University of Bristol
Bristol Composites Institute
University of Bristol
EPSRC Centre for Doctoral Training in Composites Science, Engineering and Manufacturing
UKRI Engineering and Physical Sciences Research Council

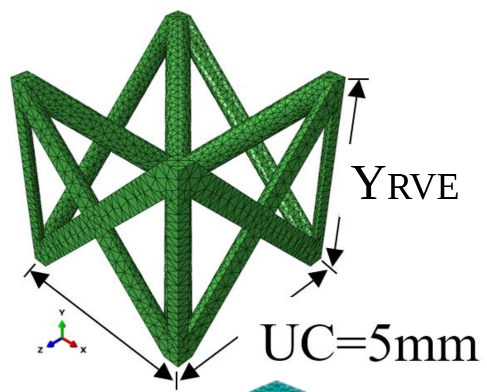
Multi-Objective Mechanical Optimisation of Lattice Cores

Athina Kontopoulou*, **Bing Zhang***, **Fabrizio Scarpa***, **Giuliano Allegri***

*Bristol Composites Institute, University of Bristol.

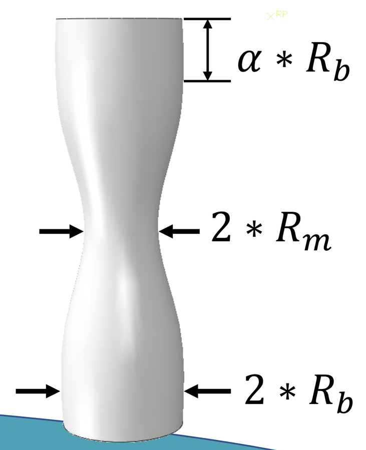
Structural weight can be reduced by substituting conventional monolithic components with sandwich ones. Our work aims to **optimise** the mechanical properties of lattice cores, which can be manufactured through conventional 3D printing techniques. The topology of the lattice unit cell is crucial for the ensuing mechanical performance. Here, we aim to **maximise** the **specific compressive (E_2) and out-of-plane shear stiffness (G_{23})** of lattice cores using a **multi-objective genetic algorithm** (GA). A Representative Volume Element (RVE) for parametric lattice designs is used in a finite element (FE) modelling framework, which is incorporated within a GA-driven optimisation loop. **Manufacturing constraints** are accounted for in the optimisation. A **relative density constraint** for the lattice design is also considered.

Micro-mechanical Optimisation

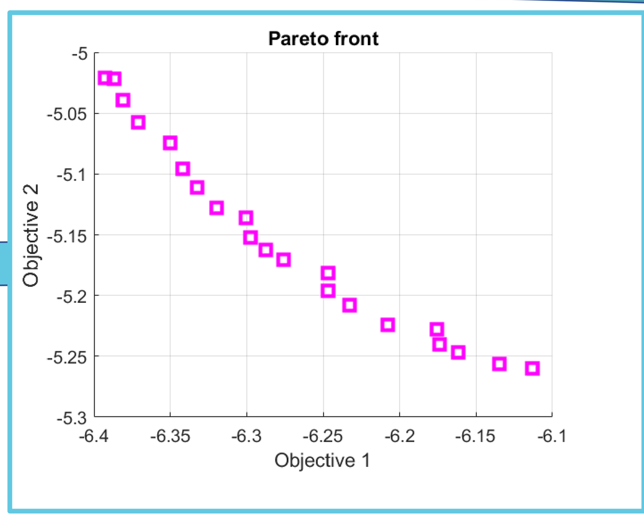


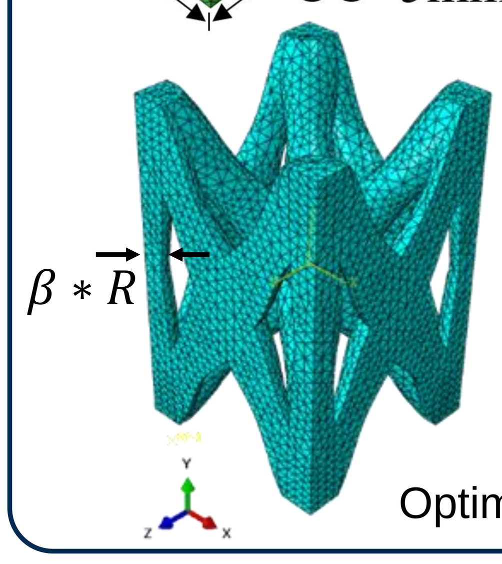
Objectives: minimise $f_1(x) = -\log(E_2/\bar{\rho}_{rel})$
minimise $f_2(x) = -\log(G_{23}/\bar{\rho}_{rel})$
Subject to relative density ($\bar{\rho}_{rel}$) **constraint**:
$$\bar{\rho}_{rel} = \frac{\rho^*}{\rho_s} = \frac{V_{lat}}{V_{RVE}} \leq 0.30$$

Variable	Lower bound	Upper bound
R_m, R_b	0.3 mm	1.2 mm
Y_{RVE}	5.0 mm	10.0 mm
α	0.1	2.0



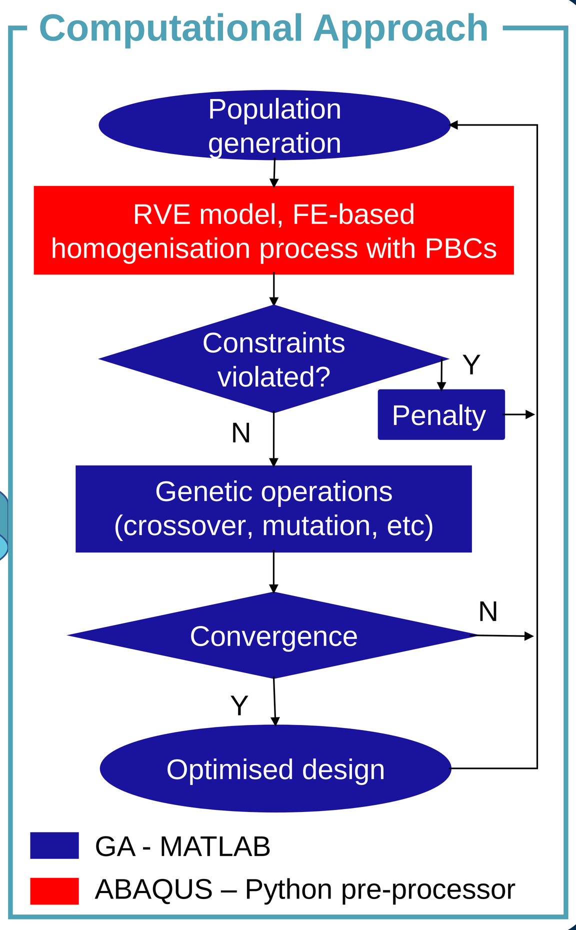
Tapering factor $\beta = \frac{R_m}{R_b}$



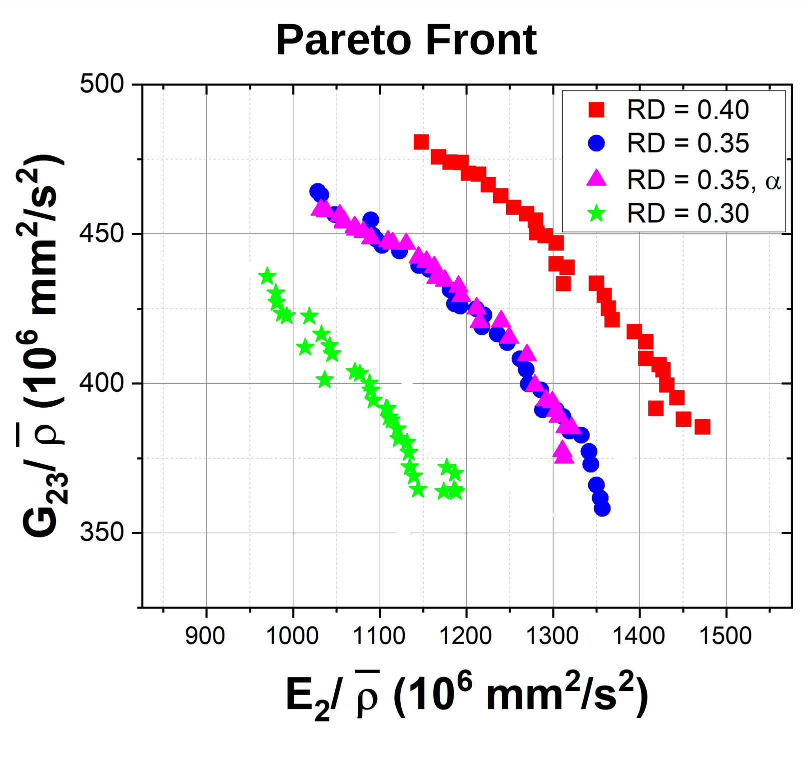


Optimum design

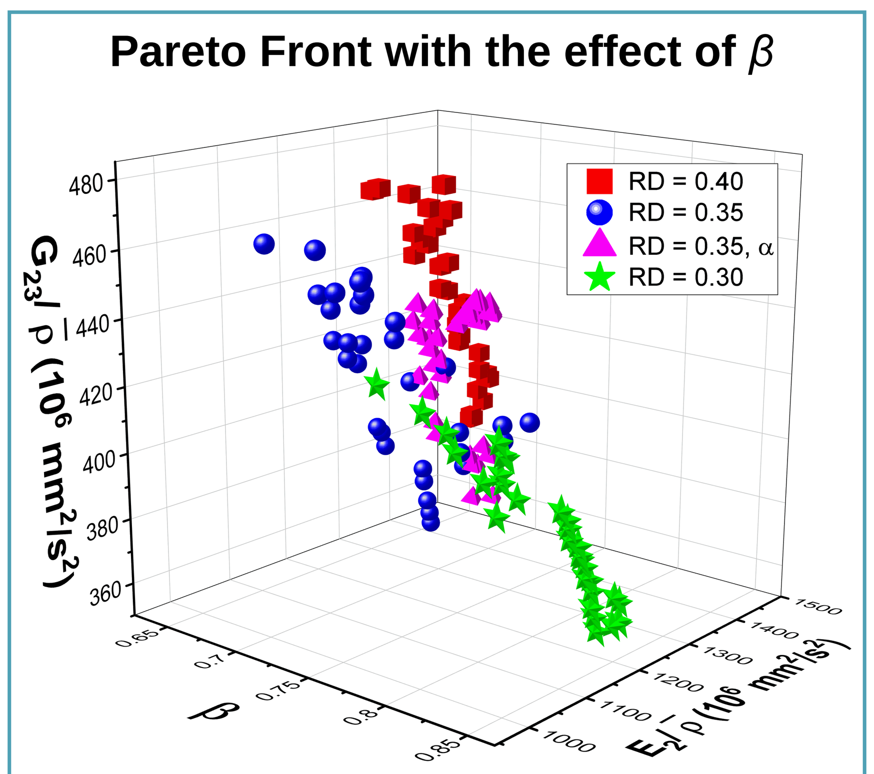
To learn more about our optimisation on other design concepts, scan here :



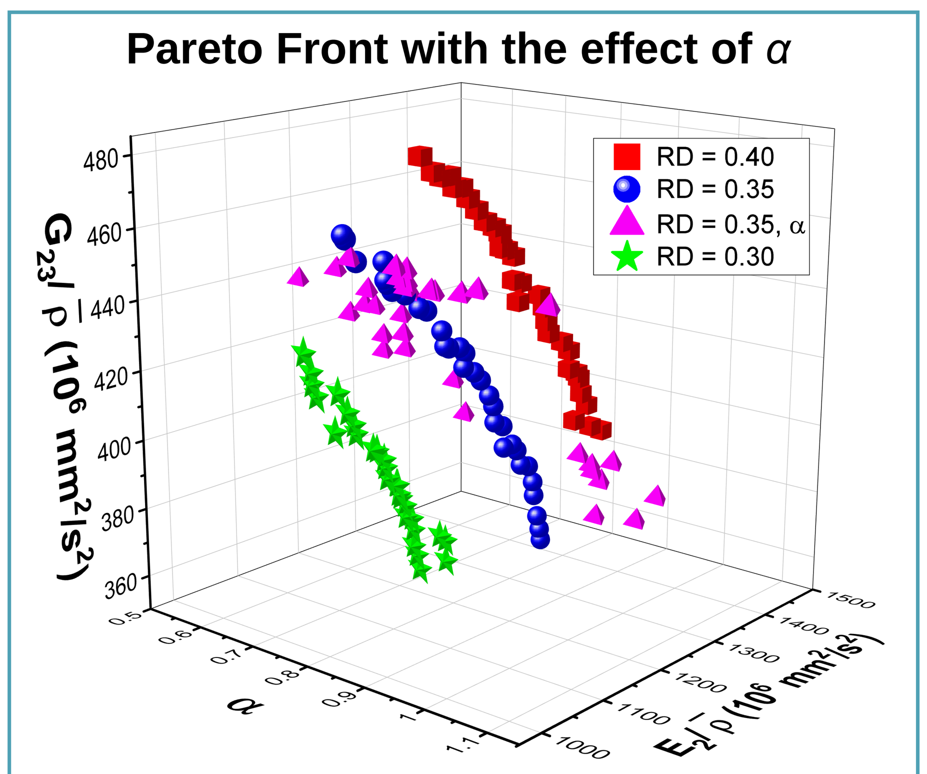
Optimisation Results



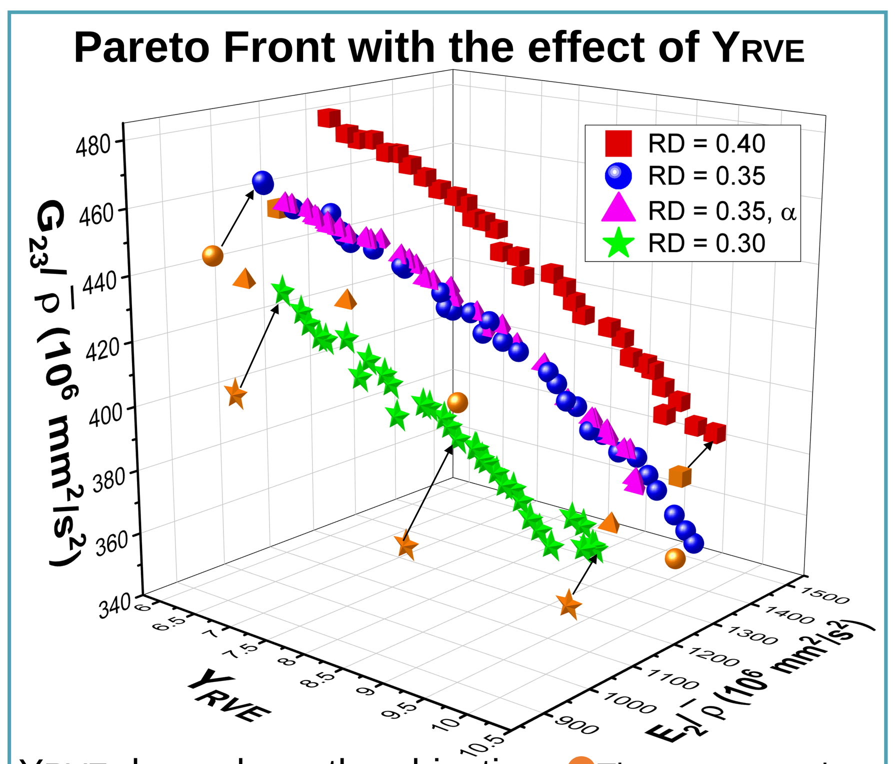
*RD = Relative Density ($\bar{\rho}_{rel}$)



Optimal tapering ratio $\beta \sim 0.7$ for both objectives.



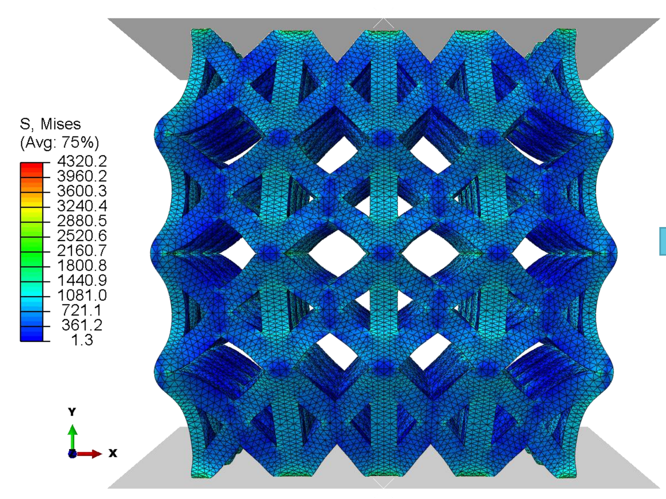
Optimum $\alpha \sim 0.82$ for both objectives.



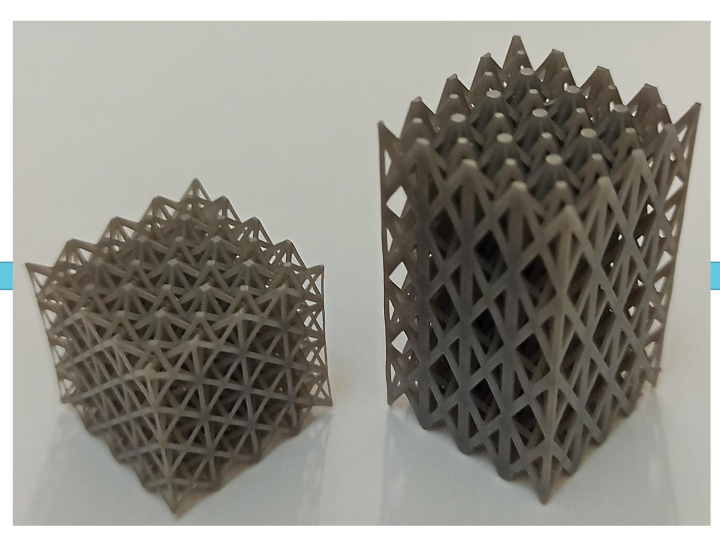
Y_{RVE} depends on the objectives. The orange markers show non-tapered lattices with the same RD and Y_{RVE}.

Macro-mechanical Validation

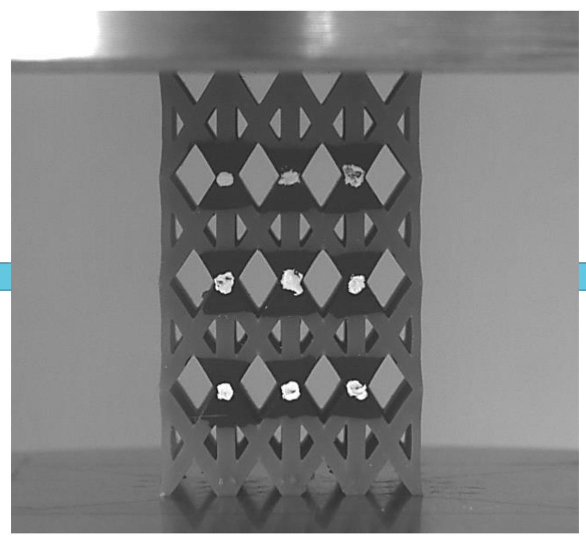
Static Performance



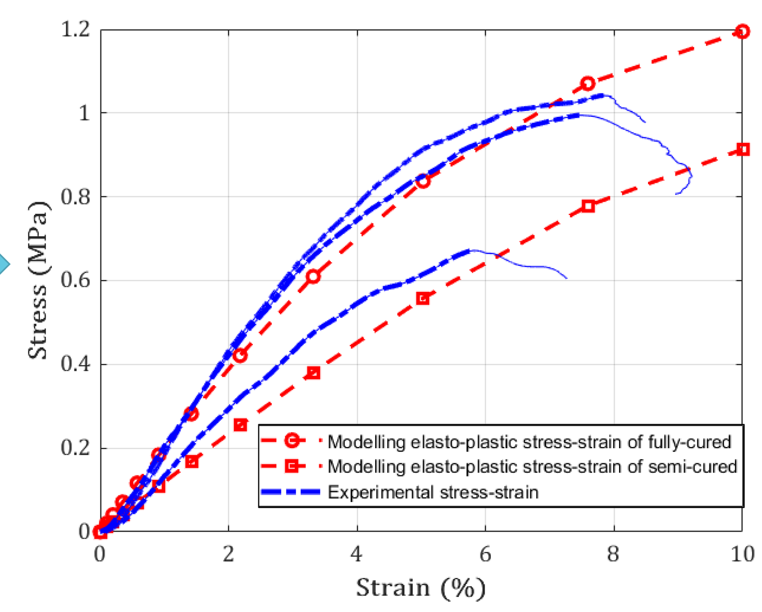
Elasto-plastic full-scale models under quasi-static compression load:
- Solid quadratic tetrahedral (C3D10) elements in ABAQUS.
- Material properties from tensile tests of 3D printed dogbones.



Additive manufactured samples through Stereolithography:
- Form 3+ 3D printer from Formlabs was used.
- Grey resin from Formlabs.
- UV curing at 70°C for 60 minutes.

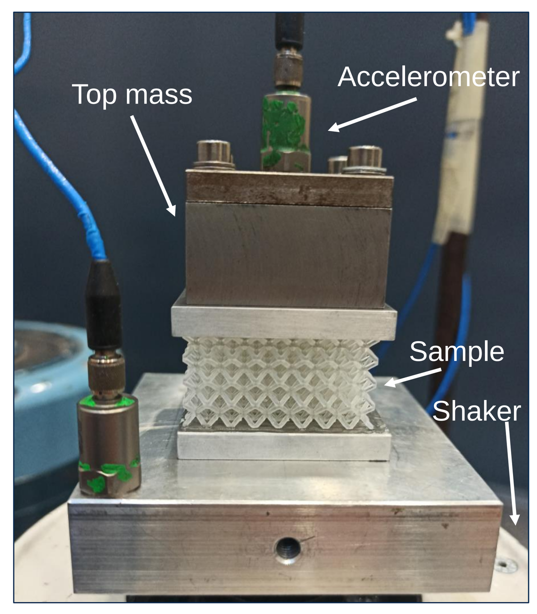


The samples are tested under quasi-static compression load:
- According to ASTM C365, loading speed 1mm/min.
- Strain recorded with video gauge.



- Comparison between the experimental results and modelling predictions of fully- and semi- cured 3D printed material properties.

Dynamic Performance



Vibration Transmissibility test rig:
- The sample is connected with superglue to the plates.
- White noise signals are generated using MATLAB.

Conclusions

Tapering the struts has a beneficial effect on both compressive and out-of-plane shear stiffnesses, which can be increased up to 11% and 5%, respectively. The optimum tapering ratio $\beta \sim 0.7$ is independent of the Y_{RVE} and relative density, with an optimum α factor at ~ 0.82.

Future work

Investigate the dynamic properties of the optimum lattice structures through numerical predictions and experimental validation with vibration transmissibility tests.

bristol.ac.uk/composites
athina.kontopoulou@bristol.ac.uk