Imperial College London

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

Aïa Ferrer **Supervisor: Professor Leroy Gardner**

Department of Civil and Environmental Engineering, Imperial College London

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.

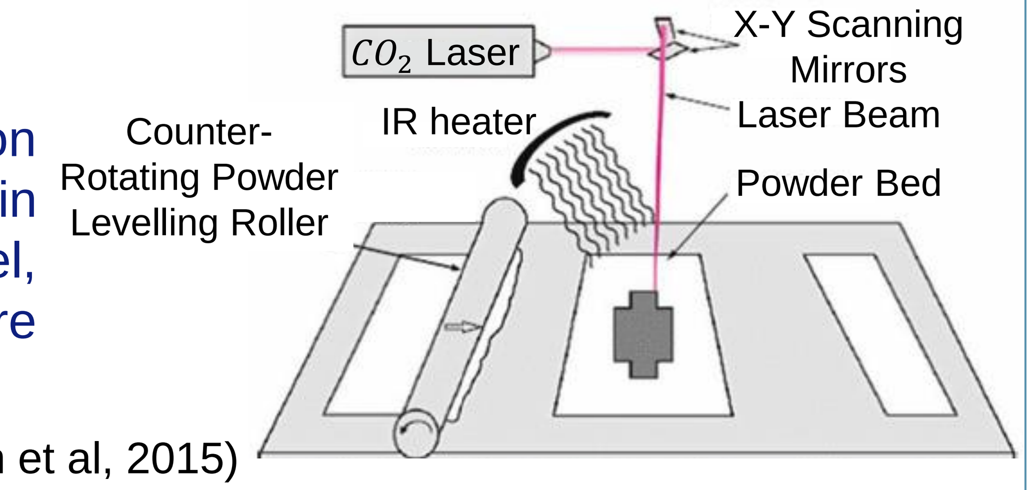
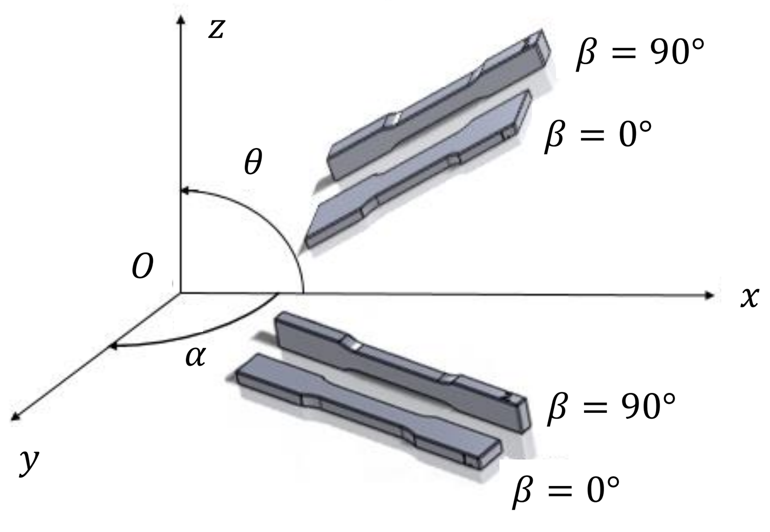


Figure 1: Schematic of PBF process (Gibson et al, 2015)

2. EXPERIMENTAL STUDY

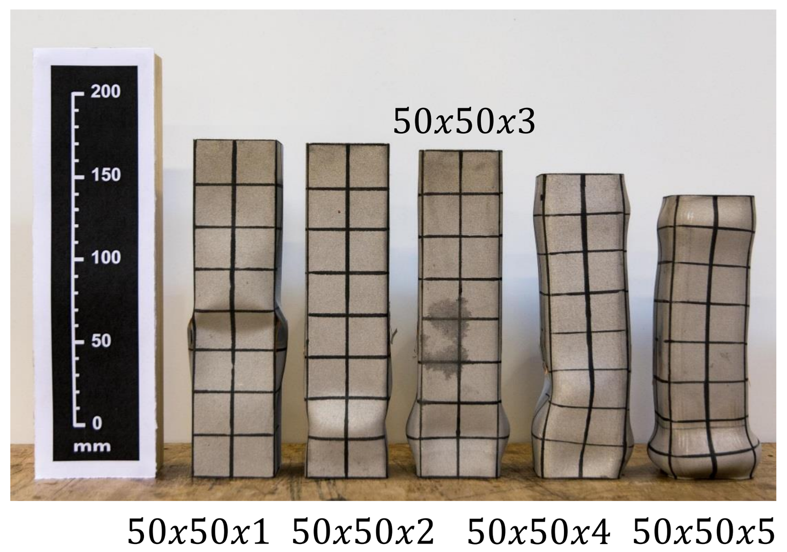
a. Material testing: Tensile & Compressive



Fourteen coupons, printed in different directions with α, β and θ varying from $0°$ to $90°$, were tested in tension.

Figure 2: Overview of coupons printing direction

b. Stub column experiments



Five $50x50mm$ 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

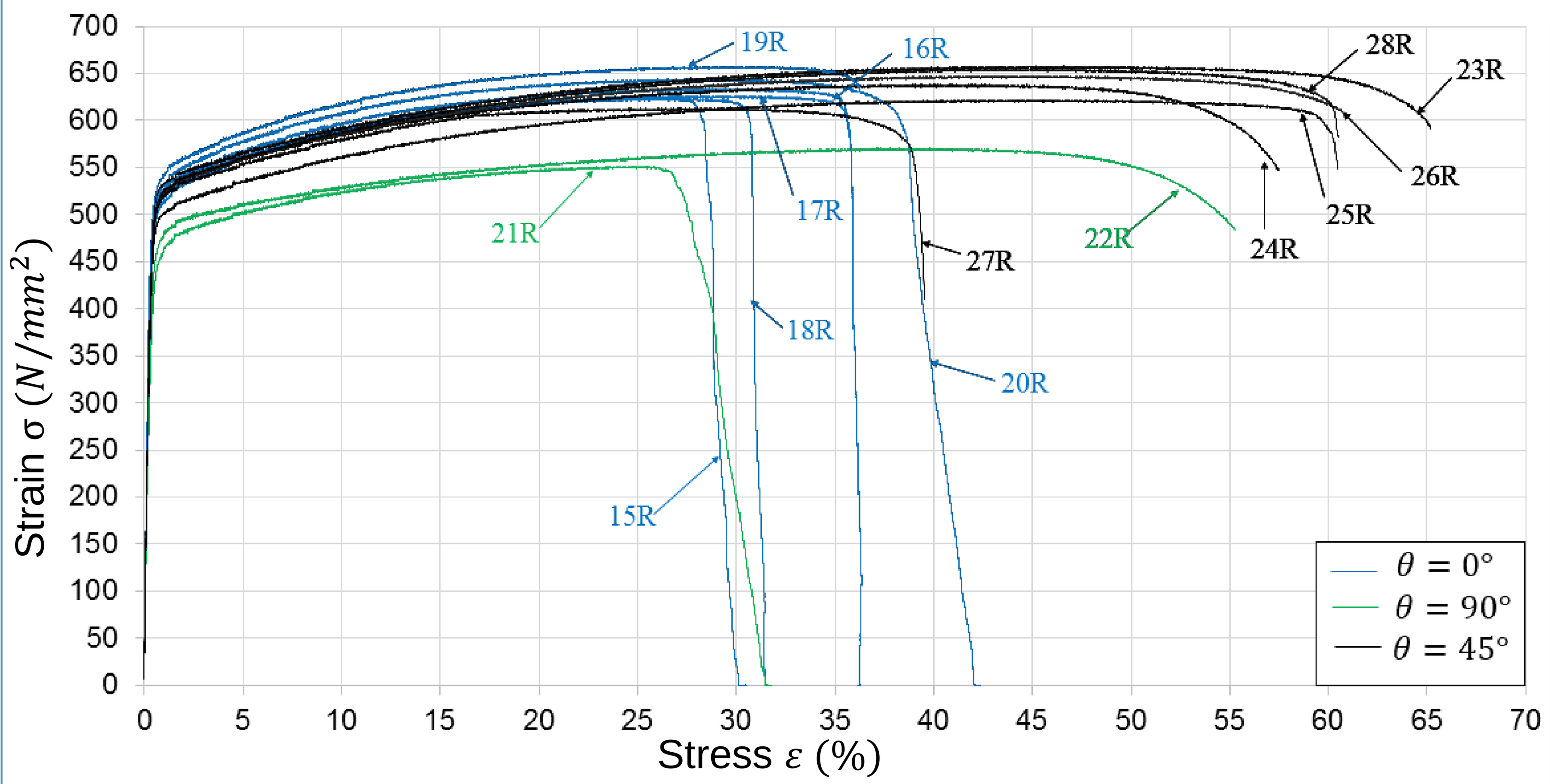


Figure 6: Stress-strain curves of the AM 316L tensile coupons

Experiment methodology:

1. Initial measurement (+ for stub columns: imperfection measurements as shown in Fig 3)

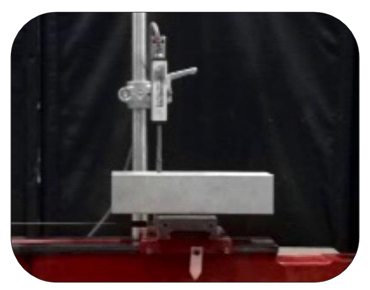


Figure 4: Imperfection measurement test

2. Fixing strain gauges

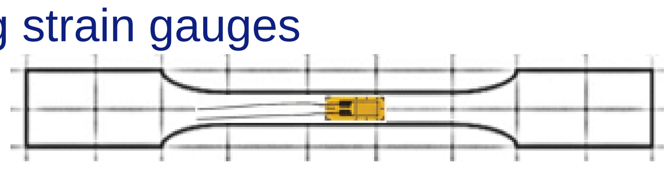


Figure 5: Strain gauge position scheme

3. Data acquisition (+ for stub columns: calculation of the true end shortening)

3. ANALYSIS OF COUPONS EXPERIMENTS

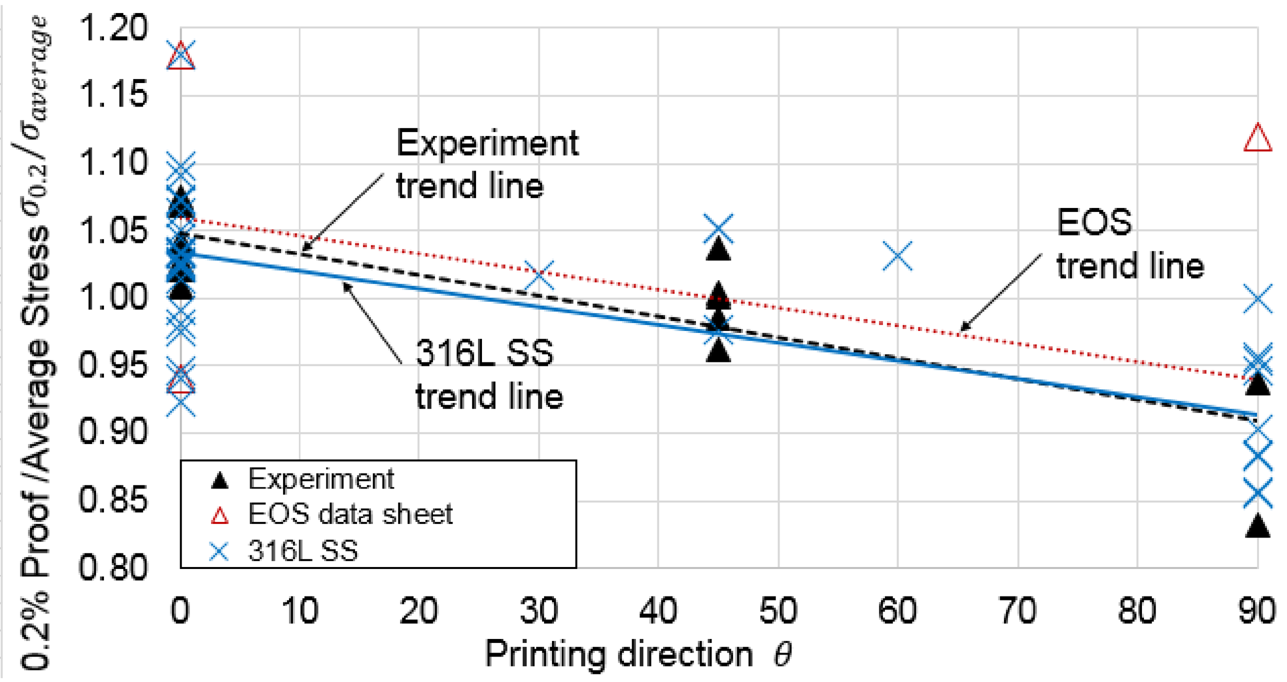


Figure 7: 0.2% proof stress $\sigma_{0.2}$ trend curve

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 σ_u are higher for $\theta = 0°$**
3. Tensile coupons minimum ductility ε goes until 30%, and so ε is not a key determinant
4. While varying α and β for $\theta = 0°$, no particular influence on the mechanical properties are observed

4. ANALYSIS OF STUB COLUMNS EXPERIMENTS

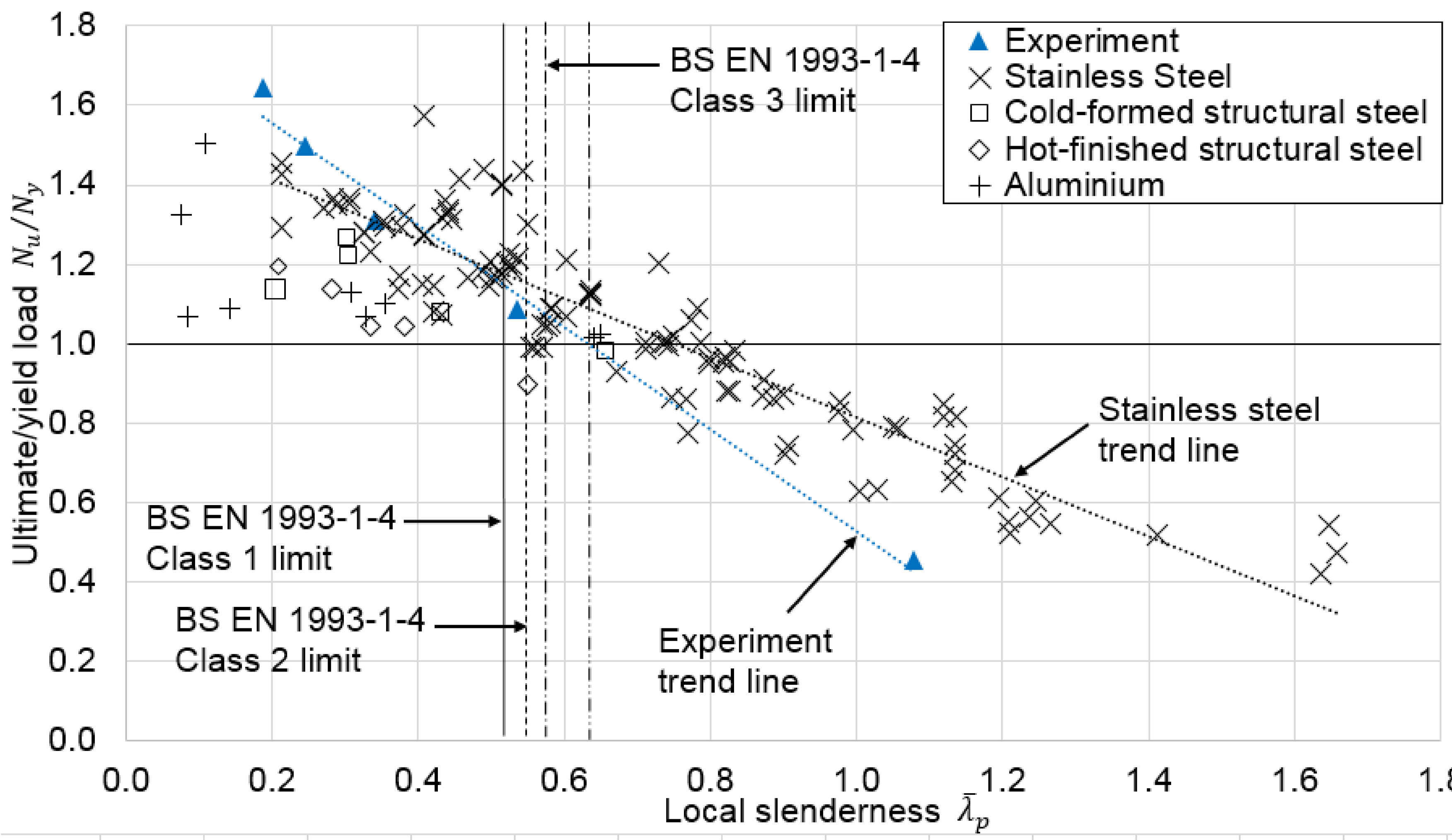


Figure 8: Normalised ultimate axial resistance N_u/N_y varying with local slenderness $\bar{\lambda}_p$

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.

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

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.

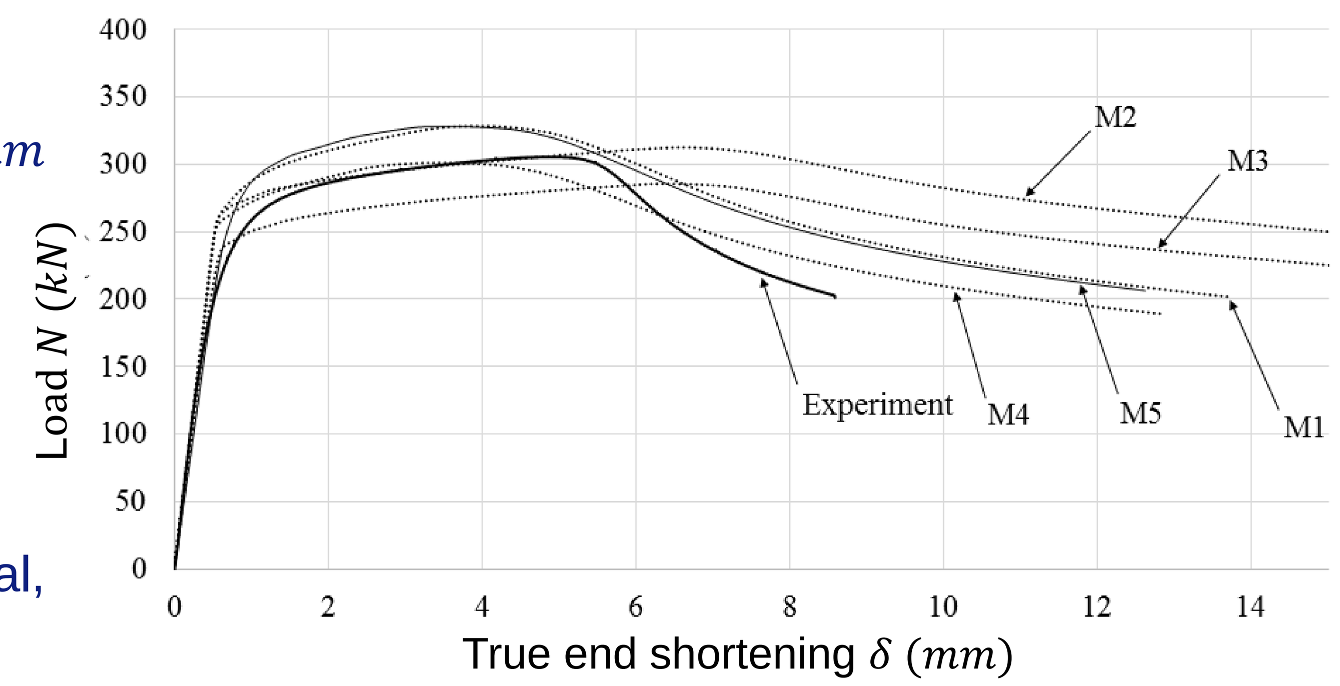


Figure 9: Results of stub column $50x50x3$ mm material modelling

b. Study on heat treatment

Heat treatment does homogenise 316L stainless steel mechanical properties. Different heat treatment methods are practicable. However, few piece 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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