Empirical Assessment of Glazing Serviceability Limits: **Exploring Occupant Acceptance.**

by

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Reflections

1. Relation between the Graduation Project Topic, Studio Topic, Master Track, and MSc Program

The building technology master's program focuses on designing innovative and sustainable building components and integrating them into the built environment. Throughout my study, I have focused on façade design and sustainable structural design. The topic of my research "Empirical Assessment of Glazing Serviceability Limit: Exploring Occupant Acceptance" is concerned with material efficiency and façade performance. The aim is to find a balance of high-performance glazing with a reduced thickness without compromising the occupant's satisfaction. To achieve this the research has studied glass deflection, assessing the structural behavior of IGU under wind loading and the occupant threshold of acceptance of IGU under this cyclic deflection.

To effectively implement my research, I have chosen the discipline of two fields of study within the Building Technology track. The facade and structural design studios provided the necessary framework to combine the study of occupant's acceptance of IGU deflection and the potential thickness reduction in glazing thickness from relaxing the current serviceability limit.

2. Relevance of Graduation Work in the Larger Social, Professional, and Scientific Framework

Glass is one of the go-to materials for the façade of a building. It contributes to 26-60% of the overall embodied carbon of facades depending on their typology. We are at a time where the building industry ought to push for a better-performing building but also decrease the embodied carbon in the building. Glazing plays a crucial role and affects both the operational and embodied carbon footprint of the building.

Nonetheless, in regulations and codes governing the design of glass, there has been an absence of a clear threshold for human acceptance of deflections in glass. Hence, glazing thickness is typically determined with the assumption that humans have a low tolerance for glazing deflection. This leads to the glass being thicker than strictly necessary.

Recent technologies have enabled the production of thin glass. However, very thin glass panes are more susceptible to deflection. The research aim is to provide an empirical assessment of occupant's acceptance of glazing deflection to reduce the weight on high-performance IGUs.

Furthermore, the research emphasizes critical questioning of the current serviceability limit on glazing. As the need to reduce the weight of structures and our understanding of structural design advances, we should consider occupant level of acceptance as a means to design thinner structures with a lower environmental footprint without compromising the intended performance.

3. What is the relationship between the methodical line of approach of the graduation studio and your chosen method?

The façade and building products focus on a multi-dimensional approach to tackling the question of sustainability in the built environment. The research conducted is in line as it has explored multiple methods including an experimental design, survey design, statistical analysis and structural optimization to answer the main research questions. The first challenge to tackle was how to mimic cyclic loading on facades. For this, a 1:1 prototype of façade glass was equipped with sensors and pneumatic systems to get a controlled cyclic deflection. Moving further, the research has tackled the question of how to document the perception of an occupant and this included a survey design. To design the survey a preliminary assessment of the perception of glazing movement was conducted by inviting 8 PhD researchers and interviewing the experience from which the different forms of perception were extrapolated. An experiment was then conducted to study the correlation of different deflection limits to the perception and acceptance of occupants. The experiment was assessed with statistical tools to come up with a conclusion. Finally, from the information gained, structural analysis and optimization were performed to deduce the design and material-saving implications of the research.

An empirical assessment of glazing serviceability is a study that ranged from the study of the perception to material saving and it has benefited from the multidimensional approach of the studio of façade and building's product.

4. Impact of Research on Design/Recommendations and Vice Versa

The ecological impact of design has become one of the important considerations in the past decade. With the EU passing new laws to regulate the impact of constructions in the built environment, it is imperative to research different means of achieving sustainability. The question is, are we using more material than we should be? This research has taken an approach that does not develop a new technology but rather a methodology to reconsidering the current convention. The results will inform decision-making, particularly in the design of highly glazed buildings where glass can contribute up to 40% of the façade's weight. Glass material reduction will then have an impact not only on how we design façades but also on the main structure of the building, potentially having a secondary impact on material savings in the main structure.

5. Does the project contribute to sustainable development?

Indeed, the project contributes to sustainable development in several keyways. Firstly, by focusing on the empirical assessment of glazing serviceability limits and occupant acceptance of glazing deflection, the research directly addresses material efficiency. Reducing the thickness of glazing without compromising occupant satisfaction can lead to substantial material savings. Thinner glass panes mean less raw material usage, which directly correlates to a reduction in the embodied carbon footprint of building façades. This is crucial given that glass can contribute to 26-60% of the overall embodied carbon of façades depending on their typology.

Secondly, the project aligns with the broader goals of sustainability by aiming to balance high-performance building components with environmental impact. The shift from assuming low human tolerance for glazing deflection to empirically determining acceptable deflection limits can lead to a better informed and optimized use of materials. This approach not only minimizes weight but also promotes the consideration of occupant comfort when setting the limit.

Finally, by integrating occupant's satisfaction into the design criteria of glazing, the research ensures that sustainability does not come at the expense of building usability and satisfaction. This human-centered approach is essential for the long-term success and acceptance of sustainable building practices.

6. To what extent are the results applicable in practice?

The applicability of the results in practice depends on several factors, including the accuracy of the experimental setup, the representativeness of the test conditions, and the relevance of the findings to real-world scenarios as more considerations come into play.

It is essential to consider potential limitations such as the scale of the study, the assumptions made during the experiments, and external factors that were not accounted for. These limitations must be acknowledged and addressed when applying the results to practical scenarios.

Future work and limitations include the need to consider the contextual impacts of the study, as it was conducted in a controlled environment with specific conditions. User expectations of glazing performance and environmental quality can vary based on context. For instance, the lab's ground-floor location may influence safety perceptions compared to glazing at height, and expectations of glazing performance in high-end office buildings might differ from those in a laboratory setting. These results are contextual, and generalizing the findings will require testing with larger populations in real office environments with different façade designs.

To extend the applicability of this research in questioning the conventional limits, prolonged monitoring of the effects IGU deformation and influencing factors ought to be studied.

7. How does the project affect architecture / the built environment?

The empirical data generated from this research can influence building codes and standards related to glazing and façade design. Establishing clearer guidelines on acceptable deflection limits based on occupant's satisfaction can lead to a more rational and efficient use of materials, potentially driving changes in industry practices and regulatory frameworks.

The incentive for conducting this research varies depending on the stakeholder. For manufacturers, there is a drive to meet the growing market demand fueled by contemporary needs. Research such as this provides a foundational basis for developing new products that are lighter and have a lower carbon footprint, thereby aligning with industry trends towards sustainability and efficiency.

From a designer's perspective, the research offers insights into enabling the design of buildings that weigh less yet perform better and have a lower environmental footprint. It opens the potential for retrofitting heritage buildings with light weight and high-performance glass that can lead to improvements in building energy class.

Beyond the designer's realm and from a policymaker's perspective, the findings support the development of regulations and standards that promote material efficiency and occupant comfort. By understanding the benefits and implications of relaxing serviceability limits, policymakers can create guidelines that encourage the adoption of innovative solutions, ultimately contributing to reduced environmental impact and enhanced building sustainability.

8. Transferability of Project Results

The research methodology has been well documented, and it is just the beginning of the study of human perception and comfort regarding glazing deflection. The experimental setup will be stored properly, and the data collected from the survey archived to be studied further. The documented procedures and findings ensure that the project can be replicated or expanded upon by other researchers in the field.

Future studies can build on this research by using the same experimental setup and data to explore additional variables or refine the existing parameters. For instance, different types of glazing materials, various environmental conditions, or alternative locations could be tested to expand the applicability of the results.

9. What are the next steps to the research?

To achieve better control of glass movement, the experimental setup must be improved. This includes refining the control of airflow to regulate the frequency of movement across different scenarios and eliminating noise from solenoids switching to minimize distractions. Additionally, upgrading to a more accurate pressure sensor will enhance the reliability of the setup.

Further research should investigate factors influencing perception and acceptance, such as the angle of view, distance from the façade, and type of view. Long-term monitoring is essential to assess the effects over time and conduct a contextual study to evaluate how perception and acceptance vary across different building functions.

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