A CHANGE OF STATE

THESIS REFLECTION

K.J. Hendriks

Delft University of Technology

1.1 THESIS REFLECTION

This thesis reflection looks back on the different steps taken during the development of the master thesis "A change in state: A thermodynamic and cost-effective optimized Trombe wall based on latent heat storage (LHS) for year round application". First the graduation process and the scientific relevance is discussed and after the societal impact is shown. A literature study showed that the available information on the cost-effective application and optimization of phase change materials within the built environment was limited. The technology readiness level of this material is rapidly growing and the first applications with PCM are already on the market, therefore this study aims to give insight on the actual performance of PCM on a cost-effective application. With this research study three main fields are addressed regarding the Building Technology track, part of the Architecture, Urbanism and Building Sciences master study. These fields are the Building physics, Building Product Innovation and Design Informatics, these fields togeher result in the enhancement of the thermodynamic performance using computational optimization platforms to create an integrated design solution using PCM.

This optimization mainly focuses on reducing the energy demand, the maximum power-load and the actual price of the product. Creating a design solution which is both cost-effective and sustainable, considering the reduction in mechanical devices, at the same time can lead to an interesting business approach for creating a more sustainable office environment.

1.1.1 Research process

The Building Technology master track incorporates a broad spectrum of courses focusing on developing the combination of engineering and architectural design skills to become the sustainable designer of the future. The track is about creating innovative solutions of building components, which can be integrated within the built environment. During my study I created an interest in the use of innovative technology to improve the built environmental and in particular the comfort and energy usage within the building. Therefore this research study explores different optimization strategies to improve the benefits of employing phase change materials within office buildings using knowledge from literature as base for the optimization of a latent heat storage trombe wall.

"A traditional trombe wall is not particularly interesting due to the combination of a heavyweight and opaque structures with a large section thickness; these structures block direct daylight and reduce the amount of usable area within the building. However, the working principle of the system shows some interesting characteristics for the application of PCMs."

Within this study it is about a combination of understanding the working principle of the material and designing a system that encompasses the benefits of the material within an integrated solution. Several methods are used to come to this integrated solution, starting with a literature study to define the concept of thermal energy storage and the commonly found applications and implementation in the built environment. This information is then used to do a more in-depth research on the principle of heat transfer and heat transfer enhancement techniques to improve the rate of heat transfer of the passive trombe wall. These different techniques are translated into various design strategies that are used as input for the simulation and optimization phase, assumptions are made for some of these strategies, these assumptions are made for some characteristics of the wall related to convection and conduction. In the beginning, a combination of a more detailed Computational Fluid Dynamics study within Comsol and an energy reduction optimization within Matlab/Simulink was included in the research framework. The former simulation approach is omitted, this was needed due to the time available for the research study. This resulted in more time available for the main simulation and optimization approach, therefore more time is used for the optimization to give an indication and an overview of the results within different applications. This knowledge is used to gradually lead the process to one optimal design using the information from all the different simulations and optimizations.

Results from the literature study, simulation and optimization phase are directly incorporated into the Design of requirements for the final product and these requirements are used as fundament of the design. Four different optimization paths are adopted, one focusing on the reduction in heating, one in cooling, and all-season energy reduction and one in a combined economic optimization. The results together give a huge insight into the differences between the strategies and the actual difference between the thermodynamic optimal design and the cost-effective optimal design. The study showed that some major differences are observed between the two main optimization strategies, within the target climate chosen for this research study some major contradictions are seen according to the difference in magnitude for the energy demand and the maximum power-load. For the energy demand the summer season is dominant and for the power-load the winter season is the main period to target. Most of the studies seen in literature focus on the detailed optimization and evaluation of the PCM and thermodynamics within the material, this broad study gives another view on the performance of each parameter on the different target applications. Therefore, this research focusses on an combined quantitative and qualitative analysis on the yearly performance of the PCM.

In the end one optimal design is chosen for the design of the PCM product, however not one optimal design is possible when considering this multi-objective optimization. When working with a cost-effective optimization it depends on the scale of consideration, the results within this study are based on three main objectives. Therefore some other important objectives are neglected which also affect the performance on the cost-effectiveness. These objectives are for instance the quality of the product, which is affected by the thermal properties of the material. The choice for these three objectives is mainly based on the accuracy of the optimization, when considering more objectives the results will converge too slow to an optimum value and the algorithm can get stuck at local optimums where the global optimum is wanted. So for the time and computation power available for this research study this method is the most appropriate approach.

1.1.2 Societal impact

Buildings are responsible for almost 40 percent of the total energy consumption from the EU (European Commission (EC), 2018). In many developed countries the use of active climate control systems from buildings and Heating, ventilation and air-conditioning (HVAC) have an enormous contribution to these total greenhouse gas emissions (European Commission, 2018). Sustainable methods to reduce these gas emissions are topics widely discussed and researched within the Building Technology track, creating insight in the use of PCMs to reduce the need of HVAC systems contributes to the knowledge in creating a more sustainable built environment.

At this particular moment in the transition to a sustainable built environment more passive systems are needed to reduce the reliability on for instance Heating, Ventilation and Air-conditioning (HVAC) systems. A major drawback from these passive strategies is the fact that they are mainly based on the use of natural resources such as sun radiation or wind. These resources are unreliable and no constant input can be obtained, this results in a strategy that always needs a backup system to rely on when the sources from nature are not available for specific times of the day. Or, the building user needs to take the temperature exceedings days for granted, on yearly base just some days will possibly exceed the comfort temperatures.

Besides this, the market revenue of latent heat storage is expected to grow significantly due to the interest in more passive heating and cooling solutions. This will reduce the costs for these materials, which results in more economically applicable products. The benefits from the application are especially the reduction in the peak temperatures and the possibility for daylight entry, due to the translucency of the material, creating a more stable and comfortable environment for the occupants.

The results from this study give insight into the benefits related to the energy reduction using different optimization strategies for applying PCMs within the built environment. Results that can easily be adopted and used as input for new innovative solutions when the market revenue of the PCMs increases. In the end this all answers the question: Do the extra benefits of an adaptive passive system outweigh the working principle of a combined system? This question is difficult to answer due to the immeasurable benefits of the adaptability, visible access to the outside and improved daylight entry.

1.1.3 Concluding

Looking back on the overall simulation and optimization study showed me that considering too many variables, categories and target applications resulted in a less detailed research approach,, therefore the results from all the different strategies are analysed less in detail due to an overload in information. The main trends between the different strategies are identified but the more detailed information can be missed during this study, however in this way a more broad view on the application of PCM is given and the actual performance of the simulated parameters within the different target applications are given. The PCM trombe wall is optimized for a cost-effective application within an office building in the Netherlands, giving a considerable investment space available for the design of the PCM product.

European Commission (EC). (2018, May). Energy efficiency - Buildings. Retrieved November 21, 2018, from europe.eu: https://ec.europa.eu/energy/en/topics/energy-efficiency/buildings

European Commission. (2018, November 28). The Commission calls for a climate neutral Europe by 2050.