# Exploring force distributions in concrete structures using graphic statics

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## Abstract

Graphic statics represents a powerful tool in the field of structural design, because the reciprocity between form and force diagrams allows for a constant and simultaneous control of both the geometry and the magnitude of internal forces. Used by Robert Maillart in the early 20th century for bridge design, the method has been improved in the last decades thanks to its implementation within interactive parametrical software. This allows overcoming the relative obsolescence of graphic statics in terms of speed with respect to analytical and numerical methods.

Graphic statics has recently been extended by Corentin Fivet [1], who has developed solution spaces for the points of the force diagram. These solution spaces show the set of structural forms in which equilibrium, boundary and yield conditions are fulfilled. When employed within the context of robustness assessment, these solution spaces can also be used as admissible geometrical domains, indicating the range of alternative force distributions that can be activated in the structure in case of damage [2].

Pursuing the ongoing research [3], this paper tackles using statically indeterminate strut-and-tie networks to model forces inside continuous reinforced concrete structure. These strut-and-tie networks take the shape of an orthogonal square mesh with 45° diagonals, representing potential rebar positions in concrete. Several damage scenarios are obtained by deleting one or more bars from the initial mesh; the associated admissible geometrical domains indicating potential force redistributions are drawn in each case. Ratios are then extracted from the comparison of admissible geometrical domains obtained for both intact and damaged cases, showing the structure's level of ability to survive unexpected damage. The influence of several structural design concerns (such as geometry, material properties and reinforcement layout) on the possibility of force redistributions is finally outlined and depicted graphically.

## References

[1] C. Fivet, *Constraint-Based Graphic Statics, a geometrical support for computer-aided structural equilibrium design*, PhD thesis, Université catholique de Louvain, Belgium, 2013.

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[3] A. Deschuyteneer, J.-F. Rondeaux, P. D'Acunto and D. Zastavni, "Application of graphic statics and parametric force diagrams for the design of reinforced concrete structures", *Proceedings of the IASS annual symposium 2018*, Boston, USA, July 16-20, 2018.