Quantitative Assesment of Resilience in Residential Building Envelope Systems

Problem

Resilience refers to "the capacity to adapt to changing conditions without catastrophic loss of form or function"[i]. The term is often used in the context of individual buildings, but in reality, resilience involves numerous elements of complex systems, as depicted in Figure 1. Resilience does not describe an independent attribute of a building but rather the dependencies between the various dimensions, which determine the building's resilience within the context of the surrounding system. The residential building design and construction industry has zeroed its attention on the physical aspect of resilience (highlighted in the figure), with a specific focus on a building's response to hazards. As such, methodologies are needed to quantify a residential building's contribution to a community's overall resilience.

Figure 1. Resilience is not an isolated attribute of a building, but rather a concept that describes the interdependencies between different dimensions of the surrounding system[ii].

Approach

The goal of the Hub's research is to explore the current state of tools and methods that attempt to quantify the resistance of residential structures to destructive events and incorporate those into a cost-benefit analysis. The research is focused on the role of envelope systems within the larger framework of multiple building strategies. Process-based cost models are used to calculate cost, which enable exploration of the cost drivers for different construction scenarios. Physical resilience is one of multiple metrics that will be incorporated into a life cycle cost analysis to characterize the benefits of construction systems. As part of the research, we surveyed current practices in the insurance and construction industries to identify methods that are used to quantify the resistance of buildings to various hazards.

Findings

Methods of quantifying physical resistance differ in terms of their scope of analysis, where the focus can range from community dynamics (systems approach) to physical properties (resistance and durability). The functionality and recovery time after a hazard is used as a proxy to determine the building's level of resilience. Furthermore, incorporating the risk of damage, which is a relationship between the probability of a destructive event and the probability that damage occurs through a destructive event, allows for considering the dependency on the building's environment. In addition to private risk modeling companies that provide services to the insurance industry, the U.S. Department of Homeland Security has developed risk modeling (Hazus), resilience screening (IRVS), and target analysis (OPR) tools to assess options for more resilient structures. However, available tools neglect the notion that a building is embedded in a system, which limits the value of assessing resilience for single buildings independently. Furthermore, identifying the beneficiaries, such as insurances companies or homeowners, would allow for a better understanding of the benefits of more resilient structures.

Impact

The intent of our research is to help designers and builders quantify the physical resilience of residential structures as a portion of the overall systems concept of resilience. Comparing this performance against costs will inform decision-making and facilitate communication of the cost and performance trade-offs of alternative designs.

More

Research presented by Christoph Wüstemeyer and supervised by Randa Ghattas, and Jeremy Gregory.

[i] Park, J., et al. "Integrating risk and resilience approaches to catastrophe management in engineering systems." *Risk Analysis* (2012).

[ii] Renschler, C. S., et al. "Developing the 'PEOPLES' Resilience Framework for defining and measuring disaster resilience at the community scale." *Proceedings of the 9th US National and 10th Canadian Conference on Earthquake Engineering (9USN/10CCEE)*. 2010.

This research was carried out by the CSHub@MIT with sponsorship provided by the Portland Cement Association (PCA) and the Ready Mixed Concrete (RMC) Research & Education Foundation. The CSHub@MIT is solely responsible for content. For more information, write to CSHub@mit.edu.