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	Kyujin Kim
Student number	5570743

Studio		
Name / Theme	Building Technology / Sustainable Structures	
Main mentor	Simona Bianchi	Structural Design (Structural Design & Mechanics)
Second mentor	Alessandra Luna Navarro	Façade & Product Design (Design of Constructions)
Argumentation of choice of the studio	For my graduation project, I aimed to create a digital environment that enhances research through design. I chose to focus on the topic of resilience, specifically designing tools for climate resilient structures that would aid in making resilience based decisions.	

Graduation project	
Title of the graduation project	A design Tool for Heat and Seismic Resilient Façade System
Goal	
Location:	Groningen, Netherlands (for a case study)
The posed problem,	The current procedure for designing facades does not ensure resilience under multi-hazards, despite the significant damage and danger posed by the fragility of facades. This is due to a lack of tools that can apply hazard to the performance analysis and induce design factors that determine resistance to proposed risks. To address this issue and facilitate the resilience-based design of facades, a quantitative resilience assessment procedure needs to be implemented. This requires evaluating the complete range of building performance that the facade contributes to, including thermal and structural characteristics, during disruptive events and the recovery phase that follows. Additionally, there is a lack of available tools that can solve the multi-hazard problem, as existing procedures do not consider the combined effect of multi-hazards. It is difficult to understand how the performance of various building components of the façade work together to form overall resilience to multiple hazards. With the increasing number and diversity of disruptive events imposed on the built environment, the need for robust methods that allow for the quantification of

	resilience is becoming increasingly important. However, existing frameworks are mostly qualitative, which has limited applicability in emergency cases or retrofit scenarios with high uncertainties and lack of time for broad assessments. This issue is further compounded by the fact that indices that express the degree of hazard and performance metrics that assess building performance vary from study to study.
research questions and	The main research question is: How to identify which facade system of combined technologies promote integrated resilience to heat and seismic hazard? The main research question can be divided into: - How does heat and seismic hazard act on the facade, which functional layer of the facade and consequently which building performance? - How to model facade system for simulation, to enable comparative analysis of both structural and thermal performance? - What intensity indexes, performance indicators, and resilience metrics should be used to analyze failure behavior of facade in the wake of a disruptive event?
design assignment in which these result.	The purpose of the research is to promote facade resilience, to facilitate resilience based design decision making. More specifically, is to identify the design/decision parameters that impact the resilience of a facade system under two or more hazard factors. With more knowledge of these determinants will allow facade resilience to be included in early decision making, enable a more integrated approach to facade design. As a research outcome, "A design tool for heat and seismic resilient façade systems" is proposed. This design tool is a framework in which risk and design factors are input parameters, and the quantitative resilience capacity of a set of facade systems to the corresponding hazards are output variables. The framework aims to address the complexity of facade design by utilizing a multi-hazard approach. By considering the potential impact of different hazards on the facade and presenting design solutions that address those hazards, the framework helps architects and engineers make informed decisions about the design of the building's facade that enhance its overall resilience.

Process

Method description

The thesis aims to deliver a digital tool that aids in facade design decision making through quantitative resilience assessment. The research draws upon multiple domains of knowledge, including 1) Facade Resilience, 2) Facade Design Process, and 3) Quantitative Resilience Assessment, which are integrated throughout the research process. The methodology of the thesis follows the process of a digital tool development, including the following steps:

Domain Analysis

In order to establish the overall framework of the design tool, a state-of-the-art research is conducted on the three sections of the research. 1) The Application Scenario of the tool is researched to define the problem domain that the tool should be able to address. The goal is to identify the major risks posed to facades and their impact on the facade. 2) The Potential Users of the tool are investigated to define the priorities of the functions the tool should serve. Specifically, the research focuses on robust methods where it can make use of existing databases while still providing quasi-design solutions during the preliminary facade design stage. 3) Measurable Resilience is explored to identify all the input and output variables that are necessary to quantify the resilience of a specific system. The research examines what intensity indexes, performance indicators, and resilience metrics are relevant for measuring facade resilience.

Framework Design

Based on the key features identified from the domain analysis, the framework for the design tool is developed, which includes the general architecture and digital data flow chart. 1) Multi-Hazard Approach investigates the combined impact of multiple hazards on the performance of the facade and determines appropriate design criteria based on the analysis of this relationship. 2) Design Decision Support Tool generates hazard-specific facade design solutions by combining components with resilient technologies and screens the design solutions to identify those that meet the targeted resilience capacity. 3) Quantitative Resilience Assessment utilizes metrics such as Acceleration and Heatwave (risk); Interstorey Drift and Overheating (impact); Structural Stability and Indoor Thermal Comfort (performance); Fragility and Recovery Curve (resilience) to assess the resilience of the system.

Implementation

The focus is on implementing the framework in a digital environment, which is composed of different modules that stem from various data types and simulation engines. The project will go through multiple iterations of the entire process to generate relevant data for sensitivity and correlation analysis and to optimize the flow of data. 1) The Hazard Analysis module determines the lateral load pattern for linear static analysis and generates climate change weather scenarios using CCWorldWeatherGen. 2) The Facade Design module conducts finite element modeling of RC structural frames and EnergyPlus building zone modeling of resilient facade configurations. 3) The Resilience Analysis module processes structural and thermal performance simulation and Fragility and Damage analysis (repair time, repair cost) using PACT.

Case Study

A case study is used to validate the framework proposed by the research. Groningen, Netherlands, which has recently experienced both heat and seismic hazards, is selected as the location. The KNMI dataset on heatwaves in Groningen and earthquakes at the Groningen gas field is used for the case study. Sensitivity analysis is used to determine the parameters of facade resilient technology that relate to its resilience capacity. Correlation analysis is used to examine the relationship between seismic resilience and thermal resilience of facades.

Evaluation

The evaluation of the tool aims to identify areas for future research and potential changes to be applied. The effectiveness of using a multi-hazard approach in comparison to single hazard analysis, the ease of integration of the design tool into current facade design processes in terms of accessibility and usability, and the efficiency of the digital tool's architecture in data management and consistency of simulation results across domains will be evaluated.

The summary of the methodology is illustrated in the figure 1.

Figure 1 Research Methodology for Framework Development

Literature and general practical preference

Attia, S., Levinson, R., Ndongo, E., Holzer, P., Berk Kazanci, O., Homaei, S., Zhang, C., Olesen, B. W., Qi, D., Hamdy, M., & Heiselberg, P. (2021). Resilient cooling of buildings to protect against heat waves and power outages: Key concepts and definition. Energy and Buildings, 239, 110869. https://doi.org/10.1016/J.ENBUILD.2021.110869

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Chiu, G. L., & Chock, G. Y. (1998). Multihazard Performance Based Objective Design for Managing Natural Hazards Damage. IFAC Proceedings Volumes, 31(28), 159–164. https: //doi.org/10.1016/S1474-6670(17)38490-2

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Patterson, M., Kensek, K., & Noble, D. (2017). Supple Skins: Considering the Relevance, Scalability, and Design Strategies for Fac¸ade System Resilience. 71(1), 34–45. https: //doi.org/10.1080/10464883.2017.1260919

Wang, Q., Chen, H., Wang, Y., & Sun, J. (2013). Thermal shock effect on the glass thermal stress response and crack propagation. Procedia Engineering, 62, 717–724. https:// doi.org/10.1016/J.PROENG.2013.08.118

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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 studio topic is "Digital building design tools for climate resilient structures". As a subset of the studio topic, I have chosen to focus on quantification of resilience, specifically of facade under hazard of natural disaster and extreme weather event. This project aligns with the Structural Design and Facade & Product Design chairs within the Building Technology track and requires a multidisciplinary approach, incorporating knowledge from structural and facade design, building physics, and risk management methodologies from earthquake engineering. Utilizing knowledge gained during my master's program and resources from my mentor's ongoing research, the project aims to deliver an integrated approach through the interdisciplinary environment of the AET faculty.

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

Resilience is a topic that is gaining more attention in practice, as a response to the increasing frequency of climate-induced disruptive events on a global scale that affect not only the built environment, but also a wide range of economic and social aspects. The recent trend in resilience is a shift towards a proactive approach to risk management, with a consensus that the likelihood of climate change is certain, and that the built environment should anticipate and prepare for future risks. This graduation project aims to address the increasing demand for dealing with engineering uncertainties by developing a practical tool that can provide prompt and specific design solutions to the problem. As the research in this area is relatively new, the project aims to fill a knowledge gap in dealing with multi-hazard problems and measuring resilience at the building level.