Research Internship Proposal

Analysis of the uncertainty of the thermal properties of insulation materials on the reliability of building envelope

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Table of contents

1. Context and main issue

The buildings sector is responsible for about 40% of final energy consumption in the European Union (EU) [1]. For year on year this value is tending to increase, thereby accentuating the primary energy demand and consequently the gases emissions such as the CO_2. For this reason, the 27 Members States of the UE have set energy savings target of 32,5% by 2030. Among the main solutions to achieve this objective, experts agree that building insulation is the least-cost one for reducing energy consumption. In this context, the determination of the optimum thickness of the insulation materials has gained more attention in the scientific community in the last few years [2]. The optimum insulation thickness depends on many parameters. Among them, the thermal conductivity, which is the primary property of an insulation material. The design of the building envelope is based on simulation results, which mainly uses, on the one hand, simple computation models unable to reproduce the real physics phenomena related to the thermal exchange process, and on the other hand, some parameters are considered as deterministic, by representing them through "design" or "extreme" values taken from design codes [3-6], despite of their real probabilistic behavior, such for the thermal conductivity [7]. This can lead to wrong decision making in the design stage, and consequently, a significant gap could be observed between the real energy consumption and the one given by the simulation results. In the literature, many studies [8] have been interested on probabilistic analysis of the performance of building envelope considering the uncertain behavior of the thermal conductivity of insulation martials. Unfortunately, most of these studies are based on simple computational models unable to consider the heat losses through thermal bridges. In addition, the uncertainty is taken into account implicitly by the use of safety factors provided by the design codes.

2. Research objectives and approach

The main objective of this Research Internship is to develop a numerical approach able to perform uncertainty propagation analysis through a physical model describing the thermal behavior of insulated building envelopes and to assess its efficiency with respect to the randomness of some material properties. The research work will follow these few steps:

- **Step 1:** Development of 2D deterministic Finite Elements Model (FEM) of a building envelope on the software Castem, and validation through data available on the literature.
- **Step 2:** Modeling the uncertainty of the thermal conductivity of the insulation material using simple probabilistic models, namely random variables.
- **Step 3:** Carrying out uncertainty propagation through the FEM developed in step 1, to assess the effect of the uncertainty of the thermal conductivity of the insulation material on the reliability of the building envelope.

3. Work plan and implications

A detailed work plan for completing the Research Internship is given in table 1.

4. References

[1] Building Performance Institute Europe, Europe's buildings under the microscope: A country-by-country review of the energy performance of buildings. 2011.

[2] Barrau J, Ibanez M, Badia F. Impact of optimization criteria on the determination of the insulation thickness. Energy and Buildings. 76:459–469, 2014.

[3] EN 12524, Building Materials and Products – Hygrothermal Properties – Tabulated Design Values, European Committee for Standardization, Brussels, 2000 (Now withdrawn, superseded by ISO 10456:2007).

[4] ISO 10456, Building Materials and Products – Tabulated Design Values and Procedures for Determining Declared and Design Thermal Values, International Organization for Standardisation, Geneva, 2007.

[5] Heat, air and moisture control in building assemblies – material properties, in: SI (Ed.), ASHRAE Handbook of Fundamentals, American Society of Heating, Refrigerating and Air Conditioning Engineers, Atlanta, 2009 (Chapter 26).

[6] Thermal properties of building structures, in: CIBSE Guide A – Environmental Design, The Chartered Institution of Building Services Engineers, London, 2007 (Chapter 3).

[7] Domínguez-Mu˜noz F, Anderson B, Cejudo-López J, Carrillo-Andrés A. Uncertainty in the thermal conductivity of insulation materials. Energy and Buildings. 42:2159–2168, 2010.

[8] Aissani A, Chateauneuf A, Fontaine JP J, Audebert Ph. Cost model for optimum thicknesses of insulated walls considering indirect impacts and uncertainties. Energy and Buildings. 84:21–32, 2014.

Table 1. *Timetable for completing the Research Internship*

	Month 1				Month 2				Month 3				Month 4				Month 5			
	1st Week	2nd Week	3rd Week	4th Week	1st Week	2nd Week	3rd Week	4th Week	1st Week	2nd Week	3rd Week	4th Week	1st Week	2nd Week	3rd Week	4th Week	1st Week	2nd Week	3rd Week	4th Week
Literature review																				
2D FE modeling and validation																				
Uncertainty modeling																				
Probabilistic coupling approach																				
Energy performance analysis																				
Internship report write-up																				
Internship report submission																				