Graduation Plan

Master of Science Architecture, Urbanism & Building Sciences

Graduation Plan: All tracks

Submit your Graduation Plan to the Board of Examiners (Examencommissie-BK@tudelft.nl), Mentors and Delegate of the Board of Examiners one week before P2 at the latest.

The graduation plan consists of at least the following data/segments:

Personal information	
Name	Gabriella Consoli
Student number	5611784

Studio		
Name / Theme	AR3B025 - Building Technology Graduation Studio	
Main mentor	Martin Tenpierik	Building Physics
Second mentor	Michela Turrin	Design Informatics
Argumentation of choice of the studio	In Building Technology there is only one studio called Graduation Studio. However, there is great variety of topics to focus on. My research focuses on Building Physics and Design Informatics. Since in my first year of Building Technology I focused more on other subjects, I wanted to challenge myself and learn more about these two topics before graduating.	

Graduation project	
Title of the graduation project	Phase Change Materials Trombe Wall: Exploring the potential application of PCMs in a modular design for thermal and daylight comfort
Goal	
Location:	Temperate climate (Amsterdam)
The posed problem,	The built environment is looking for new solutions to face climate change. Despite the potentialities of passive design strategies related to thermal inertia, their application is still limited. Building components as trombe walls could increase the wall's thermal mass. However, their traditional design is opaque, massive, and permanent. Innovative solutions such as Phase Change Materials (PCMs) trombe walls reduce the downsides of classic trombe walls. However, the application of PCMs is often customized due to their limited expansion. Therefore, great consideration must be given to the design

	of a modular and energy-efficient PCMs trombe wall that can fulfil the user's needs.
research questions and	The research evaluates the thermal and daylight performance of a trombe wall with PCMs integrated in existing buildings that are parametrically optimized to be energy efficient. This is achieved by answering the following research question: How can a **modular** and **translucent** **PCMs trombe wall** be integrated as a passive strategy in **existing** and **energy-optimized** buildings to work as **heating** during winter and **cooling** in summer? To address the main topic of the research, the following sub research questions were formulated. • Which **passive design strategies** are applied in energy-optimized buildings and **how** do they affect their thermal inertia? • Which **room variables*** are considered to achieve a PCMs trombe wall that could **adapt** to various buildings? * The term 'room variables' requires an explanation to be understandable. Aiming at a flexible trombe wall to various residential buildings, the panel must be adapted with the least number of changes. Therefore, some of the common characteristics that differ from each room have been taken into account from the design process. They correspond, for instance, to room area and orientation. • How are the **thermal performance** and **daylight admittance** affected by the room variables and the PCMs trombe wall? • What is the **final appearance** of the room and trombe wall if is researched a **balance** between the **best results** of thermal and daylight simulation? • Which **strategies** could in the future be developed to bridge the **gap** between a **customized** and **unique** PCMs product and a **standardized** and **modular** component?
design assignment in which these result.	The aim of this research is to further explore the use of trombe walls with phase change materials as infill. The study focuses on two current aspects explained in the

	following paragraphs. As a whole, the research could offer a solution to expand the application of PCMs, and more generally, of passive design strategies by designing a modular and energy-efficient panel. The first objective is to research approaches able to expand the use of passive design principles as, in this case, PCMs trombe walls. This is achieved by exploring how multiple factors affect the thermal and daylight performance of the trombe wall. The results are translated in the design of a modular panel and in a workflow that simplifies the future integration of PCMs trombe walls in the built environment. The second objective of the research is to investigate the relationship between the thermal performance and daylight admittance of buildings and how the PCMs trombe wall can act as an intermediate element between them.

Process

Method description

The first part of this study corresponds to the **theoretical framework**, which consists of the relevant literature to validate the research.

Secondly, there is the **preliminary research** phase where all the necessary factors are defined. A reference case study simplifies the data collection (orientation, temperature, climatic conditions) for the simulations. At the same time, certain properties are selected as (room and trombe wall) variables to be simulated for each value. After having defined all the contextual factors, the materials for the PCMs trombe wall are selected. On the other hand, the outcomes of previous research are translated into design guidelines to determine the first boundary conditions for the trombe wall design.

The next step consists of **digital research** through a design framework. Once the variables of both the room and trombe wall are defined, the thermal energy simulations are iterated on MatLab/Simulink. The performance of the trombe wall is tested as a heating system during the winter and a cooling device on summer days. The simulations are at room level (macro scale), and therefore, test the energy efficiency of the entire panel. While the thermal simulations are run in MatLab/Simulink, daylight simulations are performed in Grasshopper to calculate the spatial Daylight Autonomy (sDA) of the room. In particular, the research analyses the effects the various room and trombe wall configurations have on the building demands.

Once the simulations are concluded, the results are evaluated. Focus is given to the values that fulfil both the thermal and daylight building demands. The software ModeFrontier enables to read from a multitude of results by using post-processing tools. The results of the simulations are integrated in a workflow that illustrates the thermal and daylight performance of the trombe wall for the design configuration selected by a user. In general, the workflow is developed as a strategy to expand the application of PCMs trombe walls by creating an interaction between the customer and the product.

As last step, the most performing design configuration is selected as scenario for the placement of the PCMs trombe wall. On the other hand, the product is developed at macro and micro scale to assume its **final design**.

Literature and general practical preference

The **literature research** is divided into five categories, providing a higher level of detail on the research focus. It begins with an overview of computational design and parametric design, followed by a description of the building envelope, which represents the outermost layer of buildings. The level of detail is then further increased to focus on a specific building component, the trombe wall. Finally, attention is directed towards the material used in the trombe wall: phase change materials.

The literature that validates the research was found through databases such as TU Delft Repository and ScienceDirect. Some keywords - such as ‘parametric design’, ‘passive design strategies’, ‘modularity‘, ‘facade’, ‘trombe wall’, and ‘PCMs’ - simplified the research process. The sources were saved in Mendeley, an online library to organize the references. Then, they were grouped depending on their focus: computational design, building physics, and phase change materials.

Overall, the literature research was beneficial as basis to carry out the design stages of this study. The theoretical knowledge was investigated to understand concepts related to computational design, daylight, thermal energy storage systems, trombe walls, and PCMs. Moreover, the acquired information ensured a critical evaluation in the application of these topics in the built environment.

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Reflection

1. What is the relation between your graduation (project) topic, the studio topic (if applicable), your master track (A,U,BT,LA,MBE), and your master programme (MSc AUBS)?

The graduation topic belongs on the Building Technology master track of TU Delft. Indeed, the research focuses on the integration of a modular and energy efficient PCMs trombe wall in existing residential buildings in the Netherlands. The building component is developed especially on its technical aspects by focusing on its thermal performance and daylight transmittance. The research topics relate with Building Physics and Design Informatics (two subjects of the Building Technology master track).

2. What is the relevance of your graduation work in the larger social, professional and scientific framework.

The research is looking for strategies that can expand the use of PCMs in the built environment. Indeed, the few PCMs products on the market are customized and unique, thus being affordable for a small range of clients in terms of cost and time of production. The lack of modular and standardized PCMs products is due to their limited knowledge. For this reason, it is essential to keep researching this material and finding strategies to expand its application in the built environment. This is accomplished in this research by demonstrating the great potential of the PCMs trombe wall, which can act as an intermediary element between the thermal and daylight building demands.

Indeed, the research was developed to enlarge the information in PCMs by analysing unexplored aspects of the material. In particular, the trombe wall was, ideally, developed as a product to be on the market. Therefore, the outcomes of the research were converted into guidelines that simplify to customers the functioning of the product, and more generally, of PCMs.

Despite the trombe wall was only theoretically developed to be on the market, the thesis envisioned to leave its workflow as the basis for further research. The workflow consists of the research methodology and the description on how the tested parameters affect the building performance. For instance, a further researcher could investigate other room variables, and then, combine the results to gain a wider overview.

Research plan