

STRUCTURAL TOPOLOGY OPTIMISATION OF COLD-FORMED STEEL BUILT-UP SECTIONS WITH DIFFERENT SCREW ARRANGEMENTS

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The study investigates the optimisation of cold-formed steel (CFS) built-up sections to improve their flexural performance while minimising material usage. CFS is widely used in modern construction due to its high strength-to-weight ratio, cost-effectiveness, and sustainability. Built-up sections are commonly employed in long-span beams and columns to enhance load-carrying capacity and buckling resistance by combining multiple CFS members. However, conventional design methods for these sections often rely on empirical rules, which may lead to conservative and inefficient material distribution. The study addresses this issue by applying advanced computational techniques to optimise the material distribution and enhance the performance of CFS built-up sections.

The research employs the Solid Isotropic Material with Penalisation (SIMP) method within the ABAQUS finite element framework to optimise the web configurations of built-up sections under a four-point bending setup. The optimisation process explores various volume fractions, ranging from 0.15 to 0.4, to determine the most efficient material distribution. The study validates the finite element models through experimental results, which show an excellent agreement with a mean failure moment ratio of 0.97 and a coefficient of variation (COV) of 0.02.

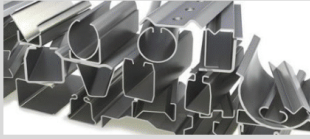
The webs of the CFS built-up sections were optimised by considering various volume fractions (0.15–0.4) and symmetry constraints, and their flexural capacity was evaluated using FEA. The optimised sections failed under localised web and flange buckling. The findings reveal that sections with moderate volume fractions (0.3–0.4) offer a good balance between material savings and structural integrity. These optimised sections exhibit an 18.6% to 21.7% reduction in material usage, with only a 7.4% to 13.9% reduction in moment capacity, making them highly efficient. In contrast, sections with lower volume fractions (0.15) experience significant strength losses (39.4% to 42.9%) due to web buckling. The study demonstrates that reducing material volume too much compromises structural performance, emphasising the importance of finding an optimal balance.

The results highlight the potential of using topology optimisation in the design of CFS built-up sections to reduce material waste without significantly sacrificing strength. The research also provides valuable insights for structural engineers, offering practical recommendations for designing lightweight, high-performance sections that can withstand significant loads while minimising material consumption. By optimising the material distribution, the study contributes to sustainable construction practices and efficient use of resources.

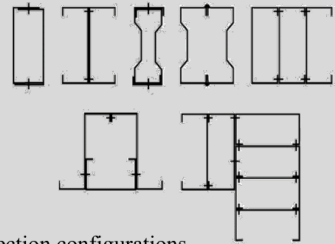
Keywords: Cold-formed steel, Built-up sections, Topology optimisation, SIMP method, Finite element analysis, Flexural behaviour

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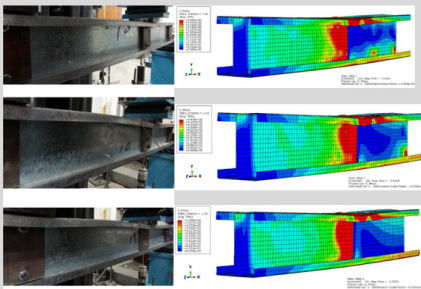
Structural Topology Optimisation of Cold-Formed Steel Built-Up Sections with Different Screw Arrangements



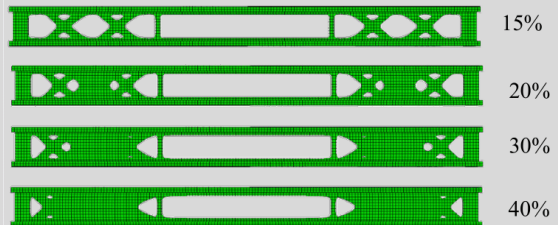
- Applications of Cold-formed Steel has grown increasingly in structures
- The built-up sections offer great design flexibility and enhance structural performance



Built-up section configurations

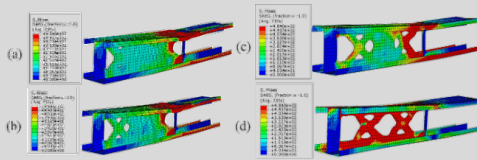


Numerical Model Validation based on Wang & Young (2017)

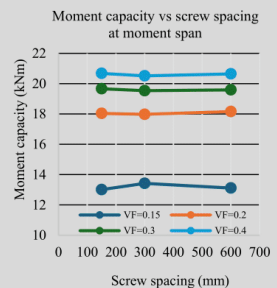
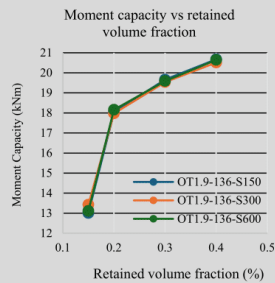


Structural Topology Optimisation of the webs to increase the compliance under different volume constraints

Parametric Study and Flexural Capacity



Determination of flexural capacities of the web-optimised built-up sections



- Topology optimisation effectively reduces material usage while maintaining structural integrity
- At lower volume fractions (0.15), significant reductions in moment capacity (39.4 – 42.9%) due to web buckling
- Optimised sections with moderate volume fractions (0.3 – 0.4) offer significant material savings without major strength loss