On the Ecology of Climate and Structures

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Abstract

Structural design interacts with its environment in terms of climate loading and climate impact. Structural design can therefore be considered, analogue to e.g. ecological economy [1], part of the ecological system by being a sub-system of the larger eco-system. Evolving from the first settlers in human history, structures were erected to create shelter from weather and environmental loadings. In all cases, a space is created by using locally available materials. Over thousands of years, the structural geometry and the concept of the load carrying system was adapted and optimized by experience through trial and error and experimentation, using the available resources and the obtainable material properties. With the advent of globalization and industrialization, materials changed, as well as the supply chain and architecture, and advanced in performance. Construction materials are nowadays produced from large-scale industrial branches, such as known for concrete and steel. The production centralized, and increasingly ubiquitous architectural/engineering standards spread over large geographical areas. Especially for remote regions, such as cold climatic regions, with an absence of large industrial infrastructure and strongly varying climates, the supply of building materials and components can represent an issue. Non-adapted architecture and high transportation costs lead to high construction costs and to a large environmental impact. Recent advancements towards digitization and automation in construction promise to lower environmental impact [2] with higher degrees of constructional freedom, highly adapted structures to local loading conditions, and the possibility of realizing minimal use of local materials.

Figure 1: a) Snow deposition reference study in Nuuk, Greenland. b) Experimental icing in climatic wind-tunnel.

This paper describes the efforts from the 'Climate and Structures' research group to optimize the interaction of structural design and cold climates with different research approaches. One aspect is to identify climate impact of wind, snow, rain and ice; thereby creating accurate loading scenarios for the design of optimized structures. A second aspect, deals with the proposition of innovative construction methods and the use of local materials. The alluded methodologies for the development of loading scenarios are identified with snow deposit simulations (Fig. 1a), icing (Fig. 1b) and wind loading studies of structures in climatic and boundary-layer wind tunnels. Proposed methods for structural design are parametric multi-objective optimization methods, as well as topology optimization, as in Fernandoy-Bak et al. [3]. Additive manufacturing with local material, as well as modular construction with light-weight materials are envisaged to render structural components. As a result of this study, a proposal for an ecological design approach of a building structure is outlined for remote regions in cold climates.

References

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[2] World Economic Forum, 2016. *Shaping the Future of Construction: A Breakthrough in Mindset and Technology*. Report, Ref.220416.
[3] Fernandoy-Bak, J., Christ, J., Koss, H., Shepherd, P. "Cases of Lightweight Structures in Polar Areas", in *Interfaces: architecture.engineering.science: Proceedings of the IASS Annual Symposium 2017*, Hamburg, Germany, September 25-28, 2017, Annette Bögle, Manfred Grohmann (eds).