Determination of Liquid Water Transfer Properties of Porous Building Materials and Development of Numerical Assessment Methods: Introduction to the EC HAMSTAD Project

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ABSTRACT: Implications of moisture in building and construction are of interest to the international community because of their huge economical consequences, including effects on health, maintenance and repair, retrofitting and conservation, as well as on common welfare. The present day knowledge offers a potential to tackle such problems, both in the design process and during the service life of building. In 2001, the European Commission initiated the project "HAMSTAD" (Heat Air and Moisture Standards Development) to propose a better modelling methodology than the traditional Glaser method. HAMSTAD focused on the development of draft standardisation procedures on determination methods of moisture transfer properties and a draft methodology for certification of advanced moisture modelling codes. To stimulate competitiveness and progress, the project was carried out following an 'open methodology' instead of a system of deterministic and prescriptive (pre-) standards. This paper outlines the project and highlights the main outputs,

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serving as an introduction to the following more detailed research papers resulting from that work.

KEY WORDS: moisture problems, improved modeling, numeric code assessment, standardization, moisture properties

INTRODUCTION

MOISTURE HAS A major impact on the long-term performance and service life of a building element. A moisture-tolerant building construction leads to the reduced costs of maintenance, repair (reduced intensity) and restoration (less frequent). Approximately 1% of the annual return in the building sector goes to repair of moisture-related damages, which equals 9 billion € per year in the EU. A poor moisture performance may also increase the energy consumption in the built environment. It is estimated that an inadequate design may add 20% to the planned consumption of a low-energy building, leading to a higher CO_2-emission in new construction in the EU of approximately 225×10^6 kg.

Moisture also affects quality of life and more specifically health of the inhabitants. Though 'moisture problems' are not perceived as being a societal problem, they in fact are. In the Netherlands, Belgium, Germany and Denmark, moisture problems were estimated to occur in some 15–20% of the housing stock [1,2], whereas in the UK they occur in about 20–25% [27] and in the coastal region of Israel, 45% of the dwellings suffered from condensation and mould growth [6]. The potential implications of indoor biological growth to human health should not be underestimated. The effects of dust mites and their faeces to human health are known, but it is only in the recent years that the general community has become aware of the effects of indoor fungi [3,28]. It is estimated that approximately 20% of the human population in Europe is allergic to mites and fungi. Reduction of moisture problems reduces costs related to public health, which exceed costs of maintenance many times.

To analyse performance of constructions, tools are needed to evaluate the overall and long-term heat-air-moisture balance. In view of a service life prediction, those tools should deliver a full picture of the 'time-moisture-temperature' situation in a building construction.

STATE OF THE ART IN COMBINED HEAT, AIR AND MOISTURE MODELLING

Combined heat, air and moisture (HAM) started as a separate research topic in the thirties of the twentieth century. A focus of interest in those early days was ‘ventilation of attics and crawl spaces’. Only experiments could be performed, calculation methods were not available [25].

In 1958, Glaser published a diffusion-based calculation method that was physically sound and usable in practice. The method combined steady state vapour diffusion with steady state heat conduction and gave answers to four questions: interstitial condensation or not?; where does it take place in the construction?; how much?; the vapour pressure profile in case of condensation [11]? The method, however, did neither include capillary water displacement, water flow by gravity, enthalpy transfer, transient effects nor initial moisture content as a starting condition and driving rain as a boundary condition. The first physical models also considering these aspects were published in the late fifties and early sixties [21,29]. With the advent of computers, attempts to use these ‘full’ models for predicting the moisture response of envelopes were undertaken [7,16–18,22,26]. Simultaneously, some researchers published methodologies that extended the usability of the Glaser method [14,30]. In the mid-seventies the first computer codes allowed prediction of the transient heat and moisture response of envelope parts and some became commercialised [23]. Meanwhile, efforts were undertaken to measure the material properties needed to run the models, i.e. water conductivity, vapour permeability and moisture retention curve for different building and insulating materials.

In 1990, an international effort, called Annex 24, HAMTIE, started within the International Energy Agency, Executive Committee on Energy Conservation in Buildings and Community Systems, to enhance combined HAM modelling. Air was added, as previous research in both North America and Europe learned that air displacement had an amazing impact on the hygrothermal response of envelopes. The annex focused on model development and comparison, material properties, boundary conditions and the impact of combined HAM-transport on energy consumption and durability. As a result, five benchmark reports were published, a number of improved 1D and 2D HAM-models came in the market and a more thorough research on material properties and durability related aspects emerged [4,8–10,12,13,15,19,20,24]. More laboratories got equipped with devices to measure moisture profiles and retention curves. Attaining some uniformity in measured material property results however remained a challenge.

At present, the actual state of the art may be judged as follows:

- International and national standards mainly rely on the Glaser method, which is physically sound but rarely applicable as a prediction and evaluation tool;
- The physics behind the combined HAM transfer are quite well understood although not always completely explained;

- Present day knowledge enables a more realistic assessment of HAM performance of building constructions.

THE HAMSTAD PROJECT

In 2001, the European Commission initiated the project "HAMSTAD" (Heat Air and Moisture Standards Development) that focused on the development of draft standardisation procedures on determination methods of moisture transfer properties and a draft methodology for certification of upgraded moisture modelling codes.

An 'open methodology', instead of a system of deterministic and prescriptive pre-standards, formed the basic principle of that work. Such approach should allow full freedom to develop and commercialise codes, thereby stimulating competitiveness and progress, whereas assessment of existing codes only would have hampered future developments instead of promoting them. Generally, two successive phases were distinguished in this open methodology: firstly, free code development given well-defined conditional requirements, and secondly, quality assessment of such (commercialised) codes.

Next to this HAM-modelling methodology, also the envisaged measuring procedures considered 'methodology' as a main element in the work. In that context, repeatability was a primary concern in property measurement.

Objectives

HAMSTAD primarily aimed at implementation of present day knowledge of HAM transfer in (new) Standards and generally accepted reference documents. The main objective was to propose a better HAM-modelling methodology than the traditional Glaser method. More specifically:

- To reach consensus on standard methodologies to determine moisture transfer properties (e.g. moisture diffusivity) with acceptable precision and repeatability.
- To propose a reference HAM-document, describing the basic physics of HAM-transport, conditional requirements (i.e. material properties, boundary, initial and contact conditions), and benchmarks with performance requirements, covering a whole range of HAM-related building design questions. Such reference should allow and help competitors to introduce full HAM software packages on the market with a CEN quality mark.

Outline

Accordingly, the project was outlined in two work packages:

1. *Moisture transfer properties and materials characterisation* addressing the process from data generation to transfer coefficient, including Round Robin determination of moisture properties as the pivotal part. The work concentrated on evaluation of six non-destructive measuring techniques on the one hand (NMR, MRI, γ-ray attenuation, capacitance, X-ray projection and TDR techniques, respectively) [35] and data processing and determination of moisture transfer coefficients on the other [36]. Furthermore, an inter-laboratory comparison of determination of basic hygric properties of three porous materials with invariable matrix (clay brick, calcium silicate plate, cellular concrete) was performed [37].
2. *Methodology of HAM-modelling* involving benchmark exercises, in order to investigate sensitivity of calculations to freedom of modelling. The methodology was developed on the basis of definition and calculation of 5 representative HAM benchmark exercises for 1D cases, and subsequently by definition of consensus solutions from the obtained results. These consensus solutions laid the foundation of a quality assessment concept of HAM models [34].

The project was carried out by a consortium of 8 European partners: TNO Building and Construction Research, the Netherlands (co-ordinator) University of Leuven, Laboratory for Building Physics, Belgium; Chalmers University of Technology, Department of Building Physics, Sweden; University of Technology Dresden, Institute of Building Climatology, Germany; University of Edinburgh, Centre for Material Science and Engineering, UK; Technion – Institute of Technology, Israel; Czech Technical University, Department of Structural, Czech; and Eindhoven University of Technology, Department of Applied Physics, The Netherlands. Furthermore, IRC/NRC (Canada) participated on a voluntary basis in the project; Fraunhofer Institute of Building Physics and Eindhoven University of Technology, Department of Building and Architecture contributed to the benchmark exercises.

MAIN DELIVERABLES OF THE HAMSTAD PROJECT

The HAMSTAD project resulted in:

- A pre-normative document describing a methodology for determination of moisture transfer coefficients [32,36]

- Documented proposals for upgrade or revision of (pre) EN Standards on measuring vapour permeability, sorption–desorption curves and water retention curves. The latter has been documented in more detail in the final report of the work package ‘Measuring’ [32].

Both deliverables are basically included in the final technical report [5].

Furthermore, the project resulted in the intended methodology to come to HAM-modelling codes meeting performance criteria, i.e. margins of error. This is covered in a reference document describing the basic modelling physics [33] and a benchmark package [34][1].

The main outputs, i.e. the HAM-reference document, the benchmark package and the methodology for determination of moisture transfer coefficients, have been forwarded to the CEN/TC89 WG10 group as a basis for drafting pre-EN Standards. This group adopted the concept and exercises of the benchmark package and intends to add an additional benchmark.

Finally, a concise scientific description of the main outputs can be found in 4 research papers [35–38] contained in this special issue of *Journal of Thermal Envelope and Building Science*.

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[1] The final reports, its complementary work documents and full descriptions of the benchmarks (including the reference results calculated by the consortium) are available for downloading at www.bouw.tno.nl

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