Ph.D. Research Proposal

Probabilistic analysis of the thermal performance and the environmental impact of buildings envelopes

Supervisors:

Dr. Hassen RIAHI
hassen.riahi@univ-angers.fr
Dr. Thierry LEMENAND
thierry.lemenand@univ-angers.fr

Host institutions:

Laboratoire Angevin de la Recherche en Ingénierie des Systèmes (LARIS)
Polytech Angers School of Engineering
Angers University, France

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1. Context and mains issues

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 thermo-physical properties of the constitutive materials and the climate parameters such as the temperature and the moisture. 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 as 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 [8-12] have been interested on probabilistic analysis of the performance of buildings envelopes considering the uncertainty observed on some input parameters. This variability is usually represented by a simple probabilistic model, namely random variable, unable to model neither the space-variate uncertainty of the thermal conductivity of insulation materials and/or the time-dependent uncertainty of the climate parameters. This is the first issue to solve in the framework of this thesis. The idea is to use random fields and random process instead of random variables. Unfortunately, these advanced probabilistic models contribute most of the time to a significant increase of the probabilistic dimension of the problem, which leads to unfordable computations when using classical uncertainty propagation methods such as Monte-Carlo simulations. Hence, the second issue of the thesis is to develop an efficient uncertainty propagation method based on metamodeling techniques able to handle problems with high probabilistic dimension.

2. Research objectives and approach

The main objective of this PhD thesis is to develop a numerical approach able to assess the effect of the space-variate uncertainty of the thermo-physical properties of the insulation materials and the time-variate uncertainty of climate parameters on the thermal performance and the environmental impact of the building envelope. The research work will follow these few steps:

- **Step 1:** Setting up an experimental device able to evaluate the uncertainty associated to thermo-physical properties of some insulation materials.
- **Step 2:** Development of 2D deterministic Finite Elements Model (FEM) of a building envelope on the software Castem, and validation through data available on the literature and data provided by the experiments conducted in Step 1.
- **Step 3:** Modeling the variability of the uncertain parameters using advanced probabilistic models.
- **Step 4:** Development of an efficient probabilistic coupling approach, able to perform uncertainty propagation through the FEM developed in Step 2.
- **Step 5:** Application of the probabilistic coupling approach to study the effect of the uncertain parameters on the energy saving and the environmental impact of the building envelope.

3. Ph.D. candidate qualifications and skills

The applicant must hold a master's degree in civil engineering, mechanical engineering, thermal engineering or, alternatively, in applied and computational mathematics. Candidates having a prior knowledge on the fields of thermal simulations, stochastic computations and numerical methods will be appreciated. In addition, the candidate must be persistent, and having the ability to work independently without constant oversight.

4. Work plan and implications

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

Table 1. *Timetable for completing the PhD thesis*

	1st year												2nd year												3rd year											
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
Literature review	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Research proposal	■	■	■																																	
Experimental device setup		■	■	■	■	■	■	■	■	■	■	■	■																							
2D FEM of the envelope					■	■	■	■	■	■	■	■	■	■	■																					
Uncertainty modeling														■	■	■	■	■	■	■	■	■														
Coupling scheme																■	■	■	■	■	■	■	■	■	■											
Validation and analysis																							■	■	■	■	■	■	■	■	■	■				
Thesis (and articles) write-up										■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Submission of PhD thesis manuscript																																		■		

5. References

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