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](mailto: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:

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<tr>
<th>Personal information</th>
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<td><strong>Name</strong></td>
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<td><strong>Name / Theme</strong></td>
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| **Teachers / tutors** | dr. Martin Tenpierik  
dr. Michela Turrin |
| **Argumentation of choice of the studio** | n/a |

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<tr>
<th>Graduation project</th>
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| **Location:** | Delft - Netherlands  
Seville - Spain |
| **The posed problem,** | Due to the constant strong rise in energy demand in the building sector, efforts have been recently focused on taking advantage of innovative materials and technologies. One of the attempts to reduce the demand is to make use of the available thermal energy whereby it is captured and released in a later period. This technology dates to ancient architecture, but has been abandoned in modern architecture. Thus, current buildings rely on large quantities of mechanical methods of heating and cooling.  
It has been established that considering the building envelope as a mediator of heat transfer and storage rather than a static boundary can help to manage the energy management effectively. This can |
be done by dampening the indoor air temperature and lowering the temperature peaks for a more comfortable indoor environment. The building envelope can take advantage of the diurnal changes in temperature and solar radiation as a means of maintaining the ever-growing comfort demands.

For the designer, the main goal is to determine the optimal design of this thermal mediator. An optimal design would be aimed at its potential to reduce the energy consumption whilst addressing the functional requirements of a façade. Research has shown that different geometrical configurations have a considerable effect on the way that thermal energy is managed within the building envelope. Additionally, the advancement in simulation and digital manufacturing has given the possibility to create complex geometries, manipulate materials and therefore establish optimal performance. Such geometrical complexity makes it possible to study the component at different scales. Thus, the role of the designer is shifting towards performance-based design. These technological advances have just started to be explored in the built environment realm. The available potential data and the effects this has on architectural parameters are infinite and have not been yet thoroughly investigated.
### MAIN
- How can the design of a translucent trombe wall system based on Phase Change Materials (PCMs) be geometrically morphed to improve thermal performance?

### SUB
- Which trombe wall parameters and requirements need to be addressed in this design, if it is situated within an office typology?
- What strategies can be adopted to improve the overall energy performance of the trombe wall for both temperate and semi-arid climates in summer and winter?
- What implications do the micro, meso and macro scales of geometry have on the thermal performance of this wall?
- What material distribution is optimal\(^1\) for the design of this wall?
- How can digital design and manufacturing aid the advancement of passive climate design?

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1. An optimal design would be aimed at its potential to reduce the energy consumption whilst addressing the functional requirements of a façade.

### design assignment in which these result.

The design of an optimized translucent trombe wall using PCM based on surface and geometrical configurations to improve the thermal performance. This wall will capture, store and release thermal energy to decrease the overall energy consumption and admit sufficient natural light into office typologies with glazed facades.
The research through design methodology will be adopted for this graduation project whereby design will play a central role to acquire new knowledge. The research will be divided into the following steps;

01 KNOWLEDGE
This graduation project will be based on knowledge arising from three aspects;
1. The building envelope as a heat sink
2. The effects of geometry on thermal performance
3. The material – translucent PCM
Throughout this phase the role of computational design with respect to manufacturing, simulation and optimization will be highlighted.

02 CONCEPTUAL DESIGN
Following the compilation of existing outcomes in geometry design within the context of heat storage, a conceptual design phase will follow. Using the reference case of an open-office typology in two different climates, several geometrical alternatives in the three scales (micro-meso-macro) will be explored. The use of evolutionary principles within parametric design to search for goals will also be adopted for the micro and the macro scales (Octopus + Grasshopper).

Parameters at each scale which will affect the geometrical designs include;
A. MICRO – where the geometrical articulation of the surface will influence the rate of heat transfer and the amount of solar radiation absorbed.
   1. Self-Shading
   2. Airflow
   3. Surface Area

B. MESO – where the material distribution within a module will influence the heat storage and thermal lag.
   1. Thermal Lag
   2. Material Selection
   3. Material Distribution
   4. Wall Thickness
   5. Material Buoyancy

C. MACRO – where the overall geometrical configuration of the modules will influence the daylight admitted and the global energy demand reduction.
   1. Daylight Admittance
   2. Energy Consumption Reduction
   3. Wall Buoyancy
03 DIGITAL DESIGN
In this phase, the ideal concepts will be digitally modelled, and tested using simulation software (COMSOL) to determine the effectivity of the design concept for each geometry scale. Although the scales will be approached separately, this phase will specifically address the effects that one scale has on another scale and will therefore be analyzed in a holistic manner. Following the formulation of the initial results, the models will be optimized for the aforementioned parameters.

04 PHYSICAL TESTING
The optimal designs for the micro and macro scales will be 3D printed and an experiment will be set-up to analyze the effects of geometry on heat transfer, thermal storage and daylight admittance. Measurements will include airflow, degree of self-shading, heat flux at mesoscale, air temperature and heat distribution visualization by means of a thermal camera.

05 COMPARISON AND EVALUATION
All the results of the geometrically articulated models will be compared with a flat elementary model to determine the influence of geometry. The physical results and the simulation results of the microscale and the mesoscale will be compared and discussed.

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**FIG 1: GRADUATION PROJECT MAIN PHASES FLOW**
FIG 2a: DETAILED GRADUATION PLAN PROCESS part I

FIG 2b: DETAILED GRADUATION PLAN PROCESS part II


Reflection

Relevance

SOCIETAL
Heat storage strategies have been studied extensively however they are not widely embraced by designers. Therefore, this research aims to enhance the idea of the building envelope as a heat sink by integrating thermal performance within geometrical configurations. Additionally, this study promotes the use of passive climate elements thus enforcing the reduction of energy consumption within the built environment and the design of pleasant indoor working conditions.

SCIENTIFIC
Modern means of manufacturing has made it possible to explore certain aspects in passive climate design which haven’t yet been investigated. Through the use of computational methods and innovative materials, this research will challenge the existing concept of thermal mass and how complex geometries can affect the distribution of thermal energy.

Time planning

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LITERATURE STUDY
- Literature Study - Thermal Storage
- Literature Study - Heat Transfer Principles
- Literature Study - Geometry effects (Micro/Meso/Macro)
- Literature Study - Case Studies
- Literature Study - Material Selection + PCM
- Literature Study - Role of Computational Design

FOCUS
- Project Case Study - Translucent PCM Trombe Wall
- Problem Statement + Research Question
- Formulate Methodology

CONCEPTUAL DESIGN
- Micro-Geometry Design Alternatives
- Macro-Geometry Design Alternatives
- Macro-Geometry Design Alternatives

DIGITAL DESIGN
- COMSOL
- Micro-Geometry Simulation + Optimization
- Macro-Geometry Simulation + Optimization
- Optimization on a combined design

PHYSICAL TESTING
- 3D Printing of Macro-Geometry
- 3D Printing of Macro-Geometry
- Experiment Setup
- Initial Testing (specific parameters)
- Testing for Thermal Performance
- Comparisons + Discussion

DOCUMENTATION

PRESENTATION