

## REFLECTION PAPER

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### Research Contribution

This research project will provide a framework for further exploration on the implementation of PCMs in the facades of buildings and on the combination of different melting temperatures that can be used in order for a façade system to respond efficiently to the changing weather conditions. This framework will be derived from the qualitative and quantitative findings collected through a literature study (research papers, articles), hand and digital calculations and experimentation.

Moreover, this research will provide guidelines and recommendations for synthesizing the research findings into façade design parameters and changing them according to the climate of the area where the façade is implemented. More specifically, this research focuses on the South oriented facades of buildings and gives the readers an insight of how PCMs of different melting temperatures in combination with glazing façade units can create a double skin façade system that will be able to perform in different climates, to store energy and reuse it in order to reduce the operational cost of the mechanical heating and cooling systems in the buildings and provide thermal comfort in the indoor space.

By conducting this research, my aim is to provide to façade designers and architects ways to implement PCMs in the building's envelopes and inform them about all the parameters that they should take into account while implementing different kinds of PCMs into a façade system.

### Research Methodology

This research follows the "study by design" logic as it aims to develop knowledge about PCM applications in the field of façade design. The research is divided into 4 steps :

- 1)Literature Study/Case Studies\_** Knowledge background
- 2)Definition of the main research subject** and the **primary objectives** of the research
- 3)Analysis framework** generated by **the interplay through the literature review, weather data analysis** of the research areas, **hand calculations and digital simulations, concept design and performance drawings, experimentation and parametric design tools.**
- 4) Evaluation of the system** will be done by realizing thermal simulations using the Comsol software.

## **1) Literature Review**

The first part of the research includes literature study on many different aspects in order to set the basis of the design. Most information derives from relevant academic sources, research studies and case studies.

The Literature study is very important for me to understand the nature of the PCMs, their main characteristics, their working principle, with which ways they can be applied in buildings and how their integration in the building's envelope can affect energy performance. Moreover, the aspects of thermal and visual comfort in working environments by studying papers related to thermal comfort, heat and its transmission, heat loss and gain were studied, in order to define the variables that affect the indoor environment in an office building and subsequently in library buildings.

## **2) Main Research subject and primary objective**

The main research question remains the same as it was defined from the P2 phase:

What should be the design of an adaptive façade system based on PCM and how should it respond to different climate conditions so as to provide thermal and visual comfort in the indoor spaces of libraries?

The main objective of the research is to design a façade system based on the use of PCMs which is able to respond to different weather conditions and create visual and thermal comfort in the indoor spaces of buildings.

## **3) Design Logic**

### **Weather Data Analysis**

Weather data related to the solar irradiation, the mean and the average maximum temperatures and the wind speed are analysed using the Climate Consultant software and grasshopper for both study areas (Amsterdam, Athens). This step was really important because with these data I was able to make hand calculations and find out in an approximate way the thickness of the PCM containers for each area, the temperatures that may arise in the façade during the four seasons for both climates and the melting temperatures that should be used for each climate separately.

### **Energy Simulations**

Initial energy calculations using as a study case the silent room of the TU Delft library creating an approximate but more normalized rectangular geometry of the room and checking different ratios of PCM and glazing, different PCM types or combinations of different PCM types so as to get an insight on how the type of the PCM and the ratio between the pcm and the glazing in the outer skin of the façade can affect the totals energy demands of the building.(electricity, heating and cooling).All the energy simulations were done using the Design Builder software. Unfortunately, the lack of time and the difficult interface of Mat Lab and the complicated nature of the performance of the system made it impossible every kind of simulation in this software.

### **Design Parameters**

Specifically, in this research I examined different façade patterns applying simple geometries (applied in hexagonal or a rectangular grid). More specifically, I created different types of PCM façade containers having as a base the hexagonal or the rectangular shape. Each one of these types

have different ratio between the glazing and the PCM .The alternate designs that are examined have to do with different combinations of these different types. Unlike the initial design logic which was referred to the exploration of different geometries for the containers which would contain the same type of PCM and the same ratio between the glazing and the PCM, now the design is more focused on the experimentation of simple geometries for the containers and the possibility of implementing façade modules with different melting temperatures and different ratios between the PCM and the glazing per panel. The logic has been changed so as to end up in a more feasible façade design that could be easily constructed and create a final realistic façade product. The use of different melting temperatures instead of only one temperature in the façade design is a result coming from a series of initial digital simulations, hand calculations and from my own assumption that the façade will be able to respond undergoing different weather conditions in an efficient way through the whole year. The interface of Grasshopper was quite difficult as I was not familiar with the parametric design logic before I start working on my thesis project. However, I was given a really nice opportunity to learn a new software and have in terms of seconds a new design to evaluate just by changing some parameters of the definition.

### **Evaluation of the design/ Hand calculations, experimentation and digital simulations**

The façade design will be evaluated through a series of numeric calculations, simulations and physical tests. The most demanding process of this research was the lab physical measurements that were conducted in the Building Physics Lab of TU Delft. The process of the experimentation required much more time than it was expected and as a result not all measurements took place till P4 presentation. The physical measurements gave me useful data about the thermal and the optical behaviour of the PCMs (duration of thermal cycle, optical properties changing with the solar irradiation and the changes in the air temperature). However, the measurements of the heat fluxes did not show logical results and I ended up to the conclusion that something maybe went wrong with the measurement procedure or the function of the heat flux sensors themselves

### **Mock up façade element**

Unlike the initial logic of creating final façade design product, no construction of the façade element will take place because of time limitations. However, under other circumstances it would be nice to be created a façade segment in 1:1 scale in order to be evaluated the thermal performance of the system and the optical properties of the façade when it is exposed to the sun and the air temperature.

