

Form follows availability – Designing structures through reuse

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Abstract

This work proposes a new direction in structural design: the synthesis of structures through the reuse of elements. Reusing structural elements reduces the environmental impacts of building structures as it avoids sourcing new material, it reduces waste and it requires little energy. Designing structures from reused elements is very different to conventional structural design because the stock element availability is a design input. In other words, structures must be designed to fit certain element characteristics, e.g. cross-sections and lengths. In this new paradigm structural *form follows availability*.

This work formulates novel computational methods for the synthesis of reticular structures through reuse. Two scenarios are presented: 1) reusing reclaimed elements from a stock, and 2) the design of kits of elements that can be reused to build multiple structures. The objective is to minimize a performance metric such as weight, waste or environmental impact subject to ultimate and serviceability limit states. Both scenarios require the solution of the combinatorial problem of assigning available elements to appropriate positions in the structure, which is a form of discrete topology optimization. To encourage high reuse rates, scenario 2) features optimal clustering of elements into groups with identical cross sections and lengths. Once an optimal assignment is obtained, geometry optimization is employed to best-fit the structure shape to the length of assigned elements in order to reduce element cutting, which would generate extra waste.

The potential of the proposed method is demonstrated via its application to spatial structure case studies. Optimizing structures subject to different stock availability (number of elements, cross-sections and lengths) illustrates the influence of the stock on the optimal structure layout and form. As expected, depending on stock element availability, structures designed with this method might be oversized with respect to minimum-weight solutions. However, structures made of reused elements have a significantly lower environmental impact than structures made of new elements. Accounting for stock availability in parallel to system design optimization allows to include environmentally sensitive decisions since early stages in the design process. Design through reuse of stock elements therefore opens up new directions in form finding and optimization of space structures.