Popular scientific summary of master thesis in structural mechanics, LTH, Lund University.

Adapting to the Future of Buildings

Thesis by: Erik Lundin

Adaptively adjusting the shape of structures may reduce the amount of material required to build them by up to 89 %. Nature teaches us that adaptors survive. Buildings are built with a constant capacity to withstand forces from all directions that vary in volume throughout a long life in service. When you lift something heavy, you flex your muscles, consuming energy to do so. You wouldn't flex your muscles when you're not lifting, right? That is what we ask of our buildings. Would it be possible to design buildings with the ability to flex their muscles when it's needed, and rest when it's not?

In the thesis Adaptive Systems to Reduce the Material Cost of Structures – Parametric Design of Adaptive Trusses, a program capable of modelling trusses with struts that elongate in order to reduce the deflection caused by imposed load is developed. This enables trusses to comply with requirements on deflection with less material. The deflection is countered by internal forces from the elongation of the struts when load is present, deflection in the opposite direction is prevented by shortening the struts when load is not present. Results of analysis performed using the program show that the material in the chords of the trusses can be up to 89 % less in the adaptive trusses, compared to their corresponding non-adaptive counterpart.

The cost of building materials is rising, and the production and transportation of materials is a source of pollution. Saving material in construction is a hot topic, it is essential when the industry is trying to keep up with rising demand and is transitioning to net-zero emissions at the same time. Structural optimisation, in terms of putting the material where it matters, is an established method that engineers use to reduce the material cost of structures. You can for example see such optimisation in trusses and the profiles of steel beams. In adaptive structures, optimisation of the geometry is performed when a load is present to optimise the structure against that specific load.

Designing adaptive structures is a complex task. Finding the right geometry for the right load case involves evaluating a large amount of load case and geometry combinations. Adaptive structures can be designed with parametric programs capable of evaluating alternative solutions based on information provided by the designer. The program developed in the thesis revolves around a set of optimisations that aim to find the least possible amount of material without exceeding ultimate limits, and the least amount of activation required to limit the deflection. It is based on finite element modelling of trusses consisting of two-dimensional non-linear bar elements.

The research performed is focused on finding the material saving potential, in terms of how much the cross-sectional areas of the chords may be reduced, if the adaptive system is implemented. The findings can be complemented by research focusing on developing struts that may be elongated, sensor systems, dynamic behaviour, and connection details that fit the trusses.