MECHANICAL PROPERTIES AND CROSS-SECTIONAL BEHAVIOUR OF ADDITIVE MANUFACTURED STAINLESS STEEL STRUCTURAL ELEMENTS

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1. INTRODUCTION
Additive manufacturing (AM) is set to revolutionise the construction industry in the decades to come as it allows significant flexibility in design. The study is looking at 316L austenitic stainless steel, fabricated by Powder Bed Fusion (PBF), an AM process where thermal energy selectively fuses regions of a powder bed. Figure 1.

Figure 1: Schematic of PBF process (Gibson et al. 2015)

2. EXPERIMENTAL STUDY
a. Material testing: Tensile & Compressive
Fourteen coupons, printed in different directions with $\alpha$, $\beta$ and $\gamma$ varying from 0° to 90°, were tested in tension. Figure 2: Overview of coupons printing direction.

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b. Stub column experiments
Five 50x50x3 mm square hollow section stub columns, were tested with fixed ends under axial compression. The thickness varies from 1 mm to 5 mm.

Figure 3: Picture of the 5 stub columns after testing

Figure 5: Strain gauge position scheme

3. ANALYSIS OF COUPONS EXPERIMENTS
Comparison between coupon experiment and literature data. Figure 7:

1. All values are in the manufacturer (EOS) datasheet range
2. 0.2% proof stress $\sigma_{0.2}$ (arbitrarily defined because the yield point is not easily defined) and ultimate strength $\sigma_{u}$ are higher for $\theta = 0°$
3. Tensile coupons minimum ductility $\varepsilon$ goes until 30%, and so $\varepsilon$ is not a key determinant
4. While varying $\alpha$ and $\beta$ for $\theta = 0°$, no particular influence on the mechanical properties are observed

Figure 6: Stress-strain curves of the AM 316L tensile coupons

Figure 7: 0.2% proof stress $\sigma_{0.2}$ trend curve

4. ANALYSIS OF STUB COLUMNS EXPERIMENTS

The stub columns results have been compared with their counterparts in stainless steel, aluminium, and structural steel. The comparison with conventionally produced stainless steel materials shows that AM stocky stub columns tend to resist higher loads and slender sections tend to resist lower load than their conventional counterparts, when considered on a normalised basis. The latter may be due to the high level of residual stresses in additive manufactured sections.

Figure 8: Normalised ultimate axial resistance $N_e/N_p$ varying with local slenderness $\lambda_p$

However, Figure 8 shows that the overall AM stub column cross-sections follow the same behaviour as the conventional material.

Figure 9: Results of stub column 50x50x3 mm material modelling

5. SUGGESTIONS FOR FURTHER WORK
a. Numerical modelling
Five material models were studied on 50x50x3 mm stub column numerical modelling

- M1: Stub column experimental stress-strain data
- M2: Tensile coupons averaged stress-strain data
- M3: $\theta = 90°$ tensile coupons averaged data
- M4: Compressive coupons averaged data
- M5: $\theta = 90°$ compressive coupon data

Further work: introducing anisotropy of the material, surface imperfections, and different cross-sections.

b. Study on heat treatment
Heat treatment does homogenise 316L stainless steel mechanical properties. Different heat treatment methods are practicable. However, few pieces of data are available.

Further work: for second 316L stainless steel set of tensile coupon, possibility to heat treat them following the method presented in ASM2759C (2014).

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REFERENCES