on specimens of brick compared to the efficiency of hydrophobization of specimens of air lime mortar, which may be problematic in cases where mortar joints are the primary means for water ingress. Silane-based treatments generally proved to be most efficient in brick, whereas a variety of other active components were most successful in air lime mortar treatment. The investigation of water migration showed a distinct effect of silane, cream hydrophobization, though most evident in the external part of the brick.
Material characterization models and test methods for historic building materials

Predictions of long term hygrothermal performance can be assessed by dynamic hygrothermal simulations, in which material parameters are crucial input. Material parameters for especially historic materials are often unknown; therefore, there is a need to determine important parameters, and simple ways for estimation of these. A case study of a brick wall was used to create and validate a hygrothermal simulation model; a parameter study with five different parameters was performed on this model to determine decisive parameters. Furthermore, a clustering technique has been proposed to estimate decisive parameters through simple testing of interrelated parameters that are easier to determine.

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Strengthening requirement specification in sustainable procurement - an investigation of challenges

To reap the benefits of sustainability in the construction sector, it is crucial that the stakeholders involved can implement it in practice. Investigations have shown that choices made in the early phases of the building process are of very great importance for the outcome and the initiatives and decisions taken by the building owner are crucial. This paper presents research on Danish building practitioners' ability to make requirements for sustainability in procurement. On the basis of an action research strategy, we asked practitioners to help identify the challenges involved in requiring sustainable solutions through procurement. These included among others a lack of knowledge or experience in sustainable procurement and interdisciplinary challenges. The research showed that practitioners are able to formulate specific requirements for sustainability in procurement. However the challenges found imply that a sustainable approach in procurement is not fully implemented in a Danish context. This suggests that there is a need for guidance in the area, if the practitioners are to move from good intentions to making more specific requirements for sustainability in procurement.

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A lime based mortar for thermal insulation of medieval church vaults

There are 1700 medieval churches in Denmark, and many of these have brick vaults. The thickness is only 12 – 15 cm, and the heat loss through this building component is large. Thermal insulation has not been permitted until now in respect for the antiquarian values and doubts about the effect on water vapour transport through the vault, and the risk of condensation inside the insulation. A new mortar was developed for thermal insulation of bricks vaults, consisting mainly of expanded perlite, mixed with slaked lime. These materials are compatible with the fired clay bricks and the lime mortar joints. The insulation mortar is applied to the top side of the vault in a thickness of 10 cm, and covered by 10 mm lime plaster, reinforced with cattle hair. This assembly is resistant to the weight of a person, working with maintenance of the roof. The thermal conductivity of the insulation mortar was measured to 0.08 W/mK, which is twice the value for mineral wool. It has 1/3 of the resistance to water vapour diffusion as brick, and a high capacity for liquid water absorption. This is a benefit in the case of rain leaking from the roof, because the water does not penetrate further down into the bricks.

Effect of façade impregnation on feasibility of capillary active thermal internal insulation for a historic dormitory – A hygrothermal simulation study

Internal insulation of external walls is known to create moisture performance challenges due to increased moisture levels and condensation risk on the cold side of the insulation. Capillary active/hydrophilic insulations have been introduced to solve these moisture problems, since they are able to transport liquid moisture to the inner surface and enable it to dry. Experience with this insulation type is rare in Denmark. In hygrothermal 1D computer simulations, several more or less capillary active insulation systems (AAC, calcium silicate, IQ-Therm) in various thicknesses (30–150 mm) have been tested for their hygrothermal performance. The original construction was a 228 mm solid brick masonry wall in a Copenhagen historic dormitory. All simulated systems showed critical relative humidity values above 80% and high risk of mould growth behind the insulation and some also on the interior surface. A moisture safe construction was only achieved when exterior façade impregnation shielding against driving rain was added. The best system showed acceptable relative humidity values both behind the insulation and on the interior surface, a significant increase in minimum temperature on the interior surface, and a reduction of heat loss through the external wall by 85%. The solely application of impregnation also resulted in a moisture safe solution with significant improvements in all parameters and heat loss reduction by 45%. The main conclusion is that capillary active insulation may not be feasible on solid bare masonry walls without additional driving rain protecting especially in case of multi-storey buildings with thin walls in high precipitation areas.
Hygrothermal conditions in cold, north facing attic spaces under the eaves with vapour-open roofing underlay in a cool, temperate climate

Measurements of relative humidity and temperature in eight cold attic spaces under the eaves with varying infiltration and passive ventilation strategies were carried out in a full-scale experimental setup in Denmark. The research project tests whether best practice recommendations given to ensure compliance with the current Danish Building Regulations (BR10) for airtightness (<1.5 l/m² s at 50 Pa pressure difference) can ensure acceptable moisture levels in attics with vapour-open roofing underlays. North facing cold attic spaces under the eaves constitute a worst case scenario. Following best practice recommendations concerning ventilation of the cold attic space under the eaves and fulfilling the requirements in BR10 regarding air tightness of the building envelope did not ensure the absence of mould growth in the attics. Through winter the attics with infiltration through leaks (dimensioned to allow an influx of 3.3 l/s of conditioned indoor air 20 °C and 60% RH at a pressure difference of 50 Pa) and ventilation (singed-sided, passive ventilation) contained more moisture and had significantly higher levels of mould growth than the non-ventilated attics. Under the same physical conditions the ‘pressure equalized’ attic rooms were found to have moisture levels in between those observed in the ventilated and non-ventilated attic rooms. Likewise, the observed levels of mould growth were in between those observed in the cases of the ventilated and non-ventilated attic rooms. Attics with reduced infiltration were not seen to display lower moisture levels but did show lower but still significant levels of mould growth.
Moisture transport properties of brick – comparison of exposed, impregnated and rendered brick

In regards to internal insulation of preservation worthy brick façades, external moisture sources, such as wind-driven rain exposure, inevitably has an impact on moisture conditions within the masonry construction. Surface treatments, such as hydrophobation or render, may remedy the impacts of external moisture. In the present paper the surface absorption of liquid water on masonry façades of untreated, hydrophobated and rendered brick, are determined experimentally and compared. The experimental work focuses on methods that can be applied on-site, Karsten tube measurements. These measurements are supplemented with results from laboratory measurements of water absorption coefficient by partial immersion. Based on obtained measurement results, simulations are made with external liquid water loads for determination of moisture conditions within the masonry of different surface treatments. Experimental results showed a very clear reduction of the liquid water uptake for hydrophobated cases. However, hygrothermal simulations demonstrated clear differences in the effect of the surface treatments on the moisture content of brick depending on the brick type.

Building renovation with interior insulation on solid masonry walls in Denmark - A study of the building segment and possible solutions

The segment size of the Danish multi-story building stock from the period 1851-1930 is established through a unique major database managed by the Danish authorities. The outcome illustrates a large segment with 219,202 apartment units distributed over 14,832 unique buildings, all sharing characteristic geometry. Reduction of average U-value for the exterior façade is investigated in different dimensions, insulation degrees and thicknesses. The analysis shows that compared to insulation of only the infill walls below windows, fully covering insulation yields further 100-150% average U-value reduction. The large segment poses arguments for research into challenges raised by full surface insulation. (C) 2015 The Authors. Published by Elsevier Ltd.
Field study of the indoor environment in a Danish prison
The indoor environment in a Danish prison was evaluated based on measurements made during the summer season of temperature, relative humidity and carbon dioxide, as well as through carefully conducted surveys among the inmates. The temperatures in the cells were high and well beyond common levels in Danish buildings. The mean CO₂ concentrations were generally low, but reached high maximum levels up to 5000 ppm. Thirty-one inmates responded to the questionnaire. They spent on average 19 h in the cell per day (range 12–23 h). Sixty-nine percent of the inmates expressed dissatisfaction with their general indoor environment and all responding inmates expressed dissatisfaction with the thermal climate. Dissatisfaction was mostly caused by a lack of airflow and air movement in the space as well as excessive direct sunlight from the windows. Security is a leading factor in the design of prisons, so a compromise must be found to ensure that the building can comply with minimum health and comfort standards. The findings of this study can be used as background for recommendations for renovation of prison buildings.

Retrofit with Interior Insulation on Solid Masonry Walls in Cool Temperate Climates: An Evaluation of the influence of Interior Insulation Materials on Moisture Condition in the Building Envelope
For historic buildings, where an alteration of the exterior façade is not wanted, interior insulation can be the solution to improve the indoor climate and reduce heat loss, but might also introduce moisture problems like condensation in the wall. Capillary active/hydrophilic insulation materials have been introduced to cope with the moisture problem. An extensive amount of calculations indicating where the challenges lie in the complex work with interior insulation in cool temperate climate has been carried out. In areas with high precipitation like Denmark, capillary active insulation may not be feasible without additional driving rain protecting of the façade.

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Holistic Energy Renovation of Pre- and Postwar Apartment Blocks in Denmark

A significant proportion of apartments in Denmark are built during the years 1930-1970. This group of buildings generally have not exhausted their lifetime, but suffer from immense needs for renovation, both regarding energy use and functionality, in order to bring them near to the standards of today.

This paper presents the Danish research project Holistic Energy Renovation, which aims at performing a holistic energy renovation of two case buildings. As part of the project nine parameters for a holistic renovation have been defined, a method for developing and assessing a holistic building renovation is developed, development of products especially for building renovation has been facilitated and all stakeholders, among those the users of the buildings, have been involved early in the renovation process.

The paper presents the preliminary results of the project including development and test of the assessment method and an evaluation of how the holistic perspective has influenced the project process and product development.

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Method for Developing and Assessing Holistic Energy Renovation of Multi-Storey Buildings

A large part of the Danish building stock is from the post-war era, and thus there is an immense need for renovation within a few years. Also there is a persistent focus on energy use in buildings as it corresponds to about 40% of the total energy use in Denmark. However to secure durable solutions a holistic approach is needed, which takes into account also other aspects than energy such as social or economical values of the buildings.

This paper presents a standardised method for developing and assessing a holistic energy renovation of multi-storey buildings. The method is intended to be used both in the design phase of renovation proposals and for evaluation of the improvements that follow from a holistic energy renovation.

The method was developed as part of a Danish research project on holistic approaches in energy renovation of multi-story buildings. In the project, nine overall indicators are established based on the aspects of "people, planet and profit". The assessment method comprises five elements that span across the nine indicators. The elements consider the economical, architectural, technical and social values of the buildings and also include user involvement as a central element. The assessment method is tested on two case buildings, and the assessment involves all relevant stakeholders including building owner, users, and caretakers.

An element of the project looks to the development of new products and solutions for renovation for buildings. As part of the method, user involvement will be applied in order to guide and optimize the development of proper new products or solutions especially for renovation. The paper will illustrate how this is done in cooperation with manufacturers from the building industry.

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Prospective future introduction of reduction of energy use in buildings in the Arctic regions – How might it affect the indoor climate?

Existing residential buildings in Arctic Greenland often have problems with draughts, uncomfortably low temperatures indoors, and inadequate ventilation. The standard wooden house 18D provides low thermal comfort and poor indoor air quality and has high energy consumption. On the other hand, the new Low-energy house in Sisimiut, Greenland, provides good indoor air, thermal quality and reduced energy consumption. Using measurement data from both buildings, this paper discusses the impact of various issues, such as low indoor relative humidity, temperature variations, and high indoor humidity production, the use of buildings in the extreme Arctic climate with high density of inhabitants, problems with air leakages and overheating creating by solar radiation and heating system, and other issues affecting health of inhabitants. Looking at these issues leads to interesting findings in terms of the relationship between reducing energy consumption and indoor air quality (IAQ), which result from the need for sufficient airflow and sufficient relative humidity levels in buildings situated in the Arctic.

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Super-energy wrap-up model for renovation of standard wooden houses in Greenland?

This paper is based on the developed theoretical practice of super-insulation solution for renovation of exiting standard wooden houses in Greenland built from 1950s until 2006, more than half the building stock in Arctic Greenland. From various perspectives, the wrap-up system is evaluated as a robust building renovation method with focus on applying the membrane for air tightness with a minimum of risk of leakage, high level of insulation with very few thermal bridges, focus on fire protection by using insulation material of mineral wool and high attention on solving details in the building envelope. This interesting wrap-up and package solution can easily be applied to many standard wooden houses in Greenland, but also to wooden houses across the Arctic regions. Linking all these aspects lead to interesting findings about high energy savings, reduction of oil usage and decrease of greenhouse gas emissions in retrofitting of Arctic buildings.

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Blev de billige boliger bedre? Evaluering af teknik og produktion

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The potential and need for energy saving in standard family detached and semi-detached wooden houses in arctic Greenland

The paper gives an account of the potential and need for energy saving in standard family detached and semi-detached wooden houses in Greenland. It is based on studies of house construction compared with Building Regulation requirements and the spread of buildings over time. In the climatic conditions of Greenland, there is considerable potential for energy saving in houses due to their construction, shape and condition. To estimate the total potential for energy saving and thus reducing CO2 emissions, we carried out a detailed investigation of three typical standard semi-detached family houses (type 18D). Temperature, relative humidity and air tightness were measured, and thermal bridges were determined from drawings, visual inspection, and by using a thermal camera. The findings show a current energy consumption of up to 378 kWh/(m²•a) for heating, poor air tightness, a large number of thermal bridges, and high indoor temperatures. We demonstrate a potential for a reduction in CO2 emission by a factor of 10. Finally, the paper describes a practical way of reducing thermal bridges significantly, increasing air tightness, upgrading insulation and adding mechanical ventilation to approximately half of the housing stock without changing the architectural expression or having to relocate the occupants during the renovation.
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Olesen, K. B., Project Participant, Teknologisk Institut
Johansen, C., Project Participant, Teknologisk Institut
Petersen, A., Project Participant, Teknologisk Institut
Hansen, T., Project Participant, Teknologisk Institut
Høegh, B. H., Project Participant, Teknologisk Institut
01/04/2014 → 01/06/2019
Collaborators: Teknologisk Institut

Documents:
Ansgørelse med projektbeskrivelse til - Anvendeligheden og robustheden af indvendig isolering
Ansgørelse til Etape 2 af projektet Xella – indvendig efferisolerelg
Etape 1 af projektet Xella – indvendig efferisolerelg
Experimental and theoretical investigation of Interior insulation of solid brick walls with foam concrete and another silicate based material
Hygrothermal modelling of internal insulation to solid masonry walls
Symposium Præsentation - Britt Haker Høegh (TI)
Symposium Præsentation - Søren Peter Bjarløv (DTU)
Symposium Præsentation - Tessa Kivist Hansen (SBI)
Symposium Præsentation - Tommy Odgaard (COWI)

TI rapport om målinger fra containerforsøget – GI – Anvendeligheden og robustheden af indvendig isolering
TI Slut rapport – GI – Anvendeligheden og robustheden af indvendig isolering
Undersøgelse af robusthed af indvendig isolering

Effect of Façade Impregnation on Feasibility of Capillary Active Thermal Internal Insulation for a Historic Dormitory - A Hygrothermal Simulation Study
Influence of hydrophobation and deliberate thermal bridge on hygrothermal conditions of internally insulated historic solid masonry walls with
Interior insulation - Characterisation of the historic solid masonry building segment and analysis of the heat saving potential by 1d, 2d and 3d simulation
Interior insulation – Experimental investigation of hygrothermal conditions and damage evaluation of solid masonry facades in a listed building
Hygrothermal assessment of internally insulated solid masonry walls - Fitted with Exterior hydrophobization and deliberate thermal bridge
Retrofit with Interior Insulation on Solid Masonry Walls in Cool Temperate Climates
Rapport fra DTU om indvendig efterisolering

Handout om forskning i indvendig Isolering på DTU juni 2019

**Xella – Interior Insulation - Stage 2**
Bjarløv, S. P., PI, Department of Civil Engineering, Design and Processes
Vanek, A., Project Participant, Design and Processes, Department of Civil Engineering
01/05/2018 → 31/12/2019
Collaborators: Xella Group
Documents:
Ansigelse Etape 2 Indvendig Efterisolering med bilag 1-4

**Fugtsikker energirenovering af bevaringsværdige murede ydervægge**
Vanek, A., Project Participant, Design and Processes, Department of Civil Engineering
Bjarløv, S. P., Project Manager, Design and Processes, Department of Civil Engineering
01/11/2017 → 31/12/2023
Collaborators: Danish Building Research Institute, ERIK Arkitekter, IntroFlex

**Symposium om Ventilationsforhold i kolde skunkrum – Etape 2**
Symposium 22 februar 2016 på DTU om Ventilationsforhold i kolde skunkrum – Etape 2
Bjarløv, S. P., Project Manager, Design and Processes, Department of Civil Engineering
Johnston, C. J., Project Participant
Peuhkuri, R. H., Project Participant
Hjorslev Hansen, M., Project Participant
Pold, C., PI, Goritas
22/02/2016 → 22/02/2016
Documents:
Skunkrum 2. etape - Nyhedsbrev 1
Invitation og dagsorden til symposium Fugt i kolde tagrum 2016
Skunkrum etape 2 - Symposium introduktion spb
Skunkrum etape 2 - Er det ventilation CJO
Præsentation af resultater fra kandidatprojekt CP
Skimmel i kolde tagrum RUP
DTU_20160222_Konklusion MHH
modelAttic - an OpenModelica model to examine the hygrothermal conditions in a cold, north-facing attic space under the eaves

The research project was co-funded by the Landowners' Investment Foundation (Grundejernes Investeringsfond) (GI) and supervised by Associate Professor Søren Peter Bjarløv.

Johnston, C. J., Contact Person, Energy and Services, Department of Civil Engineering
Bjarløv, S. P., Project Manager, Design and Processes, Department of Civil Engineering
Hjorslev Hansen, M., Collaborative Partner
Peuhkuri, R. H., Collaborative Partner, Danish Building Research Institute
Pold, C., Collaborative Partner, Goritas
Jensen, N. F., Collaborative Partner, Design and Processes, Department of Civil Engineering

01/09/2017 → 01/09/2018
Nature of activity type: Practical Project
Collaborators: Fonden BYG-ERFA, Goritas, Danish Building Research Institute
Documents:
User guide - modelAttic
modelAttic - OpenModelica model
Miscellaneous weather files
Info on experimental setup
Excel sheet to clean output data
Data used for evaluation
Casper Pold's MSc Thesis

Robust solutions of design of internal insulation in historic buildings with regards to hygrothermal performance
Jensen, N. F., PhD Student, Department of Civil Engineering
Bjarløv, S. P., Main Supervisor
Andersen, B., Supervisor
Rode, C., Supervisor
Fonde
01/03/2017 → 29/02/2020
Award relations: Robust solutions of design of internal insulation in historic buildings with regards to hygrothermal performance
Project: PhD

RiBuild
RiBuild will strengthen the knowledge on how and under what conditions internal thermal insulation is to be implemented in historic buildings, without compromising their architectural and cultural values, with an acceptable safety level against deterioration and collapse of heavy external wall structures. The general objective of RiBuild is to develop effective, comprehensive decision guidelines to optimise the design and implementation of internal thermal insulation in historic buildings across the EU. RiBuild focuses on heavy external walls made of stone, brick and timber framing, as most historic buildings are made of these materials. The general objective is achieved through three main activities

• To obtain a thorough knowledge level to characterise the eligibility of the building for a deep internal thermal insulation renovation. This knowledge is obtained through screening of historic buildings, investigation of material properties and threshold values for failure
• To determine the conditions under which different internal insulation measures are reliable and affordable measures based on probabilistic modelling of the hygrothermal performance, the environmental impact and the cost/benefit
• To develop a set of comprehensive decision guidelines, which are demonstrated in a number of buildings. RiBuild addresses the most difficult retrofitting measure of historic buildings: internal thermal insulation. The adoption of knowledge developed by RiBuild contributes to sustainable historic buildings with improved energy efficiency implying an easier conversion of energy supply from inefficient fossil fuels to efficient renewable energy sources. RiBuild also assesses the hygrothermal performance of the building construction, thus no collateral damage occurs; in case of failure an easy roll back of the measures is possible. The guidelines developed in RiBuild strongly support the deep and holistic retrofitting approach which historic buildings face in the coming years

Work packages
The RiBuild research programme is divided into eight inter-correlated work packages (WPs). For a short description of each work package, please see the following.
WP1: Pre-renovation assessment
Examines common structural elements of historic buildings, determines their physical properties and classifies them according to type. The objective is to observe and describe the main symptoms of a deteriorating building envelope and study their possible causes.
WP leader: RTU
Participants: AAU, TUD, KUL, UNIVPM, DTU, SP, HES-SO
WP2: Material characterisation
Provides data for material properties and threshold values for historic building materials and existing insulation materials as a background for material characterisation models and guidelines for safe retrofitting measures.

WP leader: AAU

Participants: RTU, TUD, KUL, UNIVPM, DTU, SP, HES-SO, INTROFLEX

WP3: Case studies and laboratory measurements

Supports the research with high quality measurement data from both laboratory experiments on components and on-site monitoring of test buildings.

WP leader: TUD

Participants: AAU, RTU, KUL, UNIVPM, DTU, SP, INTROFLEX

WP4: Probabilistic assessment of internal insulation solutions

Develops an efficient strategy for the probabilistic hygrothermal assessment of internal solutions.

WP leader: KUL

Participants: AAU, TUD, HES-SO

WP5: Development of cost/benefit analysis and environmental impact assessment methodologies

Develops a probabilistic assessment methodology for assessing the environmental impact and cost/benefit of internal insulation solutions. The methodologies are based on Life Cycle Impact Assessment (LCA), Life Cycle Cost (LCC) and Cost-Optimal (CO) analysis.

WP leader: UNIVPM

Participants: AAU, RTU, DTU, HES-SO

WP6: Application and evaluation of guidelines

Develops and assesses the methodology for internal insulation of historic buildings, based on the methodologies developed in WP4 and WP5.

WP leader: DTU

Participants: AAU, RTU, TUD, KUL, UNIVPM, SP, HES-SO, INTROFLEX, EMA

WP7: Communication and dissemination

Coordinates the overall communication and network partners of RiBuild.

WP leader: AAU

Participants: RTU, TUD, KUL, UNIVPM, DTU, SP, HES-SO, INTROFLEX, EMA

WP8: Project management

WP 8 is in charge of the overall management of RiBuild.

WP leader: AAU

Bjarløv, S. P., Project Manager, Department of Civil Engineering, Section for Building Design

Hansen, T. K., PhD Student, Department of Civil Engineering

Rode, C., Main Supervisor

Bjarløv, S. P., Supervisors

Hansen, H. T. R., Examiner

Thuvander, L., Examiner

Technical University of Denmark

01/11/2010 → 04/07/2016

Award relations: Bæredygtighed ved renovering af eksisterende byggeri

Project: PhD

Hygrothemal performance of internal insulation in historic buildings

Hansen, T. K., PhD Student, Department of Civil Engineering

Bjarløv, S. P., Main Supervisor

Peuhkuri, R. H., Supervisor

Rode, C., Examiner

Blumberga, A., Examiner
Interior insulation of buildings from 1850 to 1930 with massive external masonry walls and embedded wooden beam floor structure

Odgaard, T. R., PhD Student, Department of Civil Engineering
Bjarløv, S. P., Main Supervisor
Brendstrup, J., Supervisor
Rasmussen, M. H., Supervisor
Rode, C., Supervisor
Thorsen, P. S., Supervisor
Vesterlekke, M., Supervisor
Svendsen, S., Examiner
Hansen, E. J. D. P., Examiner
Harderup, L., Examiner
Industrial PhD
15/12/2013 → 06/06/2019
Award relations: Interior insulation of buildings from 1850 to 1930 with massive external masonry walls and embedded wooden beam floor structure
Project: PhD

Xella – Interior Insulation - Stage 1
Bjarløv, S. P., Project Manager, Department of Civil Engineering, Section for Building Design
Odgaard, T. R., PhD Student, Department of Civil Engineering, Section for Building Design
Svendsen, S., Project Participant, Department of Civil Engineering, Section for Building Physics and Services
Harrestrup, M., PhD Student, Department of Civil Engineering, Section for Building Physics and Services
Pallesen, N., Project Participant, Xella Group
Lauridsen, J., Project Participant, Xella Group
Jensen, N. F., Project Participant, Design and Processes, Department of Civil Engineering
01/01/2014 → 01/05/2018
Keywords: Multipor Vapour open Impregnation Moisture transport Mould
Collaborators: Xella Group
Documents:
Xella – Interior insulation – Final report, stage 1
Project: Research

Anvendeligheden og robustheden af indvendig isolering
Bjarløv, S. P., Project Manager, Department of Civil Engineering, Section for Building Design
Odgaard, T. R., PhD Student, Department of Civil Engineering, Section for Building Design
Vesterlekke, P. M., Project Participant, COWI A/S
Johansen, C., Project Participant, Danish Technological Institute
Pedersen, A., Project Participant, Danish Technological Institute
Hansen, T., Project Participant, Danish Technological Institute
01/01/2014 → 31/12/2016
Keywords: Interior Insulation Moisture transport Mould Impregnation
Collaborators: COWI A/S, Danish Technological Institute
Documents:
Ansøgning om midler til forskningsprojekt om Invendig Isolering 06022014
Project: Research

Ventilationsforhold i kolde tagrum som skunkrum og hanebåndslofter i konstruktioner med diffusionsåbne undertage – Etappe 2.
Bjarløv, S. P., Project Participant, Department of Civil Engineering, Section for Building Design
Johnston, C. J., Project Participant, Department of Civil Engineering, Section for Building Physics and Services
Peuhkuri, R. H., Project Participant, Department of Civil Engineering, Section for Indoor Environment
Hjorslev Hansen, M., Project Participant, Department of Civil Engineering
Project ID: Projekt nr. 26390
01/11/2013 → 31/12/2015
Documents:
Ansøgning om midler til forskningsprojekt om ventilation af uisolerede tagrum - etape 2

User Guide to modelAttic - An OpenModelica model to examine the hygrothermal conditions in a cold, north-facing attic space under the eaves

2019.01.20_Skunkrum etape 2 slutrapport

Project: Research

**Ventilationsforhold i skunke og hanebåndslofter i konstruktioner med diffusionsåbne undertage.**

Bjarløv, S. P., Project Participant, Department of Civil Engineering, Section for Building Design

Hjorslev Hansen, M., Project Participant, Fonden BYG-ERFA

Johnston, C. J., Project Participant, Department of Civil Engineering, Section for Building Physics and Services

Project ID: 26077

01/03/2010 → 01/10/2012

Keywords: beskrivelse af projektet, Kort Ventilationsforhold i skunke og hanebåndslofter i konstruktioner med diffusionsåbne undertage.

Collaborators: Fonden BYG-ERFA

Documents:

Kolde_tagrum_Kort_projektbeskrivelse.pdf

Fugt_i_skunkrum.pdf

Project: Research

**Helhedsorienteret energirenovaering**

Bjarløv, S. P., Project Participant, Department of Civil Engineering, Section for Building Design

Rode, C., Project Participant, Department of Civil Engineering, Section for Building Design

Eriksen, M. S. H., Project Participant, Department of Civil Engineering, Section for Building Design

Stang, B. F. D., Project Manager, NIRAS A/S

Legberg, E., Project Participant, NIRAS A/S

Simonsen, G., Project Participant, URBANlab Nordic

01/01/2011 → 31/12/2013

Collaborators: NIRAS A/S, URBANlab Nordic

Project: Research

**Udvikling af systemløsninger til energimæssigt vidtgående klimakærmsrenovering af eksisterende bygninger samt demonstration på 3 typiske parcelhuse fra perioden 1960-80**

Svendsen, S., Project Manager, Department of Civil Engineering

Tommerup, H. M., Project Participant, Department of Civil Engineering

Bjarløv, S. P., Project Participant, Department of Civil Engineering

Project ID: 26076

Miljøstyrelsen: DKK863,000.00

01/01/2010 → 01/10/2012

Award relations: Udvikling af systemløsninger til energimæssigt vidtgående klimakærmsrenovering af eksisterende bygninger samt demonstration på 3 typiske parcelhuse fra perioden 1960-80

Project: Research

**InnoBYG: Innovationsnetværket for energieffektiv og bæredygtigt byggeri**

Rode, C., Project Manager, Department of Civil Engineering

Bjarløv, S. P., Project Participant, Department of Civil Engineering

Eriksen, M. S. H., Project Participant, Department of Civil Engineering

Project ID: 26128

Forskningsrådene - Andre: DKK1,440,000.00

01/06/2010 → 31/05/2014

Award relations: Innovationsnetværket for energieffektiv og bæredygtigt byggeri

Project: Research

Activities:

**Symposium på DTU 23 maj 2019 om indvendig isolering**

Period: 23 May 2019

Søren Peter Bjarløv (Keynote speaker)

Tommy Riviere Odgaard (Guest lecturer)
Tessa Kvist Hansen (Guest lecturer)
Nickolaj Feldt Jensen (Guest lecturer)
Britt Haker Høegh (Guest lecturer)

Department of Civil Engineering

Description

DTU afholdt den 23 maj 2019 et Symposium om status på 5 års forskning i indvendig isolering med følgende indlægsholdere: Søren Peter Bjarløv (DTU), Tommy Odgaard (COWI), Tessa Kvist Hansen (SBi), Nickolaj Feldt Jensen (DTU) og Britt Haker Høegh (TI). Nickolaj Feldt Jensens præsentation vil blive lagt op når den omhandlende artikel er accepteret.

Degree of recognition: National
Documents:
- Præsentation - Britt Haker Høegh (TI)
- Præsentation - Søren Peter Bjarløv (DTU)
- Præsentation - Tessa Kvist Hansen (SBi)
- Præsentation - Tommy Odgaard (COWI)

Related organisation

Symposium på DTU 23 mai 2019 om indvendig isolering
Søren Peter Bjarløv (Keynote speaker), Tommy Riviere Odgaard (Guest lecturer), Tessa Kvist Hansen (Guest lecturer), Nickolaj Feldt Jensen (Guest lecturer), Britt Haker Høegh (Guest lecturer)
23 May 2019
Activity: Talks and presentations › Conference presentations

modelAttic - an OpenModelica model to examine the hygrothermal conditions in a cold, north-facing attic space under the eaves

Period: Sep 2018
Christopher Just Johnston (Participant)
Søren Peter Bjarløv (Participant)
Morten Hjorslev Hansen (Participant)
Ruut Peuhkuri (Participant)
Casper Pold (Participant)
Nickolaj Feldt Jensen (Participant)

Energy and Services

Department of Civil Engineering

Description

The research project was co-funded by the Landowners' Investment Foundation (Grundejernes Investeringsfond) (GI) and supervised by Associate Professor Søren Peter Bjarløv.

Documents:
- User guide - modelAttic

Links:
http://www.byg.dtu.dk/english/research/publications/software

Keywords: computational model, Building physics, OpenModelica, Moisture problems, wooden beam ends, building renovation

Activity: Other

Indvendig ydervægsisolering – Findes der en sikker metode ?

Period: 29 Mar 2017

Tommy Riviere Odgaard (Speaker)
Søren Peter Bjarløv (Speaker)

Department of Civil Engineering
Related event

Ejendomsmessen
29/03/2017 → 30/03/2017
Copenhagen, Denmark
Activity: Talks and presentations › Conference presentations

Tagboliger i eksisterende ejendomme - planlægning og løsninger
Period: 12 Nov 2015
Søren Peter Bjarløv (Invited speaker)

Department of Civil Engineering
Section for Building Design
Documents:
watch[1]

Related event

TAGBOLIGER I EKSISTERENDE EJENDOMME - PLANLÆGNING OG LØSNINGER
12/11/2015 → 12/11/2015
COPENHAGEN, Denmark
Activity: Talks and presentations › Guest lectures, external teaching and course activities at other universities

Kan Indvendig isolering leve op til kravene om en robust løsning med styr på fugt og temperaturforholdene
Period: 28 Oct 2015
Søren Peter Bjarløv (Invited speaker)

Department of Civil Engineering
Section for Building Design

Description
Invited speaker at Building Green
Documents:
DTU præsentation på Building Green 2015

Related event

Building Green '15
28/10/2015 → 29/10/2015
København, Denmark
Activity: Talks and presentations › Conference presentations

TEMAMØDE FOR ANVENDELSE AF INDVENDIG EFTERISOLERING
Period: 11 Jun 2015
Søren Peter Bjarløv (Invited speaker)

Department of Civil Engineering
Section for Building Design

Description
Anvendeligheden og Robustheden af Indvendig Isolering

TEMAMØDE FOR ANVENDELSE AF INDVENDIG EFTERISOLERING
Documents:
Presentation hos TI 11 juni 2015

Related event
TEMAMØDE FOR ANVENDELSE AF INDVENDIG EFTERISOLERING
11/06/2015 → 11/06/2015
HØJE TÅSTRUP, Denmark
Activity: Talks and presentations › Talks and presentations in private or public companies and organisations

PROJEKTKONFERENCE
Period: 5 Mar 2015
Søren Peter Bjarløv (Invited speaker)
Department of Civil Engineering
Section for Building Design

Description
Anvendeligheden og Robustheden af Indvendig Isolering

PROJEKTKONFERENCE
Documents:
Presentation GI - Indvendig Isolering - 05032015

Related event

PROJEKTKONFERENCE
05/03/2015 → 05/03/2015
COPENHAGEN, Denmark
Activity: Talks and presentations › Conference presentations

Danish Energy Agency (External organisation)
Søren Peter Bjarløv (Participant)
Department of Civil Engineering
Section for Building Design

Description
Tekniske følgegruppe i BR inddragelsesproces

Kære Michael

Med lanceringen af strategi for energirenovation glæder vi os over, at vi skal i gang med at implementere strategiens mange initiativer.

Vi igangsatte nu implementeringsarbejdet for strategiens initiativer omkring bygningsreglementet, herunder justering af lavenergiklasserne og udvikling af energiklasser for eksisterende bygninger.

Vi vil derfor gerne invitere jer til at deltage i en teknisk følgegruppe, hvor I får lejlighed til at give input til arbejdet, og hvor I kan følge processen om ændring af bygningsreglementet tæt.

Vi vil gerne invitere til det første møde den 25. juni d.å., kl. 10-12 i Energistyrelsen, Amaliegade 44. Vi har planer om at den tekniske følgegruppe mødes fire gange fra juni til oktober 2014.

Vi skal bede om, at modtage oplysninger om, hvorvidt I ønsker at deltage i følgegruppen, og hvem der vil deltage. Det er tale om en teknisk følgegruppe, og det er derfor ønskeligt, at deltagerne i følgegruppen har byggeteknisk indsigt.

På det første møde i den tekniske følgegruppmøde vil vi orientere om processen for arbejdet, herunder omkring sidelebende branchespecifikke møder med deltagelse af relevante medlemmer af følgegruppen. Endvidere vil vi på mødet fremlægge oplæg til de temaer, som følgegruppen foreslår at behandle.

I bedes sende tilmelding med navn til Niels Bruus Varming, nbv@ens.dk senest den 20. juni.

I vil inden mødet modtage dagsorden og deltagerliste.

Vi håber, at I vil deltage i arbejdet, og at vi sammen får en god proces og gode resultater.

Med venlig hilsen

Mette
- Tirsdag d. 23. september kl. 13-16
- Onsdag d. 8. oktober kl. 13-16