Additive Manufacturing for Construction Industry

Exploration of Stability of 3D-Printed Steel Members

(For complete research, see TU Delft Repository)

Dag van de Constructeur

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Graduation committee

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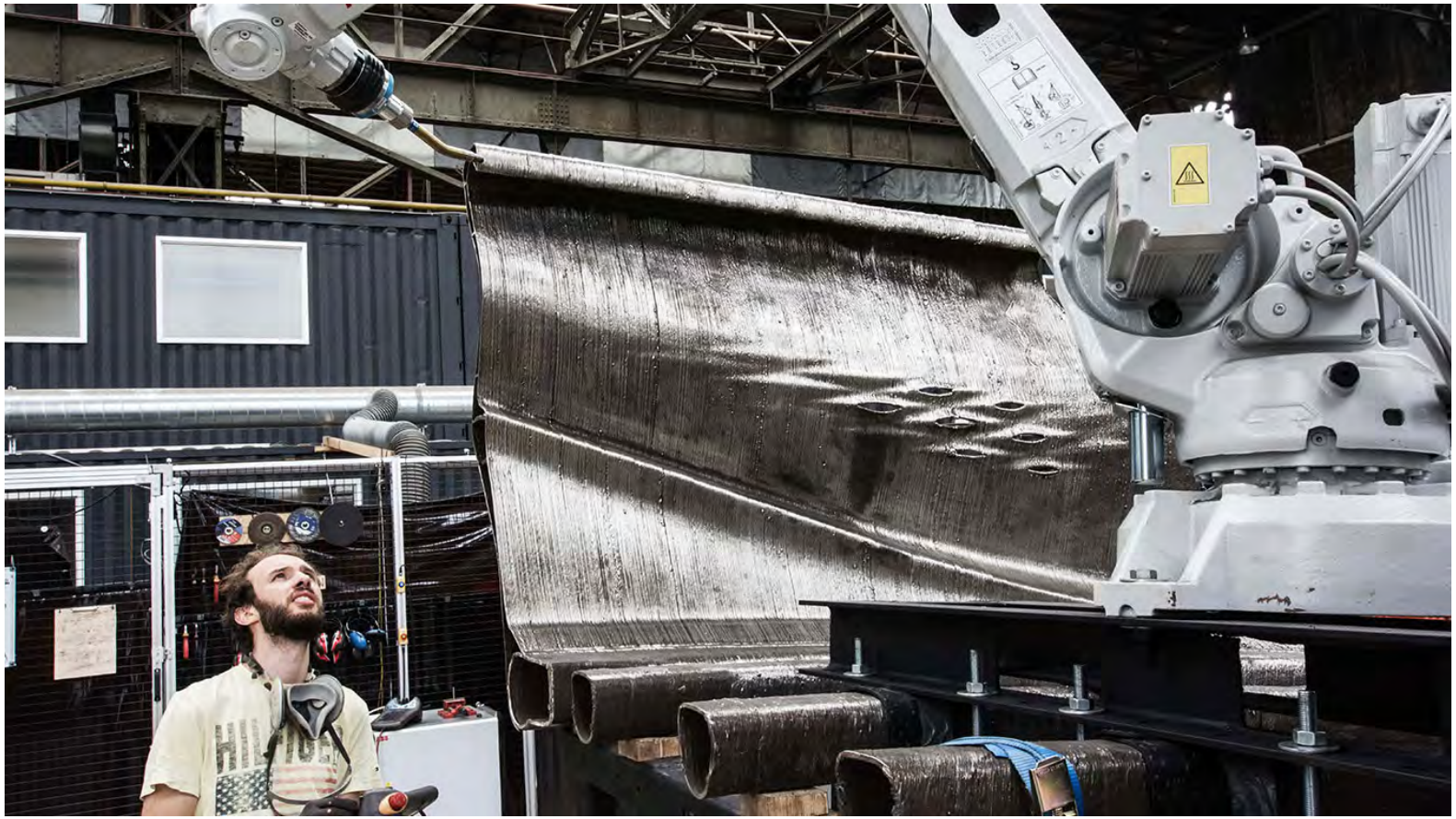
Outline

- Introduction 3D-Printing
- Background Research
- Methodology
- Results
- Conclusions
  - Opportunities
  - Challenges
- Discussion



Introduction

Additive Manufacturing

- Enables production of complex shapes
- Topology optimisation > Optimal material layout
- Reduces material use, waste and transport costs
- Mass customisation and fast construction
- Printing Techniques
  - Powder based (sintering) → Low deposition rates
  - Wire arc additive manufacturing → Print outside the box

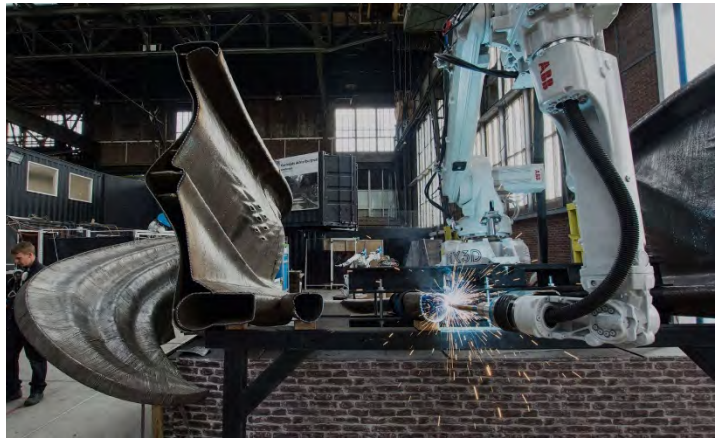
Print outside the box → Structural applications

WAAM: *Ramlab, Damen*

Introduction

MX3D Bridge

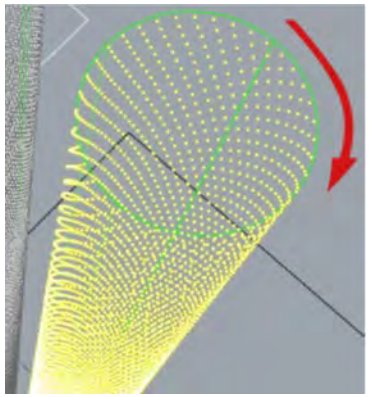
- Pedestrian bridge in city center of Amsterdam (exp. 2018)
- 12 meter span, 6.3 meters wide.
- WAAM, stainless steel (308LSi)
- Smart bridge – live monitoring of bridge ‘health’
- Goal: fully autonomous on-site robotic printing

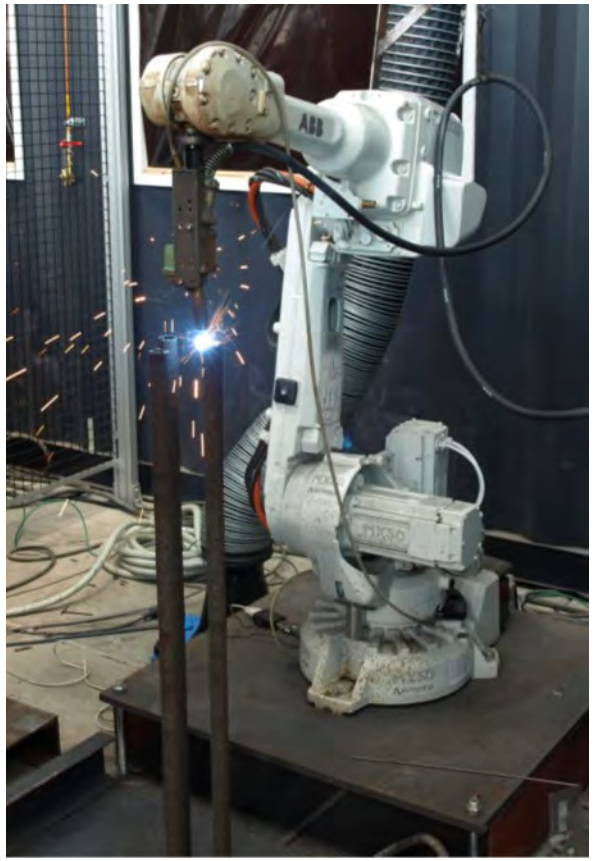


Background

Printing Process

- 15 columns in total
  - (D = 30.1 mm – 3.2 to 3.7 mm thick)
- Dot-by-dot & continuous printing
- Properties process dependent
  - Cooling rate



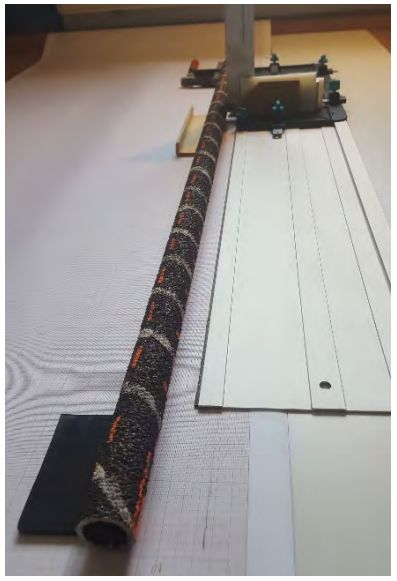


Methodology

Characterization of Geometry (1)

- Hand & Fluid Measurements,
- 3D-scanning

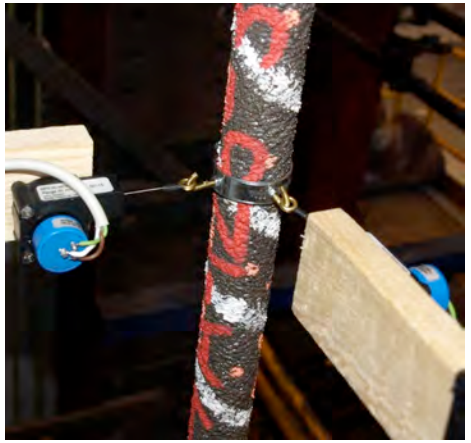
  - Out-of-straightness
  - Surface roughness
  - Weight/Length
  - Average cross-section
  - Density



Methodology

Material Properties – Buckling Tests

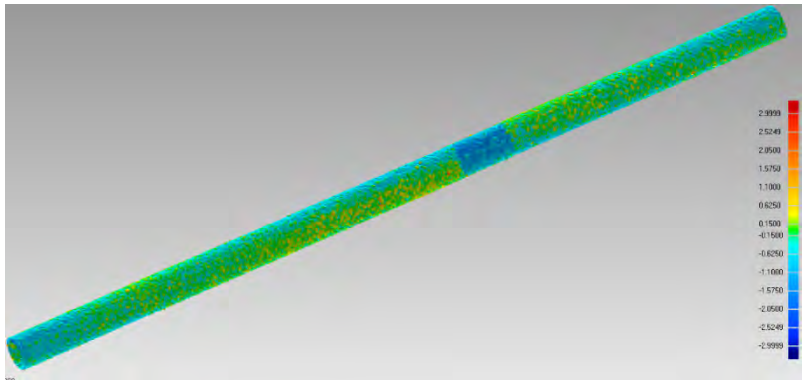
- Tubular column lengths: 450 – 1250 mm
- Lateral deflections: 6 linear displ. sensors
- Effective system length

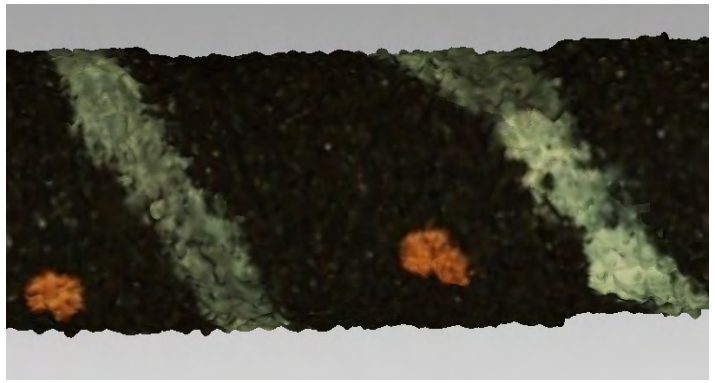


Results

Geometrical Properties

- Out-of-straightness e_0 affected by local misaligned print layers: average e_0 = L/650 >> e_0 = L/1000 (EC3)



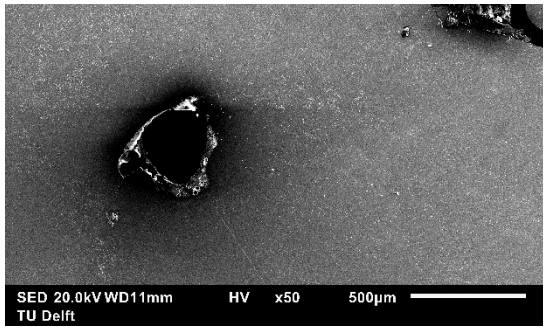


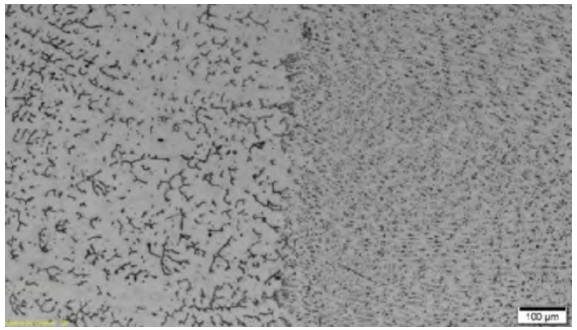
- Average cross-section: OD 33.8-3.7 mm (dot) and OD 33.3-3.2 mm (cont.)
- Density ranged 7.91-7.94 kg/m^3

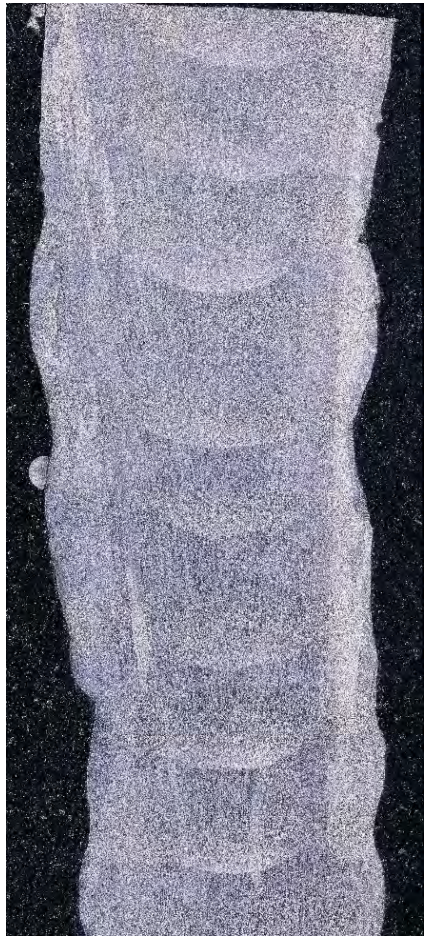
Results

Material Properties - Metallography

- Large columnar grain structures → anisotropy & ductility
- Locally coarser grain structures → strength
- Oxide inclusions & porosity → ductility & strength
- Dot-by-dot printing: more inclusions



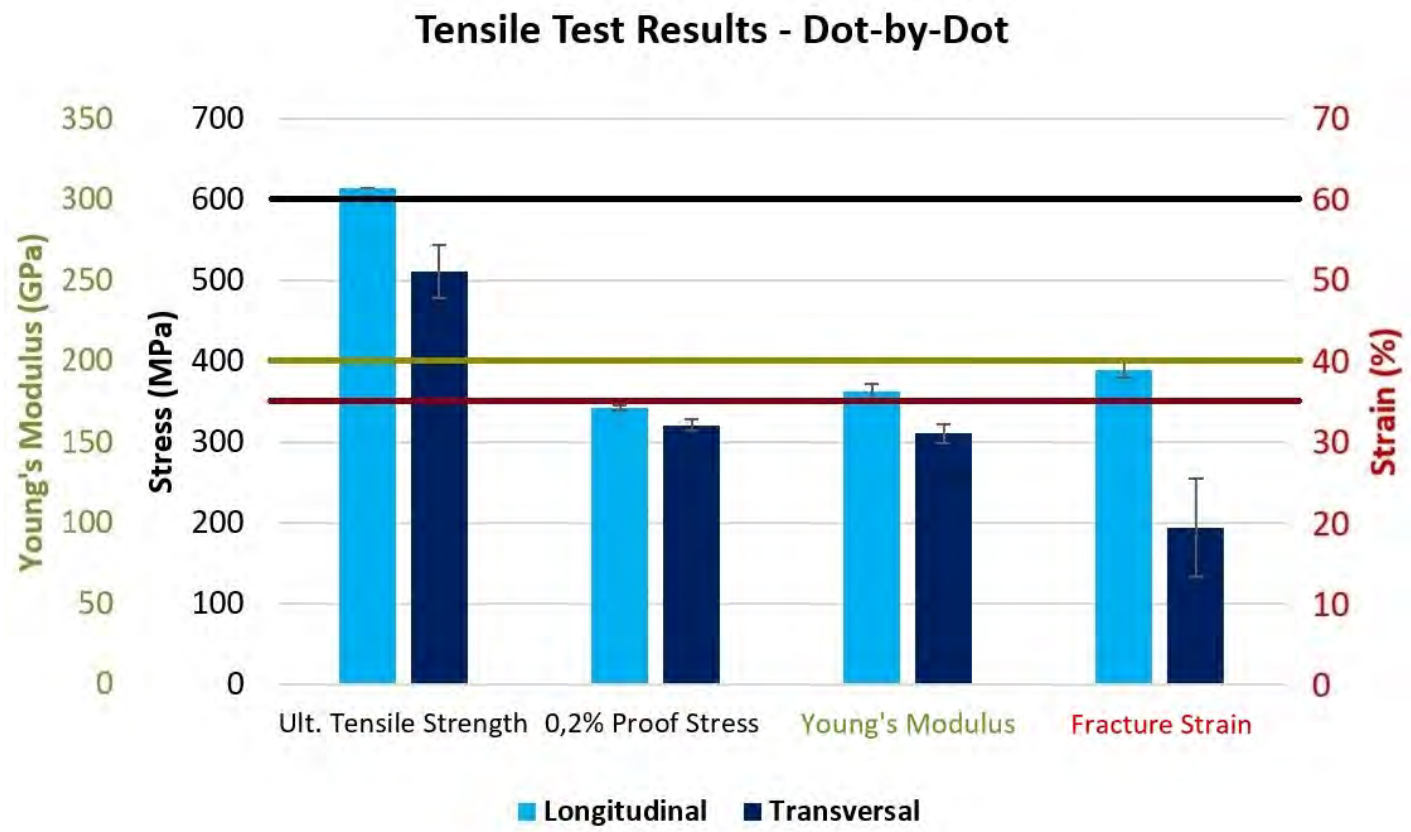




Results

Material Properties – Tensile Tests (1)

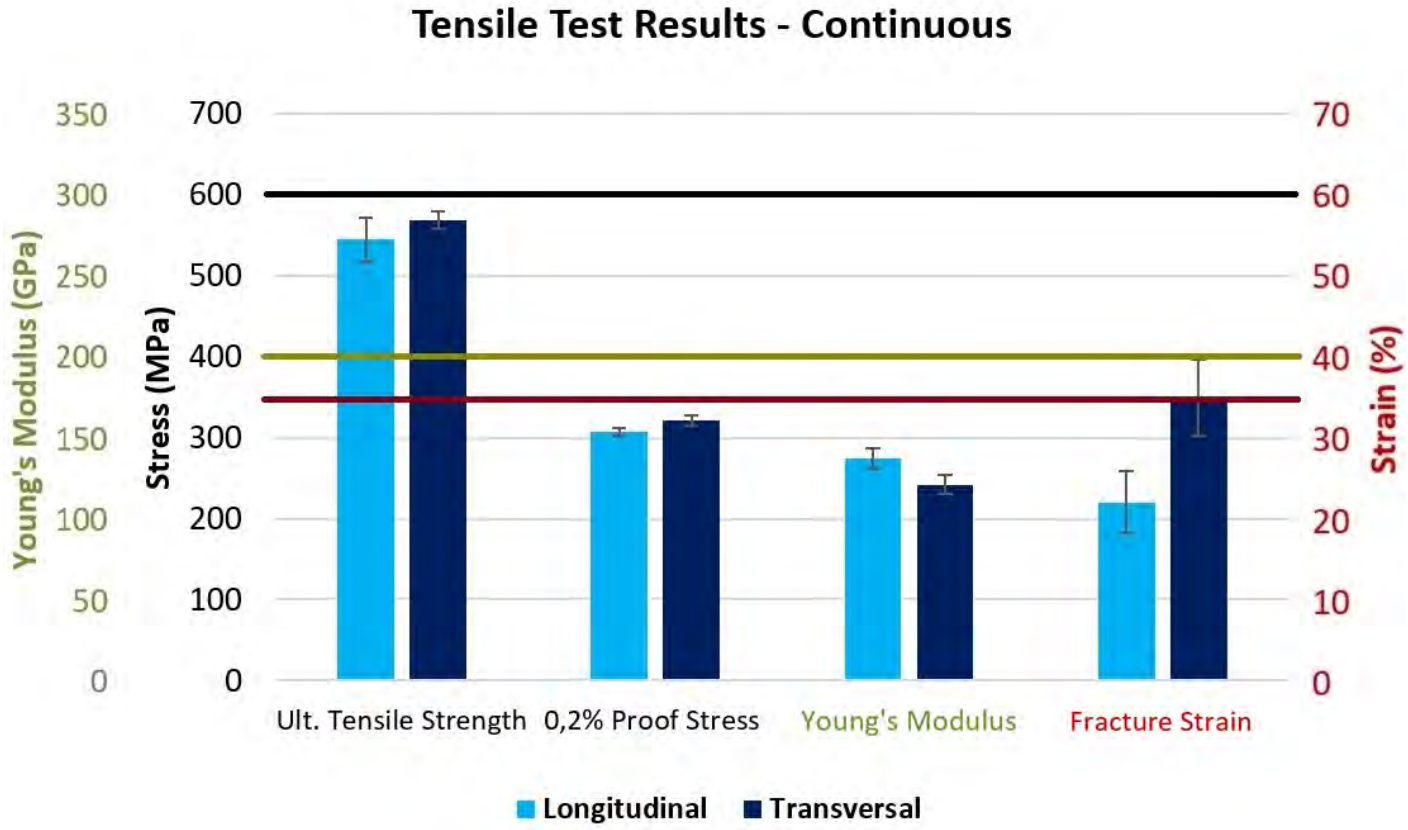
- Anisotropy
- Lowered stiffness



Results

Material Properties – Tensile Tests (2)

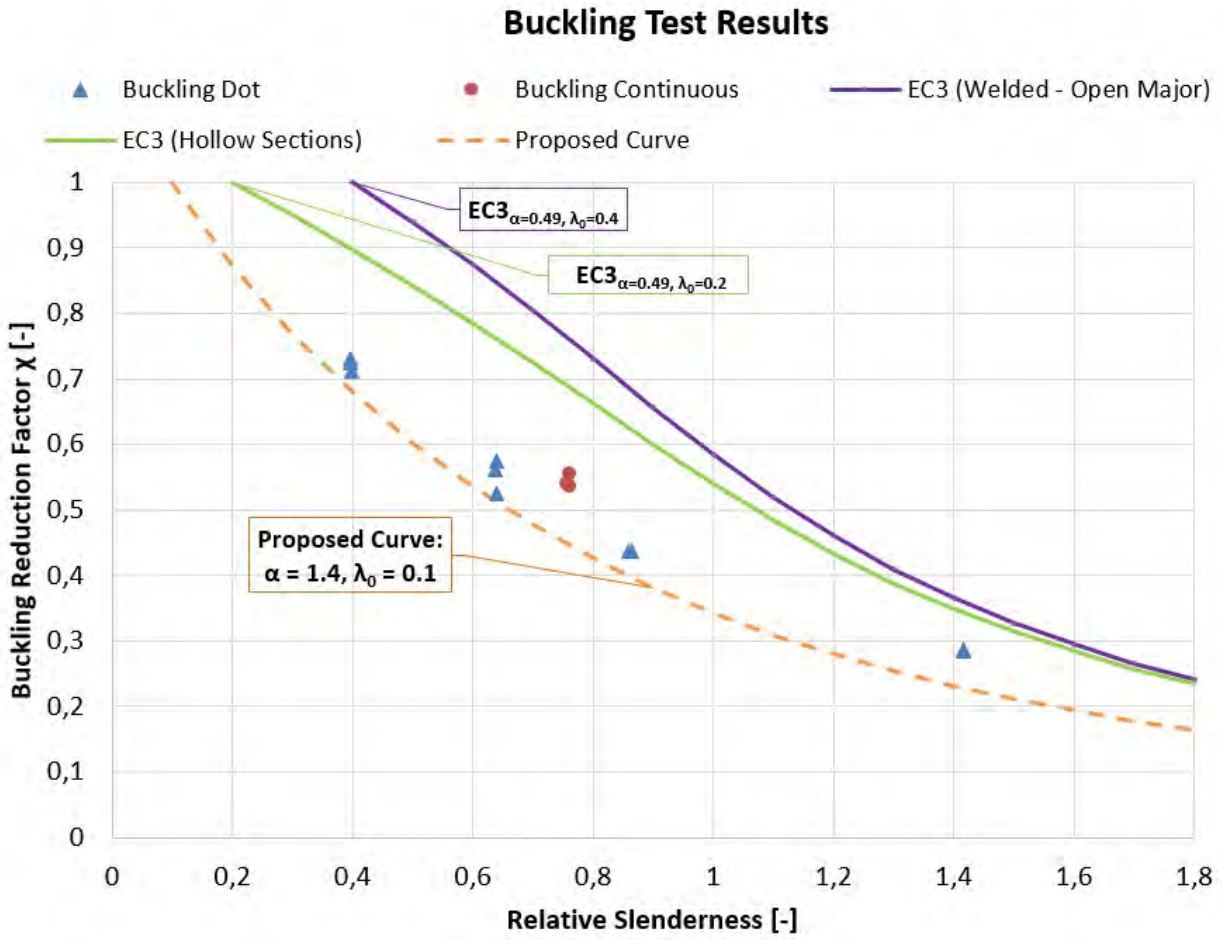
- Less anisotropy
- Very low stiffness



Results

Material Properties – Buckling Tests

- $\gamma_M = 1.1$



Conclusion

What are relevant geometrical and material properties of 3D-printed steel to assess the stability of wire and arc additively manufactured stainless steel tubular columns?

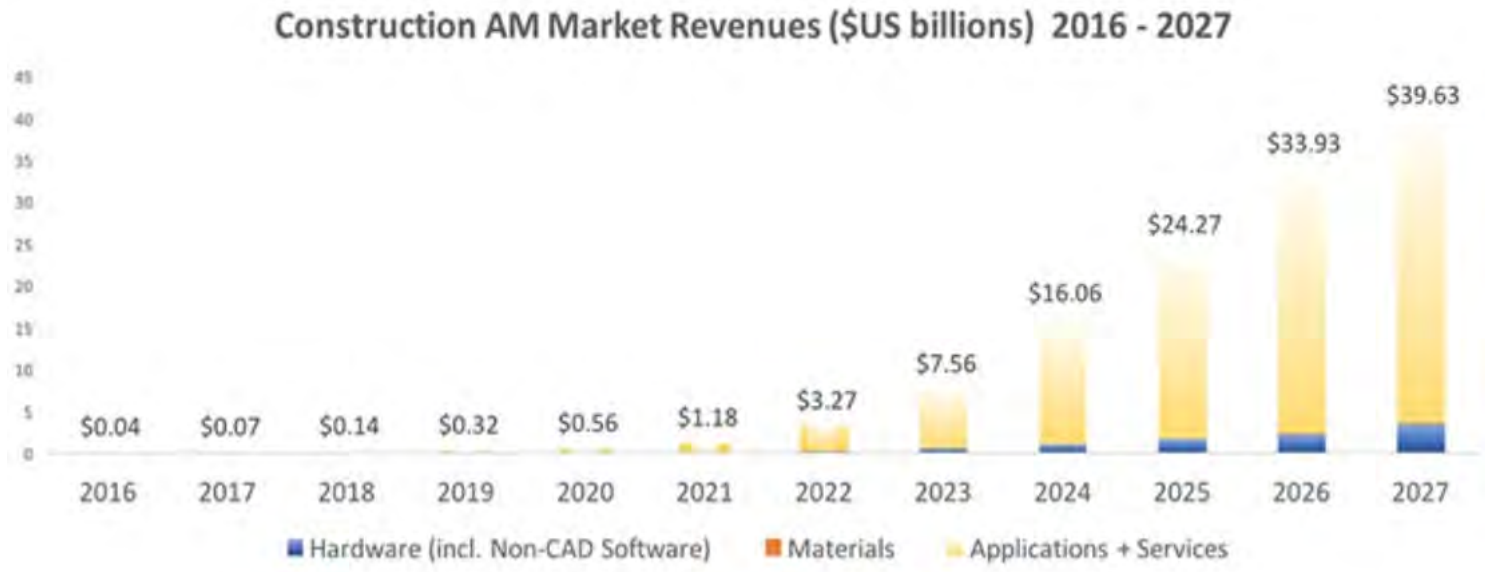
- Printing process is very much effecting structural properties
- Existing buckling curve not applicable for WAAM tubular columns
- Proposed curve for WAAM columns
  - → first step towards full understanding of buckling of WAAM tubular columns and a safe stability calculation model for structural applications
- Knowledge on both material and the printing process is required to leverage the full potential of 3D printing for construction

Conclusions

What is next? – Opportunities

- Government Strategy, achieving sustainability goals using AM:
  - UK / Dubai: 3D-print 25% of all structures in 2030.

- Increasing Investments and revenues of/for Global Construction Industry

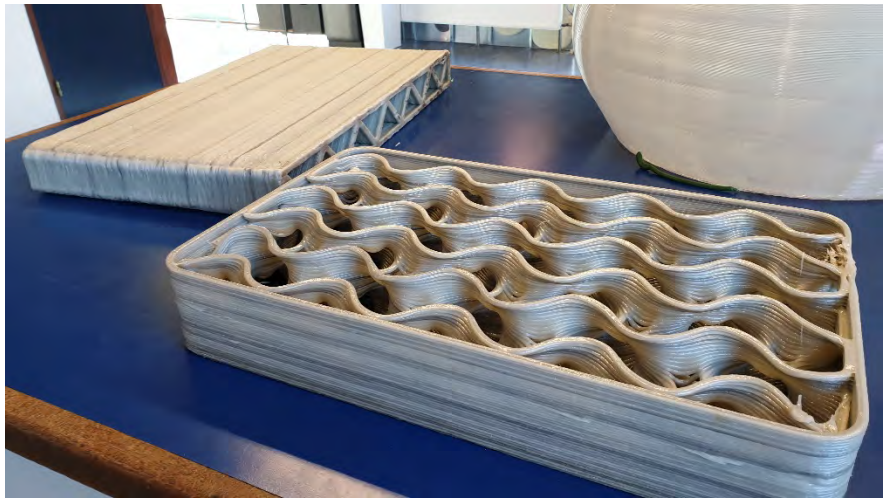


SmarTech, 2017

Conclusions

What is next? – Opportunities

METAL CURVED PANELS, MX3D AMSTERDAM



CFRP-PRINTING, CEAD DELFT

Discussion

What is next?

3D-Printen, dé toekomst of een hype?

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Exploration of Stability of 3D-Printed Steel Members

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Introduction

Additive Manufacturing - Applications

8 x 3.5 m
TU/e, BAM
October 2017


BAM INFRA/TU EINDHOVEN
Mashable
The key innovation
in the design