Optimum Frame Design with Reused Stock Elements

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Abstract

This paper presents optimization methods to design frame structures from a stock of reused elements. Reusing structural elements over multiple service lives has the potential to reduce the environmental impacts of building structures. This is because reuse avoids sourcing new material, it reduces waste and it requires little energy.

When reusing elements, cross-section and length availability have a major influence on the structural design. Previous work has shown that formulations based on mixed-integer linear programming (MILP) can be effectively applied to obtain a globally optimal usage of available stock elements for truss structures with pin-jointed members subject to normal forces only [1]. On the other hand, MILP-based discrete optimization methods for frames with beam elements subject to normal and shear forces as well as bending moments are given in [2]. We here combine the methods formulated in [1] and [2], in order to expand the range of structural typologies that can be designed from a stock. Fundamental to this problem is the optimal assignment of available stock elements to appropriate positions in the structure. This optimization approach is applied to two possible reuse scenarios: (A) the use of an individual stock element for each beam position, and (B) a so-called "bin-packing" approach, where multiple beams are cut from a single stock element and assigned individually. This formulation includes distributed loads as well as stress and displacement constraints along beams and hence it is applicable to limit state design [2].

The solutions produced by this method are benchmarked against the minimum-weight frame structures obtained in [2]. Optimizing the equivalent structures subject to different stock availability (cross-sections and lengths) illustrates the influence of the stock composition on the structure weight and its element capacity utilization. As expected, reusing structural elements may result in oversized structures if not enough suitable stock elements are available. However, the structures made of reused elements have a significantly lower environmental impact with respect to those made of new elements.

References

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