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Graphic statics in a continuum field and its application for strut-and-tie modeling

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Abstract
The geometry-based method of graphic statics has long been used to generate truss-like solutions, with the advantage of assuring the equilibrium conditions and providing force magnitudes. Although this method has been successful in the creative and efficient design of discrete or compression/tension-only non-discrete structures [1], there is a lack of investigation on its capabilities for providing reasonable solutions in continuum fields, where both tension and compression could be carried. This research tends to examine graphic statics for the design of reinforced concrete elements, where a truss model is normally developed to provide an understanding of the load transfer mechanism and an insight into the reinforcement distribution. The computational generation of truss models, also known as strut-and-tie models, has been extensively relied on optimization methods such as layout optimization [2]. While these optimization algorithms are helpful for the initiation of a load path inside a continuum accounting for the design domain and boundary conditions, the inadequacy of control over or creativity in the outcomes is recognizable. In addition, the optimized load path output sometimes requires simplifications or refinements in order to be useful or practical for instance, for the purpose of concrete design.

This paper investigates the capability of the reciprocal relationships of graphic statics for either refinement of the optimization results or providing other load path scenarios. Building upon a previously developed computational procedure, combining layout optimization and algebraic graph statics [2, 3], first, a strut-and-tie model and its reciprocal force diagram is initiated for a given design domain and boundary conditions. Useful rules for transformations of the form and force diagrams are then established to simplify or rationalize the preliminary optimized form. Through design examples for reinforced concrete, it is explored whether graphic statics can further generate appropriate or innovative designs for reinforcement layouts, where their practicality and usefulness will also be evaluated.

References

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