Handbook of Advanced BUILDING CONSTRUCTION

Contributors:

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List of Abbreviations

AHP	Analytical Hierarchy Process
BIM	Building Information Modelling
BPM	Business Process Management
BPMS	Business Process Management System or Suite
BRANZ	Building Research Association of New Zealand
BREEAM	Building Research Establishment Environmental Assessment Method
BUs	Building Units
CBR	Case-based reasoning
CCA	Copper Chrome Arsenate
CDMA	Code-division multiple-access
CRM	Customer relationship management
CSI	Construction Standards Institute
DSS	Decision support system
EATT	Environmental Assessment Trade-off Tool
EDM	Electrical discharge machine
ESGs	Electrical strain gauges
FOSs	Fiber optic sensors
GBCs	Green Building Councils
GPS	Global positioning system
ICT	Information and Communication Technology
ILT	Inter-Laboratory Test
KPIs	Key performance indicators
LCA	Life Cycle Assessment
LCC	Life Cycle Cost
LDS	Laser displacement sensor
LEED	Leadership in Energy and Environmental Design
LF	Low-frequency
MCDM	Multi-criteria decision-making
MSDSS	Material Selection Decision Support System
NACA	National Advisory Committee for Aeronautics
NIST	National Institute Standards and Technology
PC	Personal computer
PPC	Percent Plan Completed
RC	Reinforced-concrete
RRT	Round Robin Test
SHM	Structural health monitoring

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Preface

Construction is the process of constructing a building or infrastructure. Construction differs from manufacturing in that manufacturing typically involves mass production of similar items without a designated purchaser, while construction typically takes place on location for a known client. *Handbook of Advanced Building Construction* contains everything you need to know about the construction process. The objective of first chapter is to investigate inverse modeling techniques as a tool for the detection of moisture leakage locations in building constructions from inside surface moisture patterns. Second chapter shows the uncertainty of field measurements of a lightweight wall, a heavyweight floor, a façade with a single glazing window and a façade with double glazing window that are analyzed by a round robin test (RRT). A construction management framework for mass customization in traditional construction has been presented in third chapter. Fourth chapter describes the scientific advancement in applying aerodynamic theory, refined via modelling and testing, to a specific aspect of the building process of a tall building with potentially significant time and commercial benefits. Fifth chapter discusses the process of developing a decision-support system to support choices in low-cost green building materials. Sixth chapter outlines the early findings of a research project that moves research from desktop simulation to exploring the impact of a construction employing such a vapor check on unoccupied conditions in a real house. Seventh chapter examines how technologies used in energy-efficient residential building construction affect the available saleable floor area and how this impacts profitability of investment. In eighth chapter, a wireless laser range finder system has been employed to directly measure the deflection of structural members in an irregular building that is currently under construction. Influence analysis of a new building to the bridge pile foundation construction has been presented in ninth chapter. Last chapter outlines and draws conclusions about different aspects of the material efficiency of buildings and assesses the significance of different building materials on the material efficiency.

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Chapter 1

EVALUATION OF INVERSE MODELING TECHNIQUES FOR PINPOINTING WATER LEAKAGES AT BUILDING CONSTRUCTIONS

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ABSTRACT

The location and nature of the moisture leakages are sometimes difficult to detect. Moreover, the relation between observed inside surface moisture patterns and where the moisture enters the construction is often not clear. The objective of this paper is to investigate inverse modeling techniques as a tool for the detection of moisture leakage locations in building constructions from inside surface moisture patterns. It is concluded that although the presented methodology is promising, more research is needed to confirm its usability.

INTRODUCTION

Hunting Lodge St. Hubertus is one of the most prominent buildings from the beginning of the twentieth century and is noted in the top 100 list of Dutch monuments. The conservation of the building and its interior are of great importance. The Dutch Government Building Department, which takes care of the maintenance of the building, has expressed their concern about the observed damage due to high moisture levels by the rain that finds its way to the interior at places of inadequate detailing and therefore causes damage mainly near openings in the facade and on the inside of the facade below balconies. The main problem is that the location and nature of the moisture leakages are not easily detectable. We often don't know the relation between the observed inside surface moisture patterns and where the moisture enters the construction. The objective is to investigate inverse modeling techniques as a tool for the detection of moisture leakage locations in building constructions, i.e. we want to investigate the (in)possibilities of pinpointing moisture leakages from inside surface moisture patterns using inverse modeling techniques.

Summary of the Observed Moisture Problems at the Hunting Lodge St. Hubertus

Hunting Lodge St. Hubertus is located on the northern side of the Dutch National Park "De Hoge Veluwe". The Hunting Lodge is built as a guesthouse between 1916 and 1922, by Holland's most well-known architect from that time, H. P. Berlage. The building consists of a low-rise rectangular volume with wings that stretch out diagonally and with a characteristic high tower of over 30 meters height in the middle of the building (see Figure 1). A large pond is situated south-west of the building and the building is surrounded by forest in all other directions.

The damage that occurs in the tower was systematically inspected to enable a thorough assessment of the possible causes of the moisture problems by Briggen et al. (2009). The damage on the inside of the tower, and where possible also on the outside, is systematically inspected. The location and type of each moisture problem are documented in a table, illustrated with a picture of the damage. The moisture problems that manifest themselves in the tower of the Hunting Lodge can be divided in the following categories: efflorescence, cracking, soiling, moist spots, mechanical damage and biological growth.

A few pictures of the moisture damage that occurs in the tower are shown in Figure 2 (Briggen et al. [1]).

Figure 1: Hunting lodge St. Hubertus.

Regarding the location of the damage it can be concluded from the inspection that most damage occurs on the interior surface of the south-west facade of the tower. Since the prevailing wind direction in the Netherlands is south-west, which means that the south-west facade of the tower is subjected to wind-driven rain the most, there appears to be a connection between the rain load of the facade and the damage on the inside. There are no clear differences between the damage on lower or higher floors or between the damage on the middle and on the sides of the facade. Most damage occurs near openings in the facade and on the interior surface of the facade below balconies.

Figure 2: Observed moisture damage in the tower of the building: moist spots and efflorescence.

Methodology

The research method contained the following steps:

(Step 1) Measurements of the external climate, indoor climate and surface conditions (Section 2).

(Step 2) Computational model development and calibration of the parameters (Section 3).

(Step 3) From one of the prominent observed moisture spot, an inverse modeling technique was used to determine the moisture entrance for pinpointing the most likely water leakage (Section 4).

(Step 4) Discussion and conclusions of the approach (Section 5).

MEASUREMENTS

The data set is part of the measurement program at the Hunting Lodge St. Hubertus site, performed during 2006- 2007 by Briggen [1] . Details of this project can be found in Briggen et al. [2] [3] . One of problems seemed to be high moisture contents at the inside surface of the facade of the tower. The construction of this facade is shown in Figure 3.

The outside climate conditions were measured by a weather station within 50m from the building. The inside air temperature and relative humidity were measured using standard equipment (seeFigure 4). A representation of inside surface conditions was obtained by placing a small box (5 cm × 5 cm × 1 cm) against the wall and measures the air temperature and relative humidity inside. The estimation of the measurement error of this method is left over for future research.

The data consists of the measured time series of the indoor and outdoor climate as presented inFigure 5 and Figure 6.

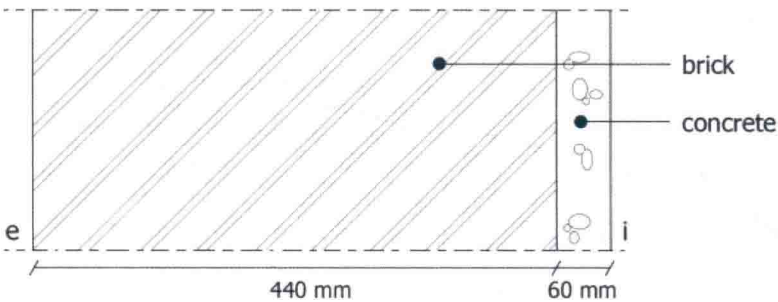

Figure 3: The building facade.

Figure 4: Measurement of the surface temperature and relative humidity using a box.

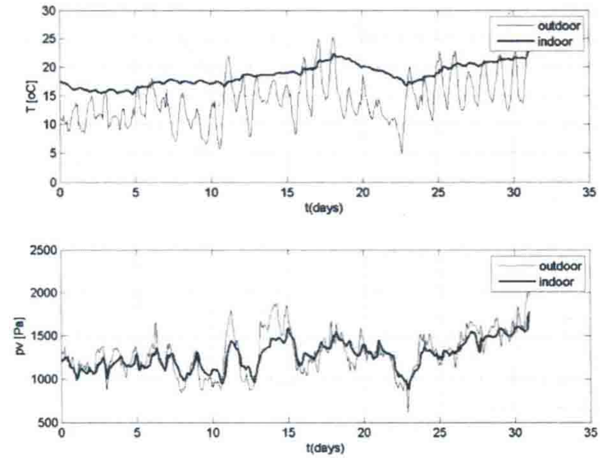

Figure 5: The measured air temperatures (top) and calculated vapour pressures (bottom, from measured T/RH).

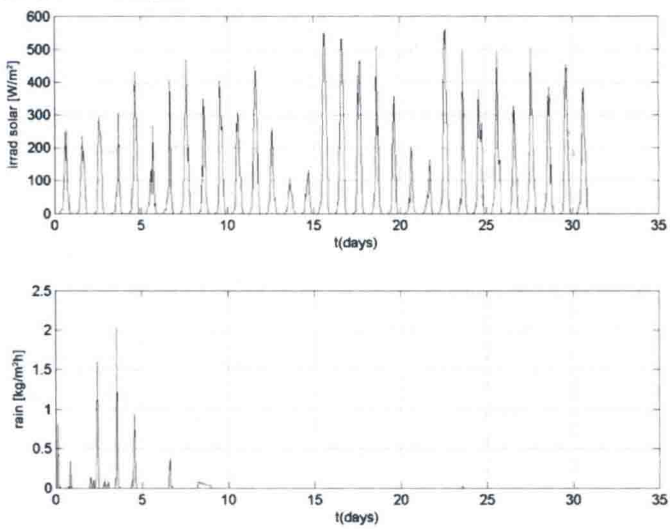

Figure 6: The measured solar irradiance (top) and rain intensity (bottom).

MODELING

The multiphysics modeling approach of van Schijndel [4] - [6] is used. The heat and moisture transport can be described by the following PDEs:

$$C_T \frac{\partial T}{\partial t} = \nabla \cdot \left(K_{11} \nabla T + K_{12} \nabla LPc \right) \tag{1}$$

$$C_{LPc}\frac{\partial LPc}{\partial t}=\nabla\cdot\left(K_{21}\nabla T+K_{22}\nabla LPc\right) \tag{2}$$

where t is time [s]; T is temperature [°C]; The reminder of the terms in the heat (1) and moisture Equation (2) are explained below:

$$LPc={}^{10}\log\left(Pc\right) \tag{3}$$

$$C_T=\rho\cdot c \tag{4}$$

$$K_{11}=\lambda \tag{5}$$

$$K_{12}=-l_{lv}\cdot\delta_p\cdot\phi\cdot\frac{\partial Pc}{\partial LPc}\cdot \mathrm{Psat}\cdot\frac{M_w}{\rho_a RT} \tag{6}$$

$$C_{LPc}=\frac{\partial w}{\partial Pc}\cdot\frac{\partial Pc}{\partial LPc} \tag{7}$$

$$K_{22}=-K\cdot\frac{\partial Pc}{\partial LPc}-\delta_p\cdot\phi\cdot\frac{\partial Pc}{\partial LPc}\cdot \mathrm{Psat}\cdot\frac{M_w}{\rho_a RT} \tag{8}$$

$$K_{21}=\delta_p\cdot\phi\cdot\frac{\partial \mathrm{Psat}}{\partial T} \tag{9}$$

where Pc is capillary pressure [Pa]; ρ is material density [kg/m³]; c is specific heat capacity [J/kg·K]; λ is thermal conductivity [W/mK]; l_{lv} is specific latent heat of evaporation [J/kg]; δ_p vapour permeability [s]; ϕ is relative humidity [-]; Psat is saturation pressure [Pa]; $M_w=0.018$ [kg/mol]; $R=8.314$ [J/mol·K]; ρ_a is air density [kg/m³]; w is moisture content [kg/m³]; K is liquid water permeability [s].

MatLab is used for the implementation of material and boundary properties. These functions are used to convert measurable material properties such as K, ϕ, δ_p and λ which are dependent on the moisture content into PDE coefficients which are dependent on the LPc and T. This is schematically shown in Figure 7.

The material database of DELPHIN [7] is used to provide material properties for the first guess. For brick, the Brick material properties of

DELPHIN are used with constant $\rho = 1700$; $c = 840$; $\lambda = 0.85$ and variable moisture properties using the tables. For concrete, the Lime plaster properties of DELPHIN $(\rho = 1800;\ c = 840;\ \lambda = 1.05)$ are used in the same way. From these data, the PDE coefficients were determined together with the boundary conditions implemented using the COMSOL [8] model of Section 3. Figure 8 and Figure 9 show the results.

Figure 8 shows that the simulated inside surface temperature is already quite close to the measured one.

The simulated relative humidity at the inside surface of Figure 9 seems to be less close to the measured one compared to the previous figure. This gives also rise to the just mentioned questions. For each material and at each point the vapour pressure can be calculated using a similar corresponding function.

DETERMINATION OF MOISTURE SOURCE CHARACTERISTICS

In this section we try to reproduce the following observed moisture spots (see Figure 10).

The modeling approach of the previous section was used. The mesh of (simplified) geometry is presented in Figure 11.

The first step of the inverse modeling procedure is to switch one or more boundary conditions from dry into wet and then investigate it's effect on the inside surface moisture print. For example,Figure 13 shows the simulated profile at the inner surface by switching the location provided inFigure 12 from dry into wet.

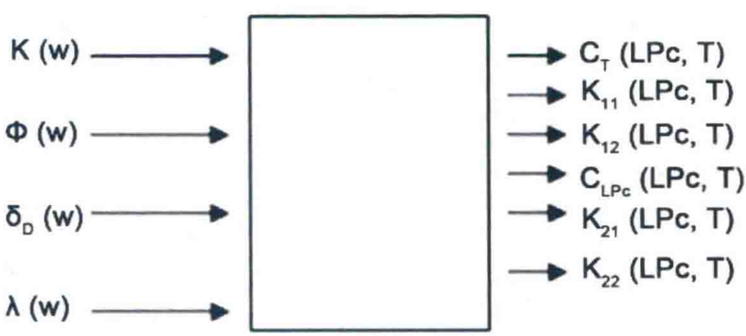

Figure 7: The conversion from measurable material properties into PDE coefficients.