A digital design tool for Floods and Heatwaves resilient facade system

Reflection

Graduation Project

Msc Building Technology track
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1. What is the relation between your graduation topic, the studio topic, master track Building Technology, and master programme (MSc AUBS)?

My graduation topic is "A digital design tool for floods and heatwaves resilient façade system" which is a subset of the Studio topic "Digital design tool for climate resilient structures". This research specifically focuses on the quantification of façade resilience in a multi-hazard scenario, taking into account both floods and heatwaves. This thesis is categorized under the Building Technology track, specifically under the chairs of Structural Design and Façade & Product Design. The project requires a multidisciplinary approach, necessitating the gathering of knowledge from structural design, façade design, building physics, and the risk management methodology derived from natural hazard engineering. The outcome of this project is expected to provide valuable insights for designers, architects, and decision makers involved in the design of building envelopes. Ultimately, it aims to enhance overall resilience in the face of environmental challenges.

2. How did your research influence your design/recommendations and how did the design/ recommendations influence your research?

The literature study provides a strong foundation for the development of this design tool. The research explores several existing methodologies and current advancements in this field. It also compares these methodologies to evaluate their impact on resilience quantification. By identifying and analyzing these methodologies, the research highlights key findings and research gaps in this area. The integration of the literature review offers valuable information on hazard stressors, such as the impact of heatwaves and floods on building facades and human comfort. Additionally, the research adapts certain methods for analyzing large datasets, which are applied in this thesis project. Thus, the literature study significantly aids in understanding hazards and their impacts, guiding the design and recommendations. Conversely, the design and recommendations significantly influenced the direction and focus of this thesis research. By establishing clear design goals and criteria, specific areas requiring deeper investigation were identified. This iterative process highlighted the need for more detailed analysis of certain methodologies and datasets, leading to a more comprehensive understanding of thermal and flood resilience. The practical application of design principles also prompted the exploration of novel approaches and tools, which were then incorporated into the research. Furthermore, feedback from the design phase helped refine research questions and objectives, ensuring that the study remained aligned with real-world challenges and practical solutions. Overall, the interplay between design and research enriched both aspects, resulting in a more robust and relevant thesis project.

3. How do you assess the value of your way of working (your approach, your used methods, used methodology)?

To assess the value of the approach, methods, and methodology used in this thesis, several criteria can be considered:

Effectiveness
This study effectively develops a digital tool for resilience quantification of the building facades against floods and heatwaves. By integrating the interdisciplinary approach and employing a robust quantitative methodology, including detailed computational simulation, the research isolates critical facade parameters and uses machine learning model to predict the output. This digital tool will assist facade designers and engineers in making informed decisions while designing the resilient facade system.

Efficiency
The digital tool helps designers save time by streamlining the comprehensive and time-consuming analysis required for resilient facade design. By simplifying complex steps, it enhances efficiency in the design process.

Innovation
After conducting a comprehensive literature review, the primary discovery was the absence of a tool capable of assessing the impact of building facades across multiple hazard scenarios in the current world. Existing studies predominantly focus on quantifying resilience at the urban, city, or building levels. Consequently, a tool is required that offers a streamlined approach for designers to assess resilience at the building facade level, given that facades serve as the initial point of contact in any hazardous event.

Impact
The development of this digital tool stands to have a profound impact both within academic circles and in real-world applications. Academically, it represents a significant advancement in the understanding of resilient facade design, particularly in the face of multi-hazard events like floods and heatwaves. By introducing innovative approach such as computational simulations and machine learning model, it paves the way for further research and experimentation in the field. Moreover, it serves as a valuable educational resource, offering students and researchers hands-on experience with advanced analysis techniques. In practical terms, the tool aims to revolutionize the design process, allowing architects and designers to expedite the creation of resilient facades while minimizing the complexity of analysis. This efficiency not only translates to cost savings for architectural firms and construction projects but also contributes to the creation of buildings better equipped to withstand and recover from natural disasters.

4. How do you assess the academic and societal value, scope and implication of your graduation project, including ethical aspects?

Currently, the world is experiencing severe climate change, leading to numerous devastating hazards. Floods and heatwaves are among those with the most profound impact on infrastructure, human health, and ecosystems. Various projects are currently ongoing to assess resilience at broader geographic scales, i.e., city, district, and region. However, there is still a need for a tool or method specifically designed to evaluate resilience and performance at the facade level during extreme events. My graduation work, focused on developing a digital design tool for a facade system resilient to floods and heatwaves, holds profound relevance in broader social, professional, and scientific contexts. On a social level, it directly contributes to community resilience by ensuring buildings can withstand multiple hazards, enhancing public safety during extreme weather events. Professionally, architects, engineers, and decision-makers benefit from the integrated methodologies, advancing design practices and supporting informed decision-making in urban planning and construction. Scientifically, the multidisciplinary approach of the project, incorporating structural design, facade design, and risk management, contributes to the understanding of creating climate-resilient structures, with potential implications for further studies in the field. In essence, my work addresses pressing societal needs, improves professional practices, and contributes valuable knowledge to the scientific community.

5. How do you assess the value of the transferability of your project results?

The primary objective of this study is to quantify the resilience of building facades against heatwaves and floods. This project employs a streamlined methodology for calculating facade resilience, which includes identifying hazard stressors (in this case, heatwaves and flood stressors) and determining their impact on the building envelope and human comfort. The methodology involves several key steps: identifying the hazard stressors, conducting computational simulations, applying machine learning models, performing sensitivity analysis, and ultimately calculating the resilience score of the facade. The aforementioned workflow is versatile and can be adapted to other hazard scenarios, such as wind storms or earthquakes, with modifications to the computational simulations. By altering the weather files and adjusting local input values, this tool can be applied to any location worldwide to quantify facade resilience. Therefore, with appropriate adjustments, this tool can be adapted to different hazard scenarios and various locations, making it a valuable resource for resilience assessment globally.

6. How does this project contribute to sustainable development?

This thesis makes a significant contribution to sustainable development by providing an assessment strategy for facade resilience. In the current world, the frequency of devastating hazards has significantly increased, directly affecting infrastructure, human life, and ecosystems. This tool assists designers and facade engineers in making informed decisions when designing resilient facade systems. Resilient facades are better able to withstand severe hazards, experience less impact, and recover more quickly after disruptions. Using this tool, designers can evaluate all critical parameters and configure facades based on the hazard intensity of a given site, thereby minimizing destruction during disruptive events. Consequently, employing this tool will directly contribute to the sustainable development of society by enhancing the resilience of buildings and reducing the adverse effects of natural hazards.

7. Did you encounter any challenges during this study, and how did you address them?

Unavailability of Hydraulic Simulation Tool for Flood Impact on Facades:

As discussed in Chapter 4, the digital tool developed in this study aims to quantify the impact of floods on facades. However, simulating the flood-facade interactions computationally proved difficult due to the lack of suitable software and the complexity involved. It took three months of trial and error with various simulation tools, including OpenFOAM, SimScale, Flow Design, SolidWorks, and Butterfly CFD, before reliable results were achieved. Ultimately, the computational simulations were successfully conducted using ANSYS Fluent. Due to the complexity and time required for each simulation, it was impractical to simulate all 163,840 scenarios. To address this, a mathematical model was developed to calculate the outputs for these scenarios, and the results were verified with ANSYS Fluent.

Modification of Heatwave Hazard Data:

Typically, weather files (EPW files) for any location contain standard data, such as dry bulb temperature, relative humidity, and wind speed. However, this thesis focused on extreme heatwave conditions, necessitating modifications to the weather data. Several tools, including CCWorldWeatherGen and EnergyPlus Weather Converter, were tested for this modification. However, the generated EPW files were incompatible with the Grasshopper script used for computational simulations. Eventually, extreme heatwave weather data were extracted from nearby weather stations and incorporated into the typical weather file using Dragonfly, a Grasshopper plugin, to effectively simulate extreme conditions.
These challenges underscore the complexity and innovative aspects of this research, highlighting the need for adaptable tools and methodologies in resilience assessment.