By Erik Larsen
Division of Structural Mechanics, Lund University
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Integrated structural analysis and design using Graphic statics

The solutions to ecological sustainability are found in thermodynamics, material science and structural mechanics. Engineers need methods to get creative with their knowledge and participate in design collaborations effectively. Graphic statics offers one such opportunity for structural mechanics.

Buildings are essential in modern society, yet they are equally a driver of climate change and of energy dependency.

We may choose to neglect the demands of sustainability or allow brutish solutions to become the norm. Alternatively, we may strive to integrate sustainable design with modern architecture.

This thesis addresses the issue of analysis tools to support integrated design.

Inspired by the structural elegancy often found in classical architecture a tool commonly used by 18th-19th century engineers and architects is evaluated in this thesis for application in modern practice.

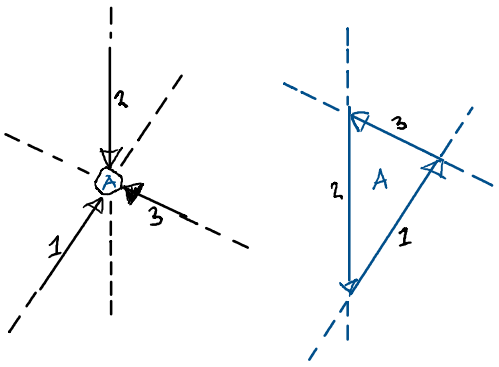

Figure 1. Reciprocal graphic relationship between form graph (left) and force graph (right). Left illustrate a node 'A' acted upon by forces. Force vectors (connected by a connectivity convention) in a closed polygon around surface 'A' indicate node equilibrium.

The tool, graphic statics is a hybrid of design- and analysis tools that combines some of the most useful aspects of structural analysis with the playfulness found in sketching.

The structural model is represented graphically. The graphic model is more intuitive than equations and easier to interact with.

The purpose of a hybrid design and analysis tool such as graphic statics is to use the information found by analysis to inform design decisions.

This thesis finds that graphic statics is a capable tool useful for integrated design. Although with limited application in practice since the static model is only applicable to limited special-case structures.

Graphic statics does both promote exploration of many design alternatives through ease of use and a simplistic model. It does also provide valuable feedback in a way that is useful to guide design choices.

An interesting quality of graphic statics for design is its potential for computational generation and optimization. Most notably

this thesis demonstrates how the graphic statics model may be implemented as an algorithm with relative ease and reliability. A design case created by Lauren Beghini[1] et. al further demonstrates how computational optimization strategies may be incorporated with a workflow to produce structures with excellent structural performance and high architectural value.

The capability of graphic statics to inform the design process with valuable analytical information is presented through the design of a Gaussian Vault. This type of vault pioneered by architect engineer Eladio Dieste is a precision engineered roof structure created to span over wide halls with a bare minimum of material. Gaussian vaults are in many ways the image of engineering elegancy. The undulating slender shape hold both high aesthetic value and high structural performance.

It is finally concluded that the greatest potential for modern application is in education. Here it may serve to teach the potential of integrated design, without the distracting intellectual weight of a complex model.

[1] Beghini, L. L. (2013). Structural optimization using graphic statics. *Structural and multidisciplinary optimization*, 351.366.