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**

<table>
<thead>
<tr>
<th>Name</th>
<th>Shirin Masoudi</th>
</tr>
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<tbody>
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</tbody>
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**Studio**

<table>
<thead>
<tr>
<th>Name / Theme</th>
<th>Building Technology – Sustainable Design Graduation Studio</th>
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<tr>
<td>Teachers / tutors</td>
<td>Dr.ir Tillmann Klein</td>
</tr>
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<td></td>
<td>Dr. G.J. Hordijk</td>
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<tr>
<td>Argumentation of choice of the studio</td>
<td>Taking advantage of the outdoor environment to achieve indoor comfort has a relevant importance in the design process to decrease the energy demand of the building. The adaptive facades are an interesting opportunity to reach this result because of their characteristic of changing condition according to the variation of the exterior environment. Among the parameters that adaptive facades can control, a study of the visual comfort will be done because, more than other parameters, it has a strong dependence on the characteristic of the façade and it is highly determined by it. Moreover, it has significant impact on the users and can help in reducing the energy demand.</td>
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**Graduation project**

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<tr>
<th>Title of the graduation project</th>
<th>Adaptive façade Design for the Regulation of Visual Comfort</th>
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**Goal**

| Location:                                           | The Netherlands                                      |
| The posed problem                                  | Architecture has been always                        |
affected by historical, political, social and artistic influences. What is now shaping architecture is the sustainability concept (Lechner 2015). In fact, it has been reached awareness on how much the human is responsible for the pollution and CO₂ emissions, in particular in the building sector. Among the aspects involved in the sustainability issue, the energy consumption covers the most important position; as reported by the European Commission, the building sector in Europe consumes, just for its operation, the 40% of the final energy. Of this amount, office buildings consume the 26% of energy and the 44% of it is used for lighting. Therefore, there is a big opportunity for the architects and engineers to deal with this problem by decreasing the energy demand and replace the fossil fuel consumption with renewable sources. Decreasing the energy demand is a relevant aspect because it requires design strategies that influence the building configuration. To reduce the energy demand, it is fundamental to look retrospectively at our predecessors in the ancient times to become aware of how they used the environment to design their constructions. These techniques can still be applied. The advantages of the contemporary architects and engineers are the technological developments that can be used as a
Some design strategies are thought to have a good performance in determined moments like winter or summer, day or night, but they do not have the same good result in other situations. This happens because of the static configuration of the buildings that does not reflect the dynamism of the outdoor environment. The façade is the element that separates indoor and outdoor space and this should have a flexible and adaptive design to better respond to indoor and outdoor stimulus and taking advantage of the latter, with the final goal of reaching the indoor comfort with low energy consumption.

Among all the parameters that the façade can control, visual comfort is the most dependent on the façade configuration. It has a strong link with the thermal comfort and sometimes with the energy production because all of these parameters depend on the solar radiation. The tendency to have fully glazed facades has some pros like transparency and high amount of daylight, but has also some cons like glare and solar heat gain in summer. The adaptive technologies usually applied to solve these problems are shading systems that are not integrated in the glazing, but are located at the exterior of the building. The shading system has advantages, but it causes also drawbacks like the reduction of view, the diminution of light and therefore a rise of energy consumption for artificial lighting. Many techniques
that are applied on the glazing have thermal purposes, but they are not always developed to contribute to the visual comfort. The big advantage in treating both the aspects is to obtain a fully glazed façade that maintains its transparency and performs to achieve the visual and thermal comfort requirements. The reduction of daylight in the late afternoon entails the consumption of energy for the artificial lighting. For this reason, it can be interesting to study the opportunity to apply smart materials that function as a light source without the consumption of energy. Unfortunately, the development of smart materials for architectural purposes is slow, but the possible application will be investigated.

Considering that this research is developed in connection with a construction company, an additional problem addressed is that sometimes there is a gap between architects, construction companies and production companies. In some cases, the demand of the designer does not find an answer in the market and vice versa the production and construction companies offer products that, even if efficient, do not meet the architectural needs.

In Addition, the main highlighted problems are the following:

- In Europe, office buildings consume the 10,4% of the final energy and specifically 4,6% for lighting;
- A static building envelope cannot optimally perform in
a dynamic environment;
- The tendency to have fully glazed façade to improve the transparency and the amount of daylight cannot be combined with shading systems that reduce these parameters, but they have to be combined into the glazing, in collaboration with other technologies that help solving other climate specifications.
- Depending on the time of the year, after the sunset there are still some hours when the offices are working and the artificial light is needed. A possibility to decrease the artificial lighting demand will investigated by studying new smart material properties and potentials.
- The possibility to apply new materials and techniques is usually impeded by the slow development of these for architectural purposes.
- Sometimes there is a gap between architects, production and construction companies. This makes complicated the relationship between demand and offer.

<table>
<thead>
<tr>
<th>research questions and</th>
<th>Main question:</th>
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<td>How can a product integrated in a glass façade, increase the visual comfort and decrease the energy consumption of an office building by using adaptive technologies? How can this solution be combined with</td>
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Sub-questions:

What is an adaptive façade and what are the current products, state-of-the-art and future trends in term of design, control and material application?

Considering an office environment, which are the requirements that influence comfort? Focusing on visual comfort, what are the parameters and the requirements that characterize the space and what is their relationship with the user?

What are the characteristics of Rollecate Group®’s products, what are their components, how do they influence the indoor comfort?

Is it feasible to apply smart materials, for example fluorescent or photochromic materials, to regulate the amount of daylight and to elongate the lighting time for the whole office day?

Considering the previous questions, how can an adaptive façade solution be designed and/or combined with products of Rollecate Group®?

Considering existing adaptive products/facades that regulate thermal comfort and energy production, how can they be implemented to perform visual comfort? How can they be applied to Rollecate Group®’s products?

How do the push and pull factors regulate the market and how should
| design assignment in which these result. | Considering the problems previously displayed, the aim of this thesis is to propose a product that improves the visual comfort of an office building thanks to the application based on the state-of-the-art and the trends of adaptive façades. The idea is to design a product integrated in the glazing façade, preferably in combination with other solutions that already solve other requirements like thermal or energy production, to eventually obtain a complete product that can contribute in reducing the energy demand. The study will also consider how to relate these solutions with the products of Rollecate Group® assuring a design that reflects the future trend of adaptability. Beside the study of adaptive façade, it is important to analyse the requirements of visual comfort and indoor comfort in general for an office building. The idea of applying smart materials can be challenging because introducing new materials in architectural context is a slow process and the simulation can be inaccurate. Moreover, to physically test the materials, an interest from Rollecate Group® would be fundamental for an investment of time and resources on the project. |

**Process**

**Method description**

This thesis has been developed in phases that are the steps commonly followed during a design process. A specific knowledge about a subject is needed to understand what has already been done and what are the potentials and the future possible developments. The following steps have been taken during the thesis:
1. Research and literature review about:
   - Adaptive facades
   - Indoor comfort and in particular visual comfort
   - State-of-the-art about materials and technologies
   - Rollecate products

2. Design process
   - Design project that starts from a Rollecate product and is implemented with adaptive techniques and materials
   - Design modelling, simulation and testing
   - Collection of the results and improvements
   - Final product

1. Research and literature review

The literature review is a fundamental step because it is the base on what the design will be developed. This thesis started with a request from Rollecate Group® to investigate the adaptive façade technology and to come up with a vision on its future trends. An analysis on the adaptive façade has been done. In particular, many examples of buildings, products and prototypes have been considered and classified according to the date of realization, on the external parameters that they take advantage from and on the final result that they achieve. This analysis helped understanding for which intent the adaptive facades are usually applied and, thanks to an overview of the products over the time, how the different techniques evolved. This was helpful to have a vision on the possible future trends. A similar classification has been done with the materials commonly used in adaptive products. The study of materials for architectural application is slow and some decades can pass before a new material can be applied into a project. Because of that, the progress of the materials development has to be considered to know if a determined material is applicable in a short time.

Because the office buildings represent the 10,4% of finale energy consumption in Europe, a reduction of their energy demand can have a positive impact in the sustainability goal. The climate requirements of this environment are investigated and a particular attention is focused on the lighting that represents the 44% of its energy consumption. Therefore, a further research has been conducted on the visual comfort and how this can be improved with adaptive envelopes. Moreover, among the materials previously classified, a further research is carried out on the ones that have a highly application for visual comfort purposes.

The visual comfort has a strong correlation with the materials used both in the indoor environment and in the façade. In particular, the latter has a strong influence on the transmission of light and the presence of glare. Therefore, a study is done on the glass typology and the frame materials used in Rollecate.
Group®’s products. This would help deciding which materials will be maintained for the final project and which have to be substituted or implemented.

A shallow analysis on the push and pull theory will be applied to generally understand what are the driving forces of the market and how this can influence Rollecate Group® and its interest in the product development. Moreover, to better address the product to the necessity of the architects a questionnaire has been formulated to have the opinion of the architects about adaptive façade and what they expect from this technology.

2. Design process

At the end of the first part of the thesis, an overall knowledge about existing adaptive facades is reached and an idea on what are the future trends can be formulated. On the base of this knowledge, the products of Rollecate Group® can be implemented according to the adaptive strategies. Some possible designs are proposed and later a dialogue with Rollecate is needed to understand their interest in the solution proposed and how these can be developed and eventually tested. Contemporarily, a model and a preliminary simulation are realized.

The most promising solutions are chosen and further developed with the realization of drawings, models and simulations. According to the design, a study of the materials and/or specific techniques is carried out. Depending on the Rollecate’s interest, some physical tests could be done to measure the performance of the different options. Simulations and tested results could be eventually compared.

At the end, the most promising product is chosen and analysed into detail. The visual comfort performance is simulated, and the correlation with the other climate parameters is detected. In particular, the visual comfort is strongly correlated to the thermal performances and the energy saving and production. According to the interest of Rollecate Group® in the project development, some physical prototypes and test could be conducted.

**Literature and general practical preference**


Reflection
Relevance

The final product will be a possible approach of improving the visual comfort in an office building by using adaptive façade strategies. This will have a social, environmental and economical relevance. The visual comfort has a big impact on the user both on his health and on his productivity. The latter has an economical benefit that is added to the more relevant reduction of energy consumption for artificial lighting. Considering that the visual comfort is usually correlated to the thermal comfort and the energy saving and/or production, the economical and environmental contribution increases.
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**Literature Review**
- First research and case study
- General research questions
- Research on Adaptive facades
- Research on Visual Comfort
- Case studies analysis
- Analysis of material
- Study products of Rollecate Group®
- Define research questions
- Graduation Plan
- Research Framework - Literature review
- Meeting with Rollecate Group®
- Presentation

**Engineering for sustainable development**
- Building Physics - retake exam
- Further research and literature review
- Meeting with Rollecate Group®
- Selection of case studies specific for the design

**First design phase (drawings, 3D model)**
- Study of microenvironment (computer models and simulation)
- Report
- Presentation

**Second design phase (drawings, 3D model)**
- Final material/technology choice (3D model, simulation)
- Meeting with Rollecate Group®
- Material/prototype + testing
- Report
- Presentation

**Final Design improvement**
- Final drawings, 3D model and simulation
- Evaluation final design and conclusion
- Final report
- Final presentation