Environmental effects on buildings and infrastructure

1. Background and objectives

Weather and climate is important in operation and design of buildings and infrastructure. Energy use in buildings is directly linked to the climate, which the building is exposed to. However, today’s models for energy use are vastly inaccurate in their prediction of energy use. One of the reasons for this is the over-simplistic way micro scale climate is utilized in the models, due to the lack of realistic models for estimating the micro scale weather variation on the different facades of a building.

The maintenance cost of building façades is significant in the operation of a building. In taller buildings it is difficult to monitor the degradation and need for maintenance. This is one of the reasons why facades are commonly made of low maintenance materials, such as metal, concrete and masonry. There is a demand for using more environmentally friendly material in buildings. This enhances the importance of understanding the weathering degradation of these materials. To be able to predict the weathering effects of porous building materials it is important to establish accurate models based on laboratory measurements on the materials as well as monitoring on site on the building.

This project will address these issues through a multidisciplinary approach combining state of the art measurements and simulations with novel sensor technology including hyperspectral cameras, IR-cameras and Remotely Piloted Aircraft Systems (RPAS).

2. Research topics

2.1 Energy use in buildings and the effect of micro scale climate

2.1.1 Project description

With increasing focus on energy use in buildings, energy simulations of buildings in the planning phase has become the standard of the building sector. However, building energy simulations show large discrepancy between measurements and simulations. The main objective of the project is to quantify the inaccuracies that are introduced in building energy simulations when using site meteorological data rather than the actual meteorological load that the building façade is exposed to.
Since the Convective Heat transfer Coefficient (CHTC) and the Convective Moisture Transfer Coefficient (CMTC) and thus heat and moisture transport from a building is significantly affected by the wind velocity, one important factor of the meteorological boundary conditions is wind.

The project will use Computational Fluid Dynamics (CFD) of airflow around buildings at urban scale to determine the CHTC and CMTC.

In addition, the method of backward ray tracing on 3D geometrical models of buildings in urban scale will be used to determine the solar heat load on facades on a high level of detail. The solar radiation will be important to determine the relative humidity in the boundary layer of the building, which in turn is central for the hygrothermal properties of the building.

The project will be divided in the following tasks:

- Validate newly developed models (Thiis, Burud, Kraniotis and Gobakken, 2015) for solar radiation, surface temperature and humidity on porous building facades with the use of multisensory technologies involving IR imaging.
- Model the Convective Heat Transfer Coefficient (CHTC) at facades at a district city scale with the use of Computational Fluid Dynamics (CFD)
- Quantify the combined effect of solar radiation and CHTC on the energy balance on buildings on a district city scale using existing building energy simulation tools.

2.2 Weathering of porous building materials

2.2.1 Project description

The main goal of this project is to achieve a better understanding and to model weathering effects on porous materials surfaces using multisensory technologies involving spectroscopy, multispectral and hyperspectral imaging in addition to traditional techniques of chemical analysis. A particular focus will be paid to the study of coated on uncoated wood.

As new developments in architecture are moving towards more use of porous materials, and in particular wooden surfaces as cladding, there is an increasing demand for a better understanding of the degrading effects of these materials by climatic exposure. All materials are naturally exposed to weathering, a general term used to define the slow degradation of materials exposed to environmental agents such as solar radiation, cyclic wetting, atmospheric temperature and relative humidity changes, environmental pollutants and certain micro-organisms. Weathering process leads to a slow breaking down of surface structures, roughening of the surface and reduction of the glossiness. As an example, rapid
changes of color of untreated wood when exposed to weathering are mostly caused by photodegradation of lignin and wood extractives in the middle lamella.

The rate of weathering varies within timber species, function of product, technical/design solution, finishing technology applied but most of all on the specific local conditions. Being able to predict the weathering effect of a porous façade hence depends strongly on the understanding of the different degradation mechanism of the material, and the combination of these as a function of a weather dose. This will be the topic for this PhD project.

There are three main tasks related to this project:

- Spectral imaging of wood

The interest in near infrared spectroscopy and hyperspectral imaging as a tool for rapid characterisation of wood surfaces has considerably increased in the last years. The main advantage of these analytical tools is the possibility of determining both chemical and physical properties of a large number of samples.

Hyperspectral and multispectral imaging is an increasingly used technique to study wood properties as a complementary tool to traditional point spectroscopy. The advantage of hyperspectral imaging is that a full spectrum is obtained in each pixel of the image. Hyperspectral imaging technology was applied in Burud et al. (2014) for evaluating growth of monocultures of fungi on the surface of wooden samples in a laboratory environment. In a follow up study the method was applied to wood surfaces exposed to an outdoor environment at the Sørås field in Ås (Burud et al. 2015).

Hyperspectral imaging of samples of wood and other porous materials will be an important task in the project, and much effort will be devoted to improving the techniques of data acquisition, spectral pre-processing methods, spectral dimension reduction for application of multispectral camera, supervised classification and combined spectral and spatial hyperspectral image filtering.

- Weather doses on weathering effects

Prediction of the degradation effects of a wooden façade depends on a good knowledge of the weather conditions on the surface. It is known that the ambient moisture conditions, temperature and solar irradiance have a large influence on the degradation of wood and mould growth on the surface. However, the exact influence of these parameters is poorly known and none of the existing models of mould growth take into account the surface conditions. Utilizing the surface conditions for the modelling is important, for example, the temperature of the surface can be very different from the ambient temperature on a façade exposed to direct sunlight. In this project we will determine the weather doses for the wood degradation using simulated weather data on the wood surface as found and described in Thisi et al. (2015). Spectral imaging data from samples exposed to outdoor environments will be used to
determine a degradation gradient that will be related to a weather dose using data analysis techniques such as neural networks.

• Monitoring on buildings

The weathering prediction models (including chemical and aesthetical effects) will be validated on existing buildings. IR imaging and imaging in some VIS/NIR wavelengths will be carried out with IR cameras and multispectral camera for monitoring of buildings. These measurements will be used to confront the laboratory predictions with real-world responses. The selection of most suitable spectral bands of the multispectral camera will be determined in the laboratory before any field tests, in order to assure highest classification capability of the system.

References

Thiis, T., Burud, I., Kraniotis, D., Gobakken, L. The role of transient wetting on mould growth on wooden claddings, 6th International Building Physics Conference, IBPC 2015


Burud, I., Gobakken, L. R., Flø, A., Kvaal, K., Thiis, T. Hyperspectral near infrared of wooden surfaces performed outdoors and indoors, NIR news, Vol 6, 1, p4 –7 (2015)