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Building Affordable Housing using 3D Concrete Printing

PJ Kruger
23 May 2024

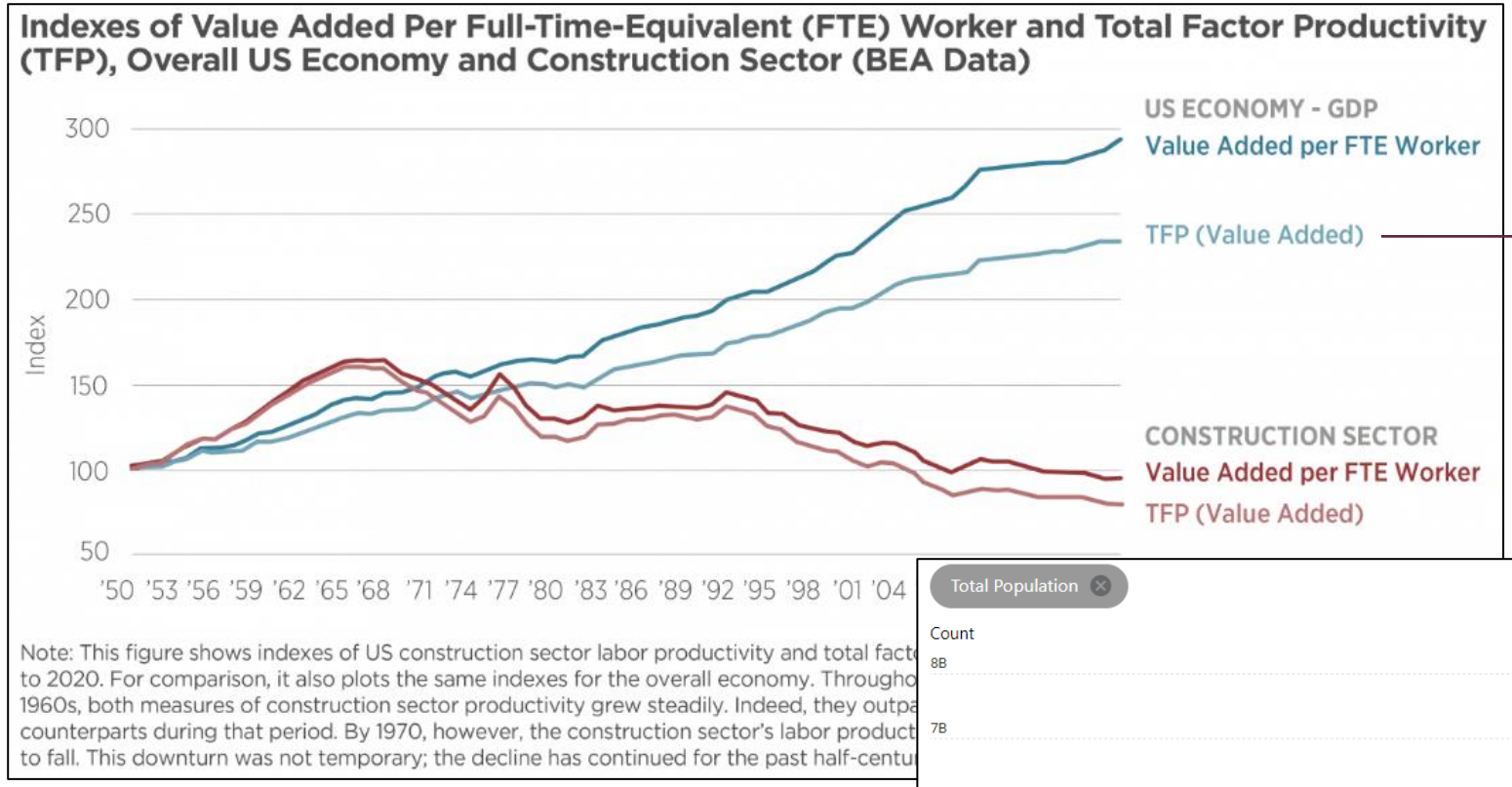
Photo by Stefan Els

Austin, TX, USA – By ICON Build (2018):

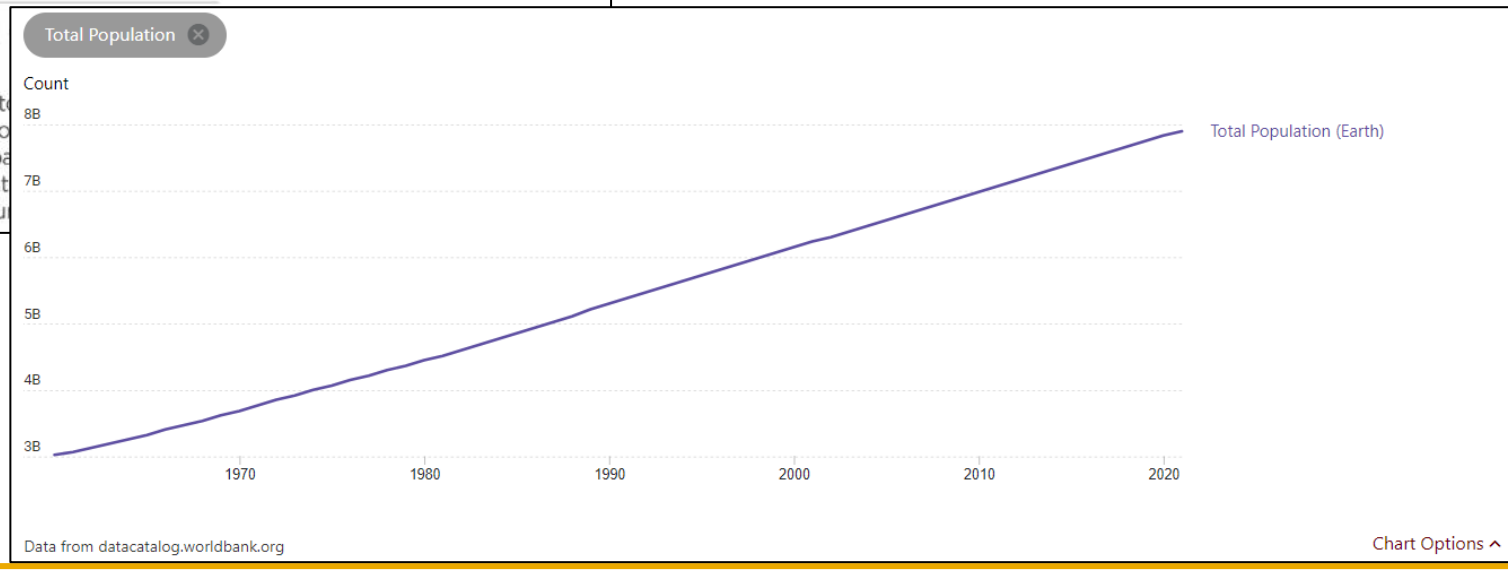
- 32 m^2
- 24 Hours (Walls)
- ≈ R150 000 (Foundation & Walls)
- ≈ R600 000 (Finished)

Wallenhausen, Germany – By PERI Group (2020): 380 m^2 3DP in 21 Days

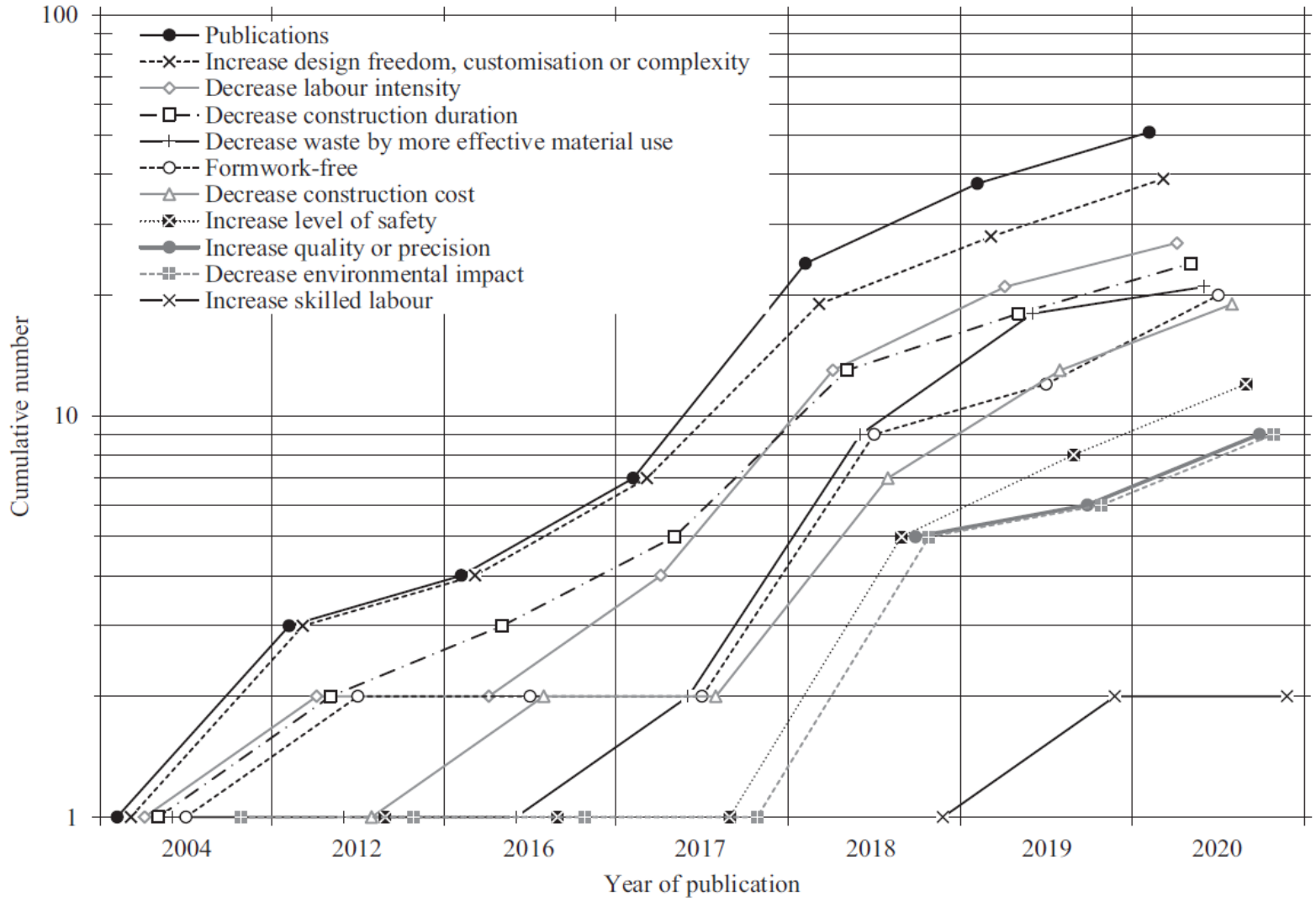
Why Automate Construction?



$$TFP = \frac{Output}{Input}$$



Why 3D Concrete Printing?

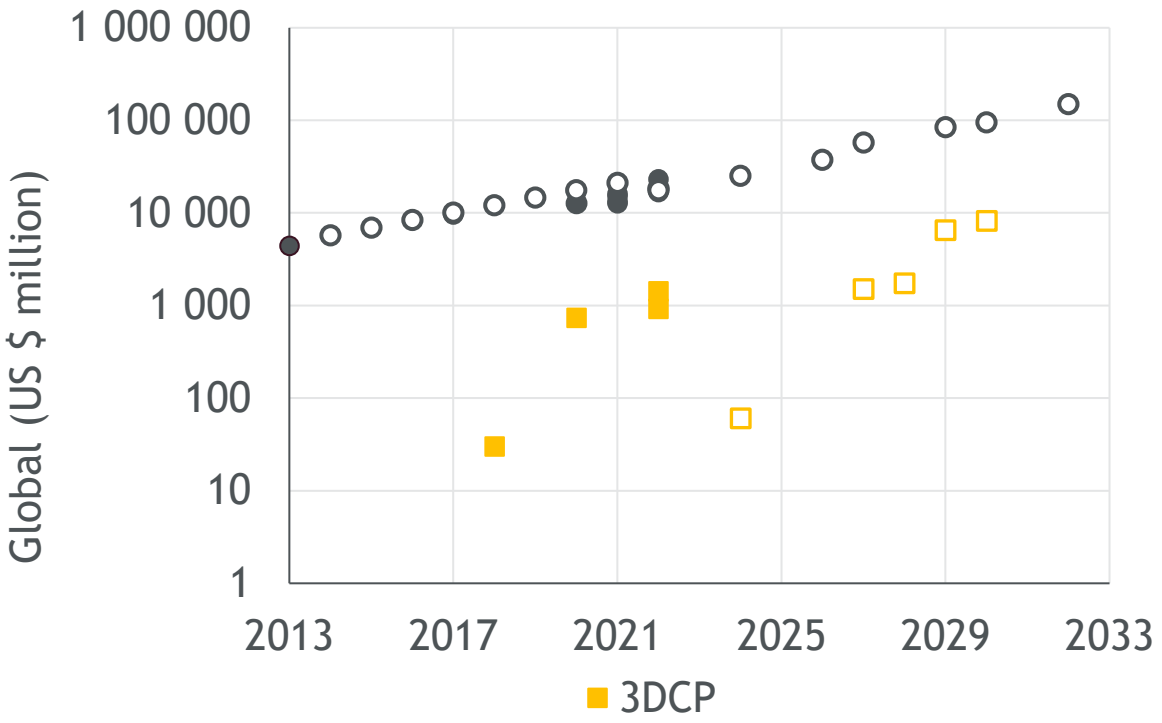


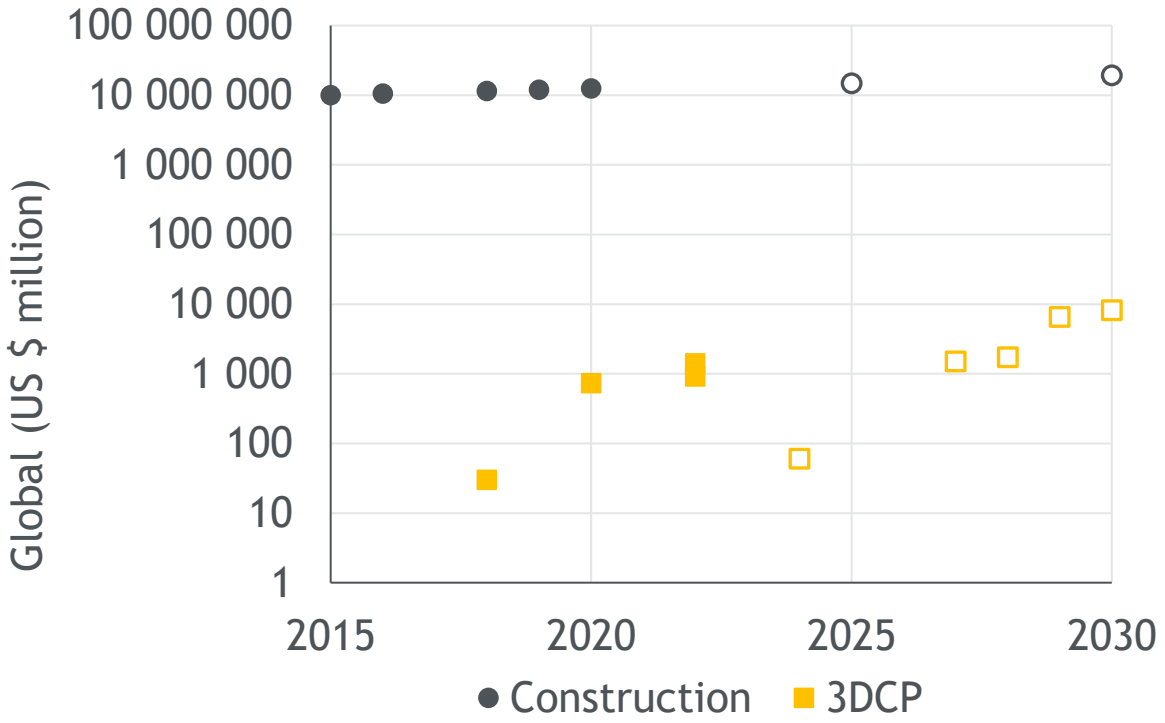
Faster

Cheaper

Increase in Quality

3D Concrete Printing Market Share





Solid: Measured | Hollow: Projected

3DCP Global Entities

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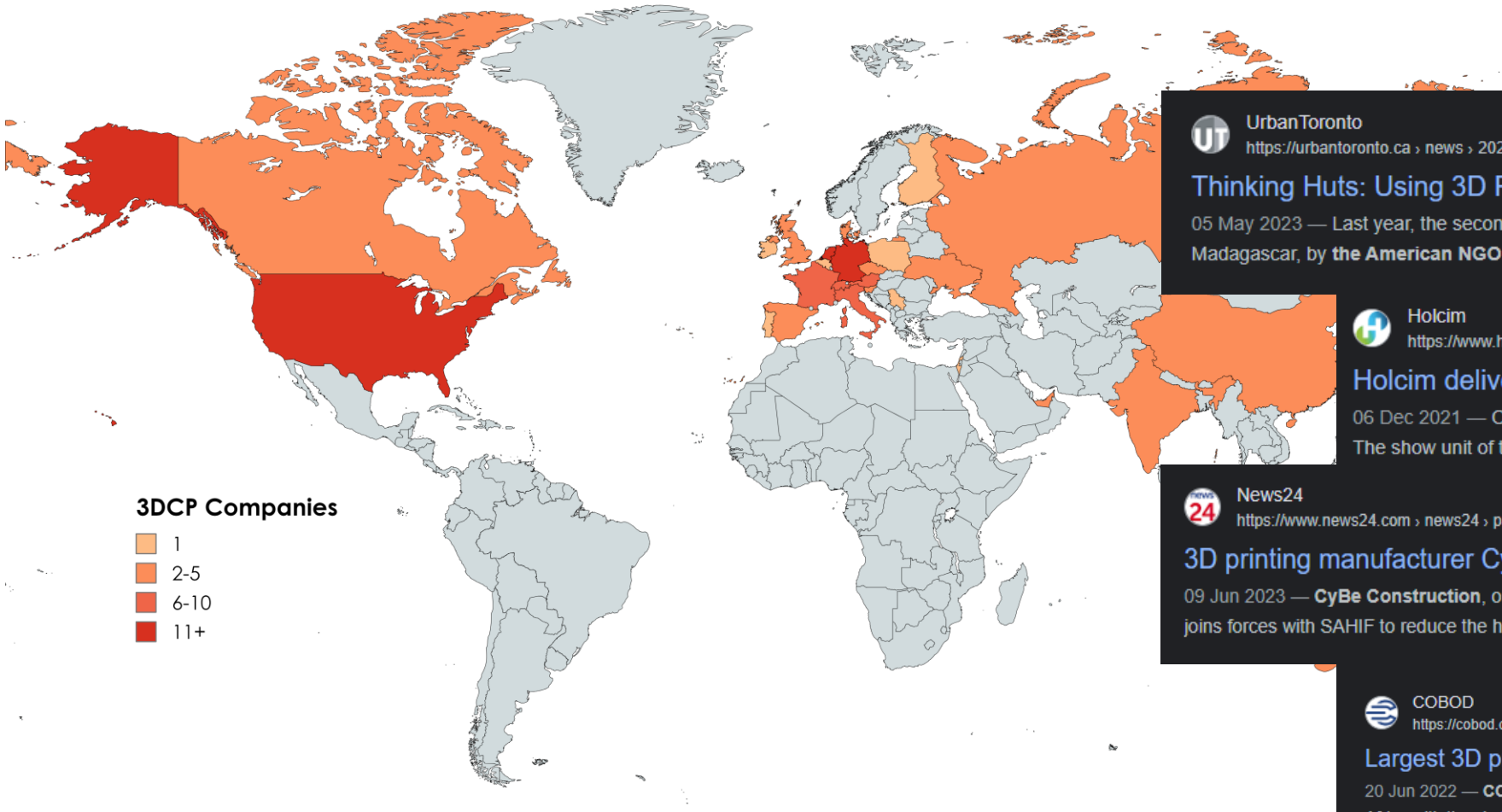


UrbanToronto
https://urbantoronto.ca › news › 2023/05 › thinking-hu...

Thinking Huts: Using 3D Printing Technology to Build ...

05 May 2023 — Last year, the second 3D printed school in the world was constructed in Madagascar, by **the American NGO Thinking Huts**. Following up on the ...

Holcim
https://www.holcim.com › Who we are › Our stories

Holcim delivers Africa's largest 3D-printed affordable ...

06 Dec 2021 — Our latest effort is **Mvule Gardens**, a 52-unit housing project in Kilifi, Kenya. The show unit of this operation, developed by our joint venture ...

News24
https://www.news24.com › news24 › partnercontent

3D printing manufacturer CyBe Construction sets foot in ...

09 Jun 2023 — **CyBe Construction**, one of the market leaders in offering 3D concrete printers, joins forces with SAHIF to reduce the housing shortage in South ...

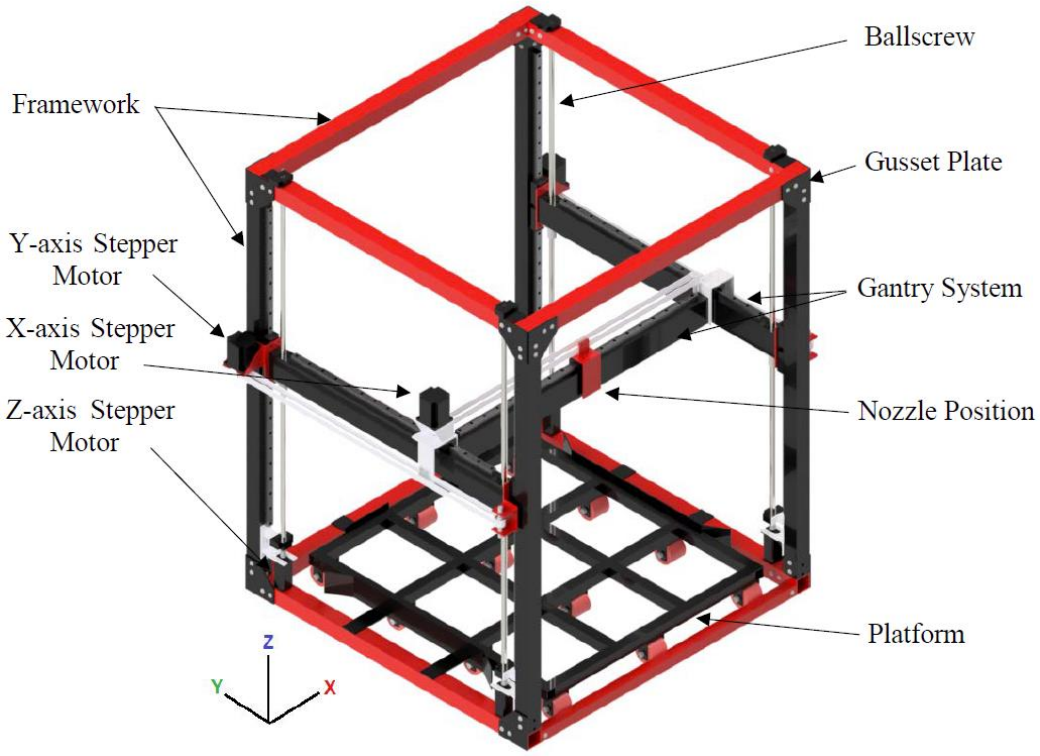
COBOD
https://cobod.com › largest-3d-printed-building-in-africa

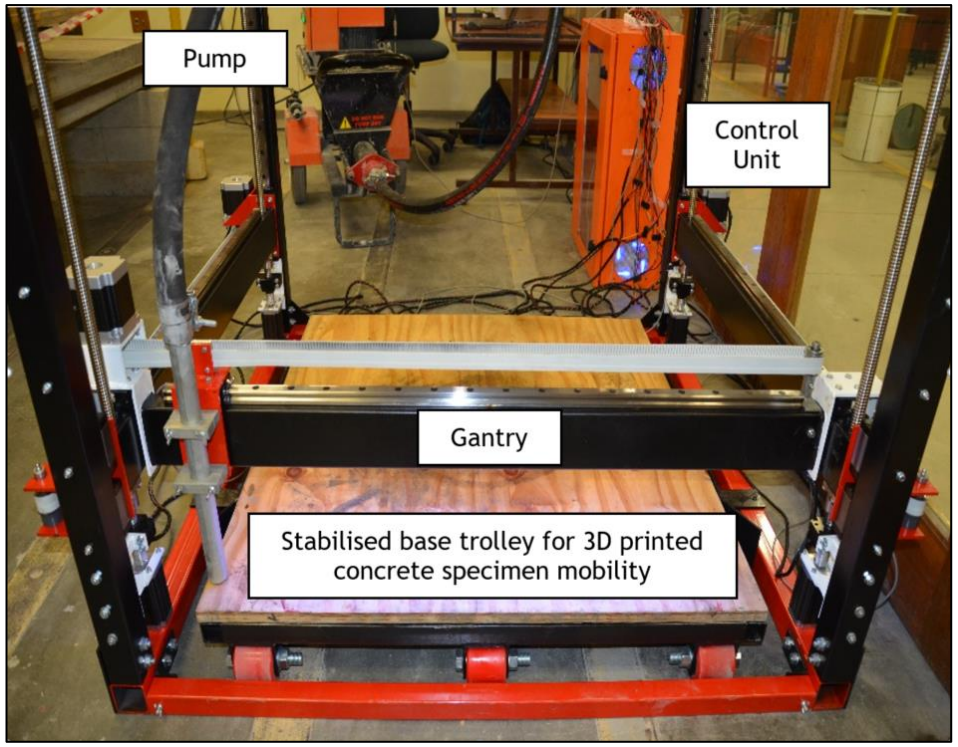
Largest 3D printed building in Africa | COBOD International

20 Jun 2022 — **COBOD completely** dominates the 3D construction printing market in Africa with the six 3D printed buildings, all done with COBOD technology.

132 Known Companies in 2023

3D Concrete Printing at SU

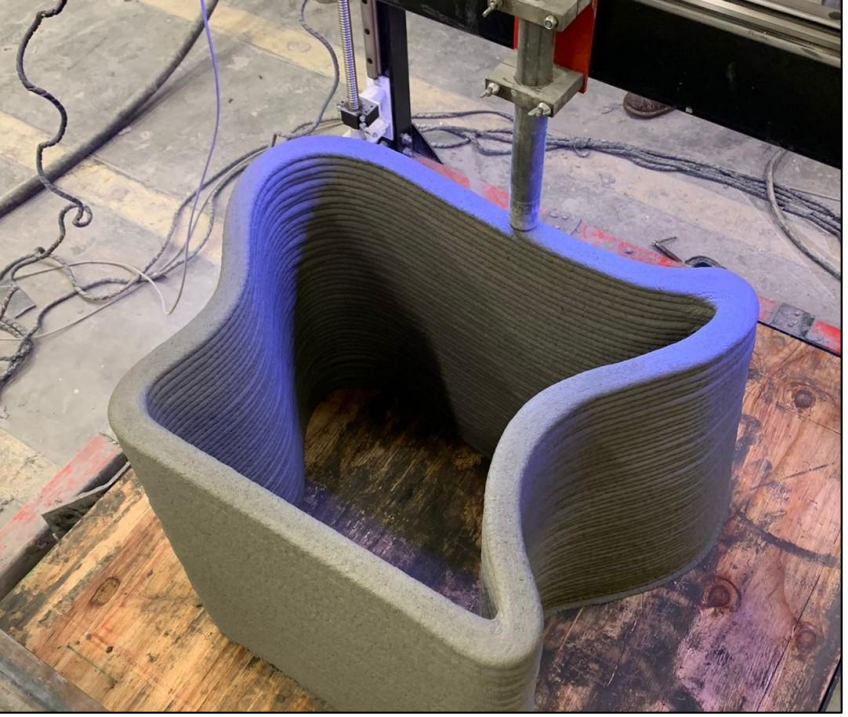


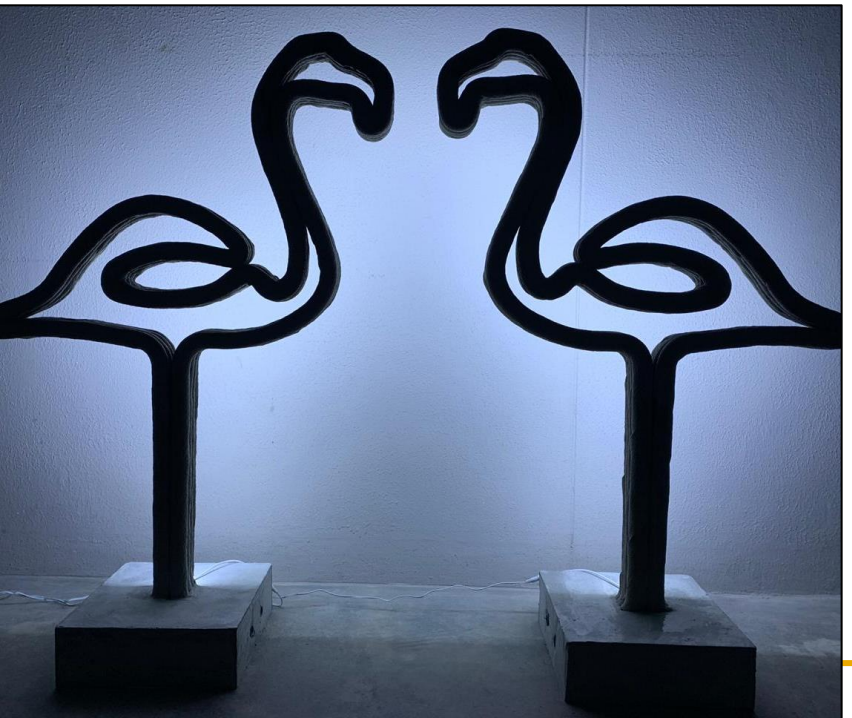


- Designed, Procured & Manufactured at SU (Completed 2018)
- 1 m^3 Build Volume
- Coupled with Progressive Cavity Pump for Batch Mixing
- Print Speeds up to 150 mm/s
- Used for Most of our Research to Date

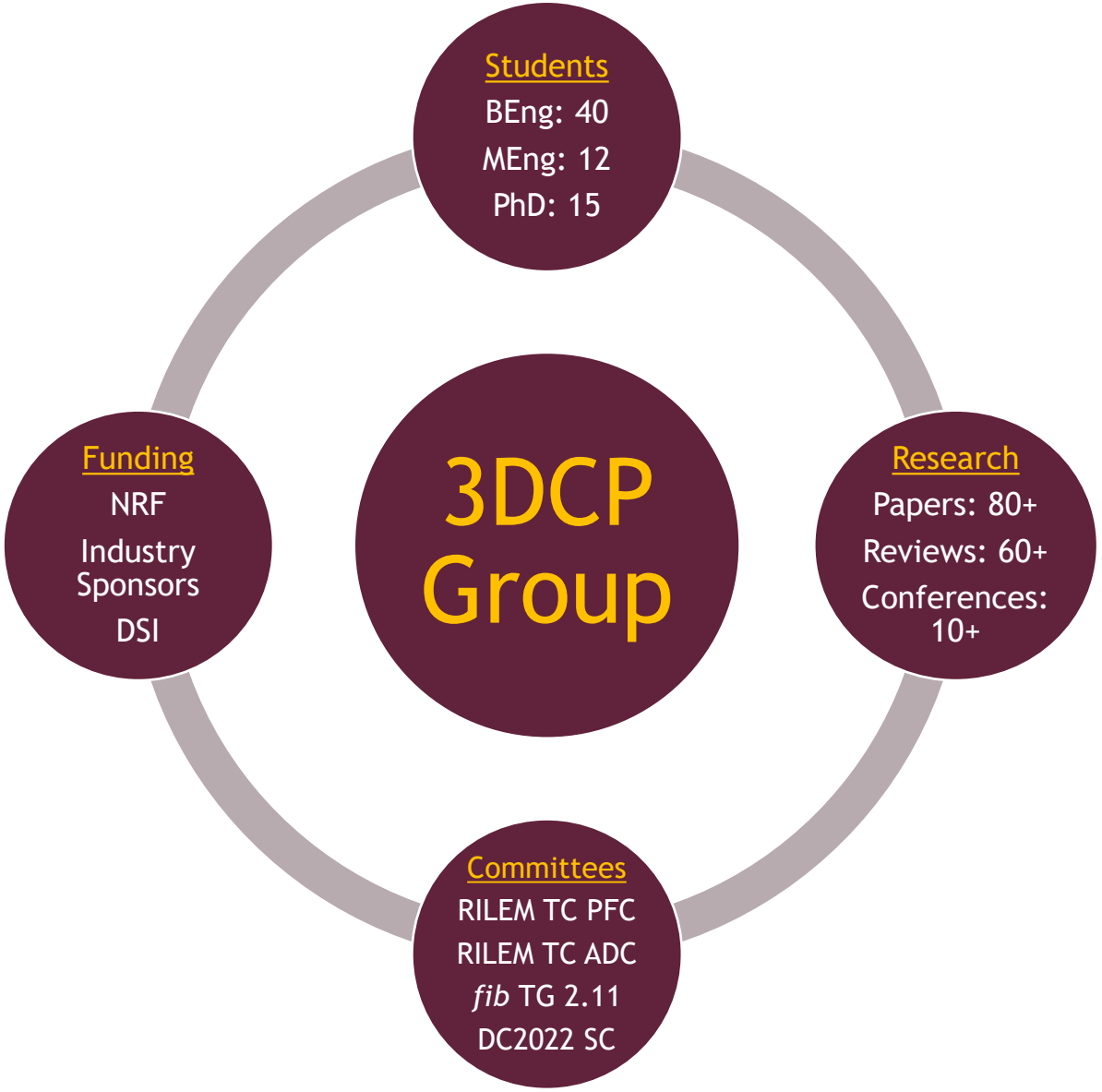
3D Concrete Printing at SU

- Designed, Procured & Manufactured at SU (Completed 2022)
- 16 m^3 Build Volume
- All Items Sourced Locally, except Pump (Germany)
- Continuous Mixing Pump
- Automated 4 m^3 Silo
- End Effector for On-Demand Chemical Dosing
- Used for Large-Scale Printing





Output since 2017



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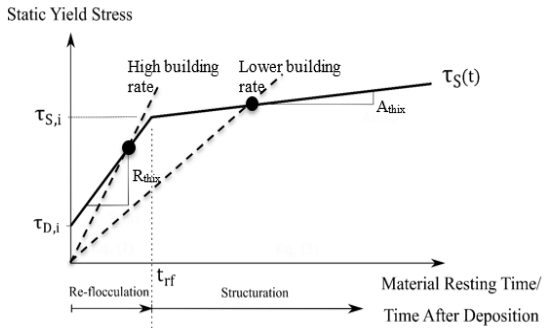
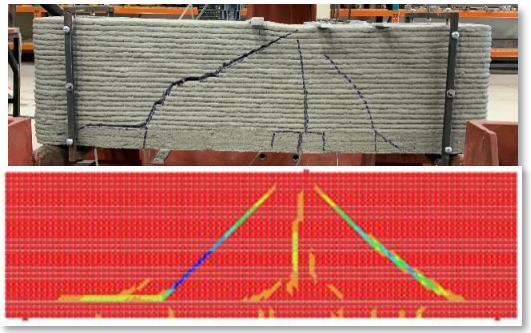
Alumni

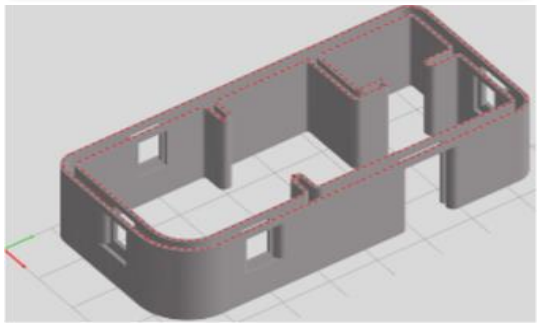
- **Dr Stephan Zeranka** – Head of Materials Research & Development at COBOD
- **Dr Gerius Moelich** – (ex) Global Head of Material Services at COBOD
- **Dr Marchant van den Heever** – (ex) Chief Technology Officer at Harcourt Technologies
- **Mr Jandré Oosthuizen** – Materials Engineer at Harcourt Technologies
- **Dr Frederick Bester** – Head Research & Development at 14Trees
- **Dr Seung Cho** – Research Fellow at UNIST

The Roadmap

2016 — 2019 — 2022 — 2025







Materials

Rheology & tests. FRC, FC, LC^3, GPC

Carbon footprint. Recycling. Circularity in 3DCP

Interfaces for strength and durability

Structural

Mechanical tests, anisotropy

Computational models

Reinforcement

Durability carbonation, corrosion, fire behaviour

Buildings

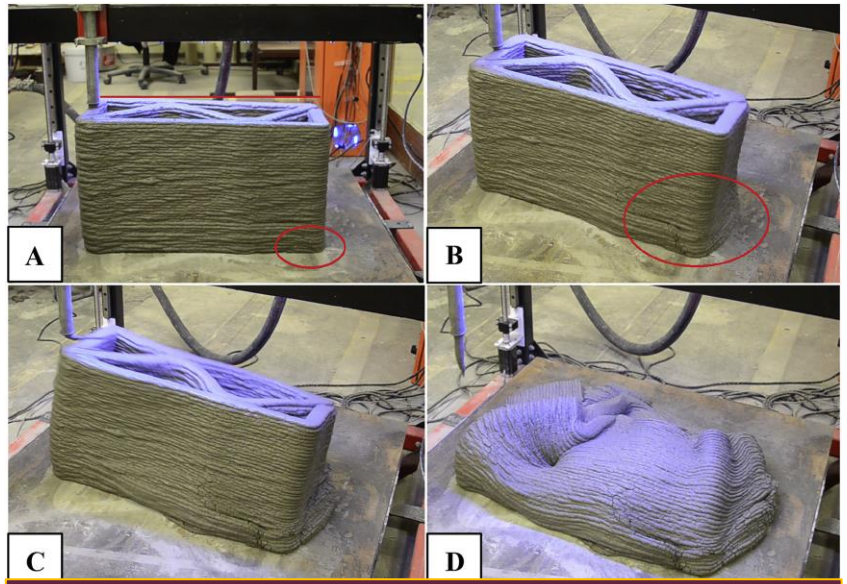
Façade heat transfer, passive design

Off-site 3DCP construction

Residential construction

3DP Full Scale House

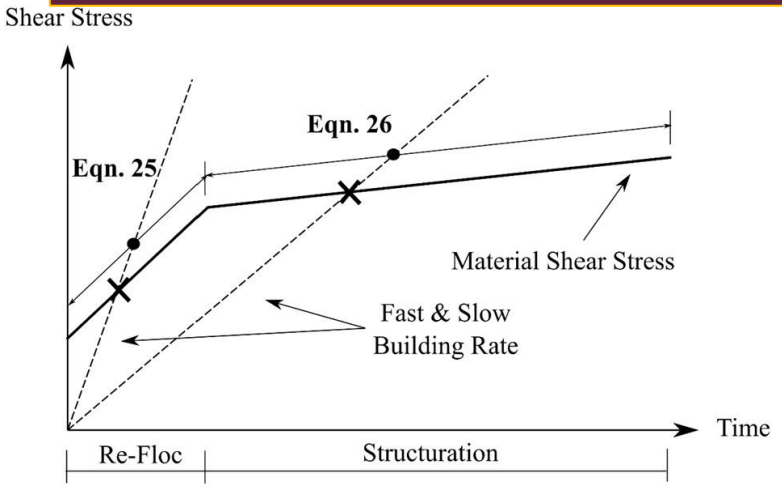
Research: Material Level



Constructability

Rheometry

Fresh State Workability Tests



$$\text{If } \frac{d}{dt}\left(\frac{\rho.g.h_l^*.v^*.10^{-3}}{2.l_p.F_{AR,expl}}.t\right) \geq \frac{\tau_{S,i}.R_{thix}}{\tau_{S,i}-\tau_{D,i}}$$

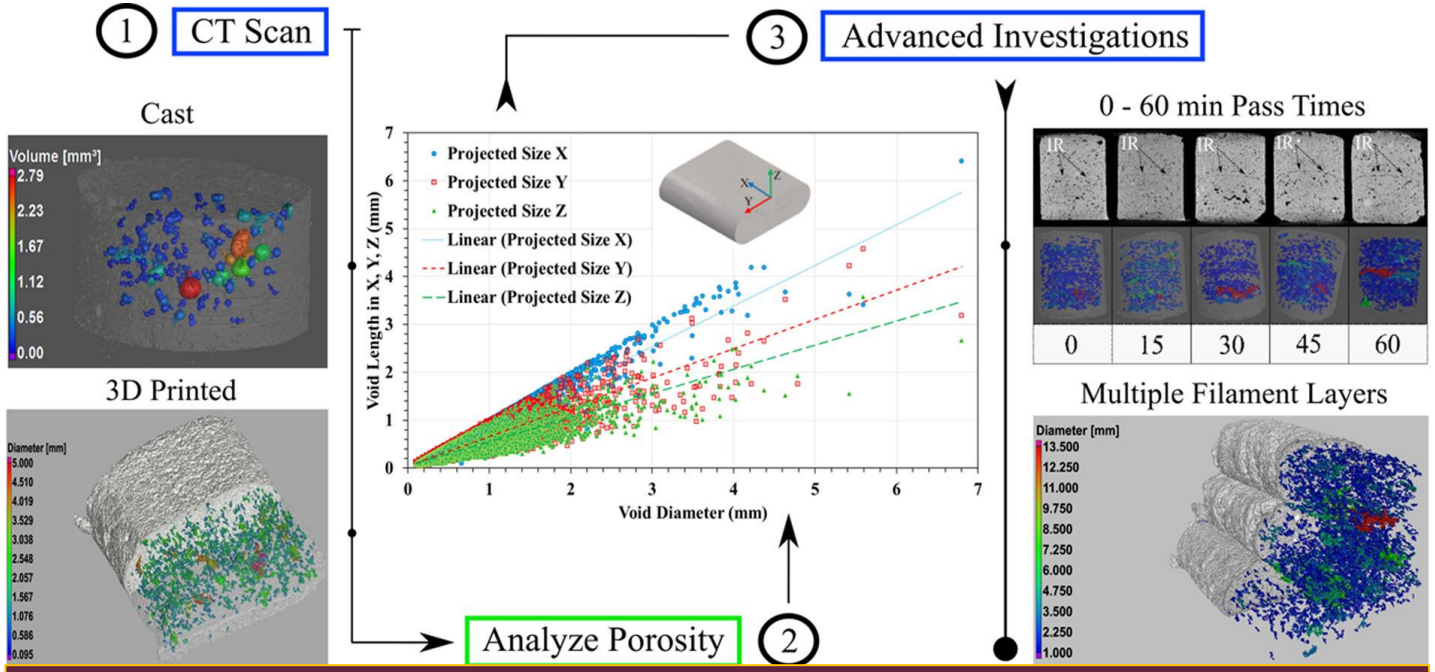
$$\text{Then use } H_{predicted} = \left[\frac{h_l^*.\tau_{D,i}}{\left(\frac{\rho.g.h_l^*}{2.10^3.F_{AR,expl}}\right)-\left(\frac{R_{thix}.l_p}{v^*}\right)}\right]$$

$$\text{Else use } H_{predicted} = \left[\frac{h_l^*.\left(\frac{\tau_{S,i}}{\gamma_{M,1}}+\left(\frac{A_{thix}.\left(\tau_{D,i}-\frac{\tau_{S,i}}{\gamma_{M,1}}\right)}{R_{thix}.\gamma_{M,2}}\right)\right)}{\left(\frac{\rho.g.h_l^*}{2.10^3.F_{AR,expl}}\right)-\left(\frac{A_{thix}.l_p}{v^*.\gamma_{M,2}}\right)}\right]$$

Material Models / Analytical Modelling / Buildability

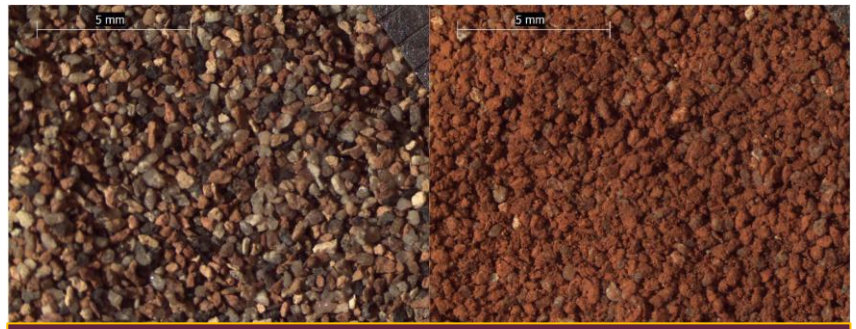
Fresh State Mechanical Tests

Research: Material Level

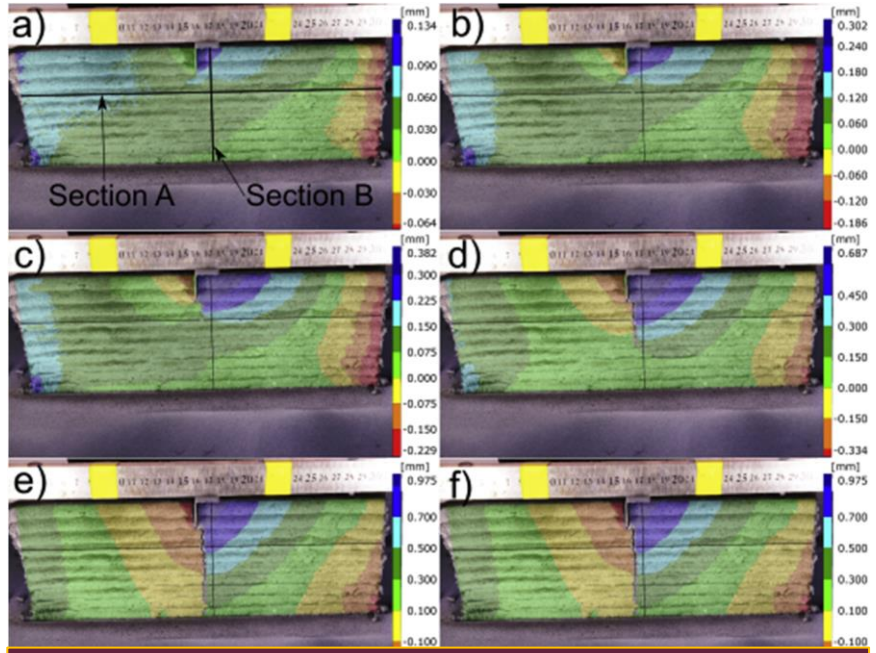


Microstructural Investigations using Computed Tomography

Interlayer Bond Strength Enhancement / Nozzles



Circularity



Plastic Shrinkage Cracking

Research: Structural Level

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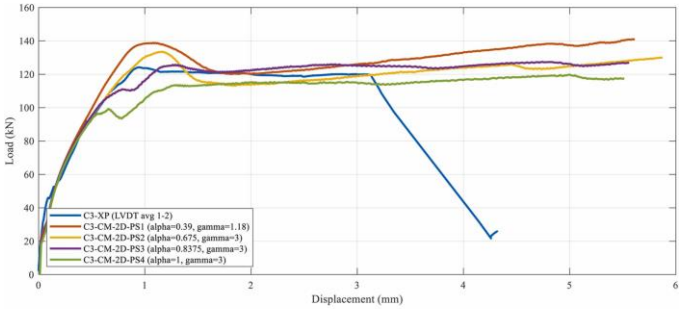
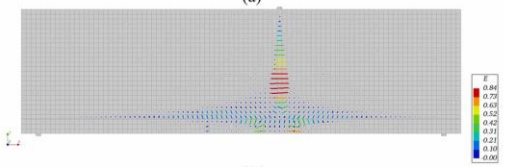
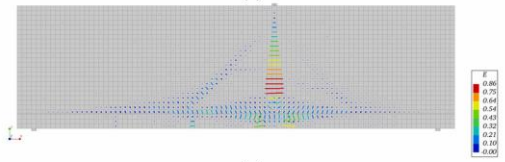
Discrete and Continuum FE Modelling



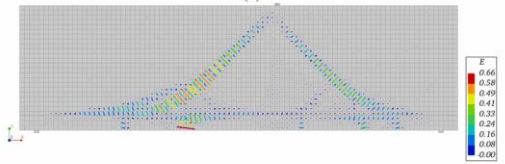
(a)



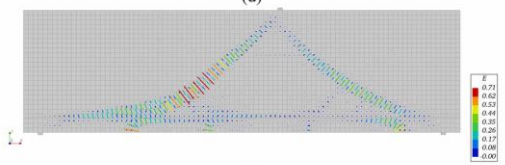
(b)



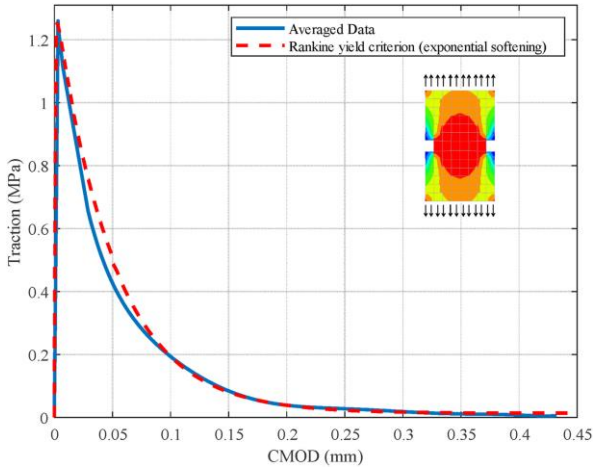
(c)



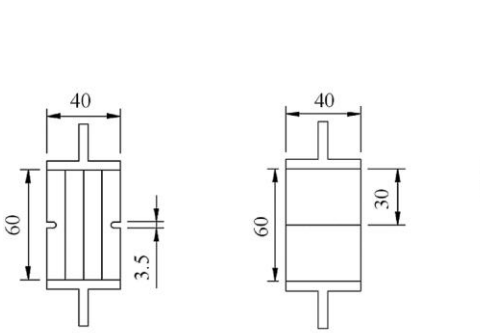
(d)



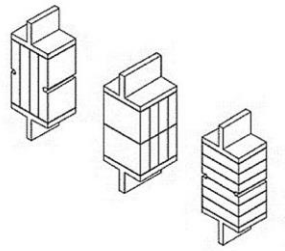
(e)



Hardened State Mechanical Tests / Anisotropy



(a) (b) (c)



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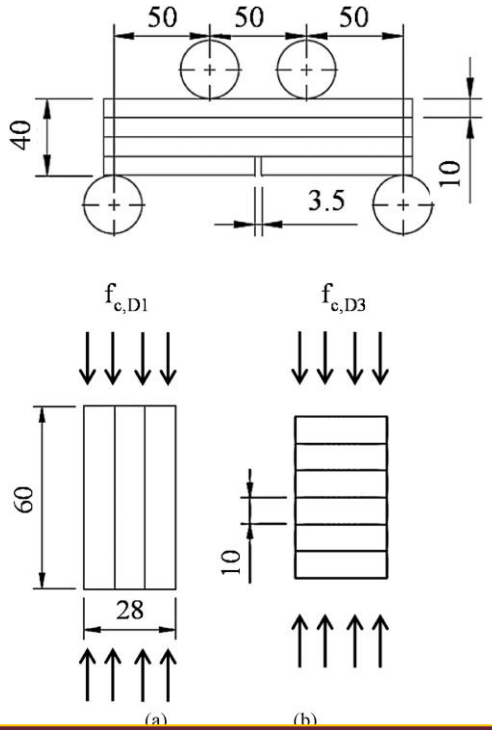
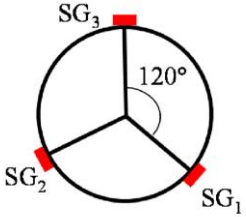
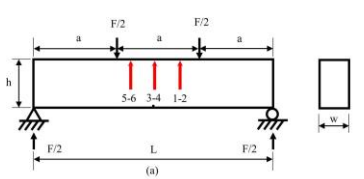


(a) (b)

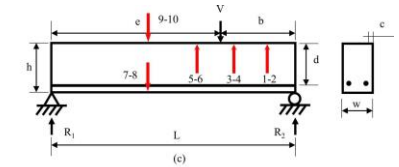
(b)



Large Scale Experimental Testing



(a)



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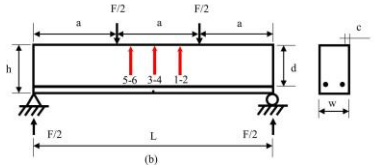
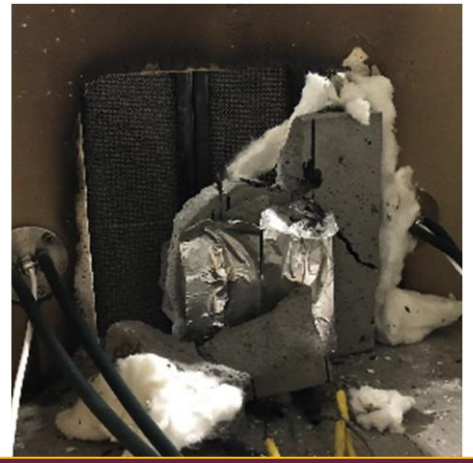


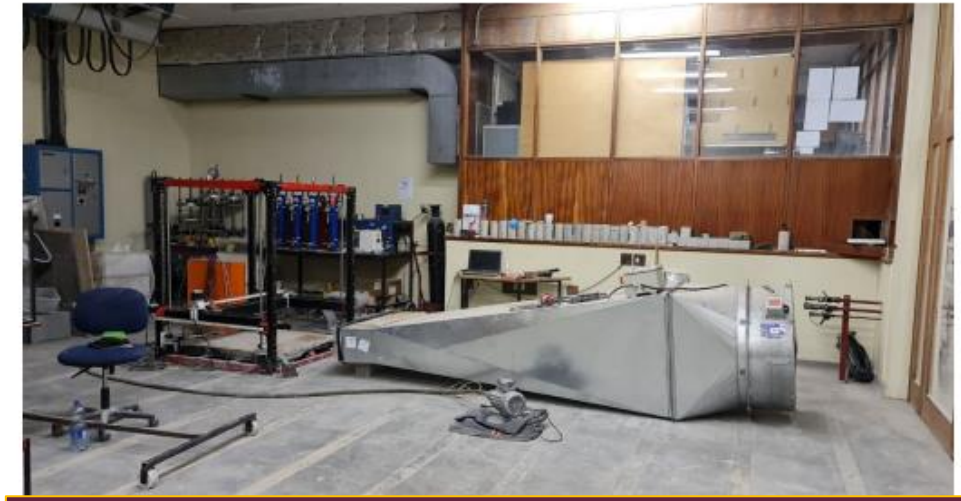
(b)

(d)

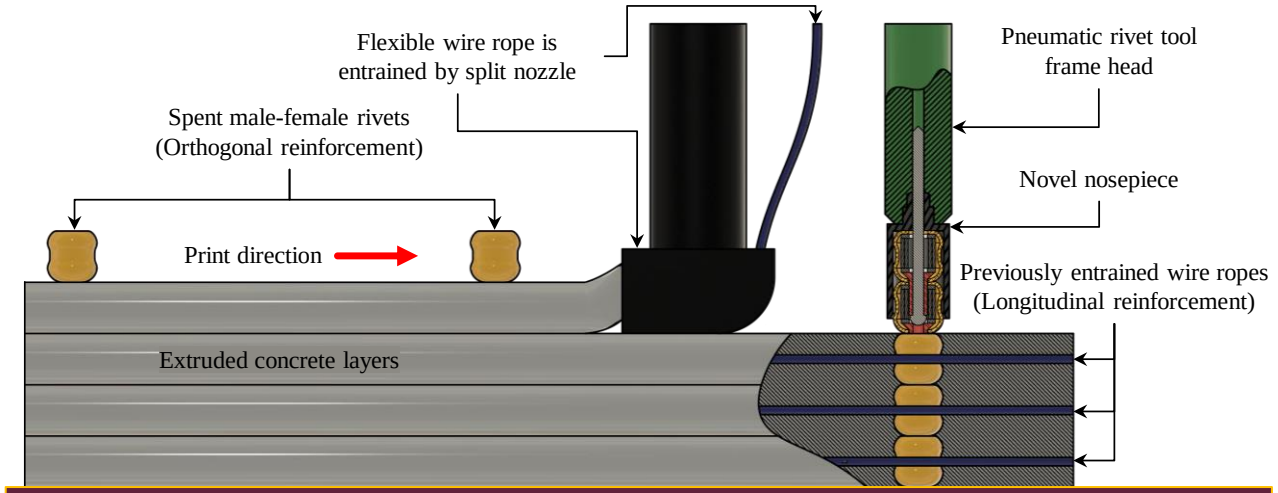
Research: Structural Level



Fire Performance Tests



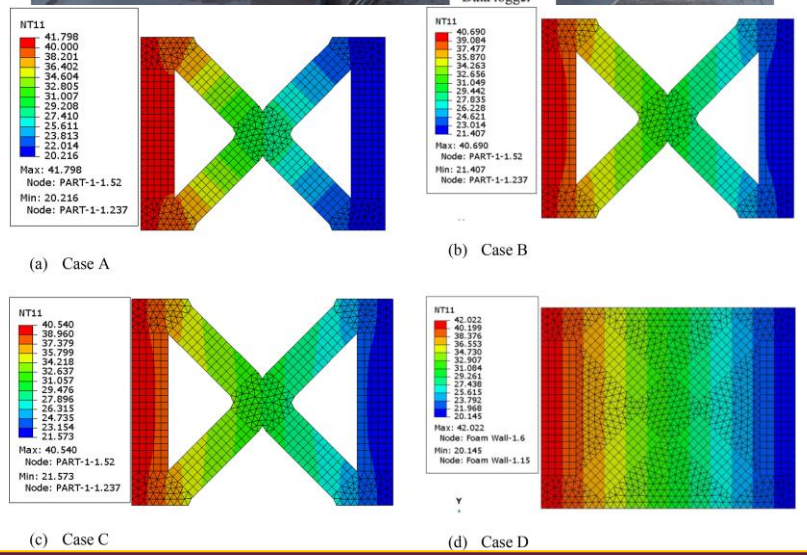
Environmental Effects / Curing



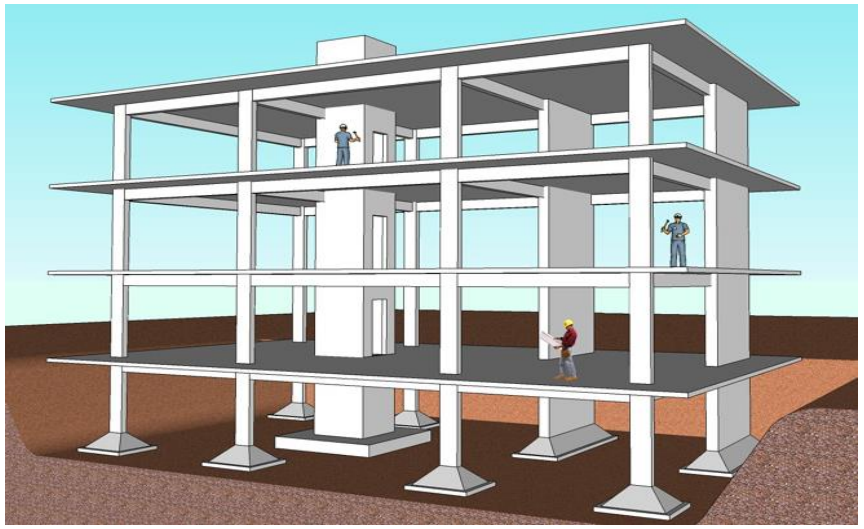
Novel Reinforcement Techniques

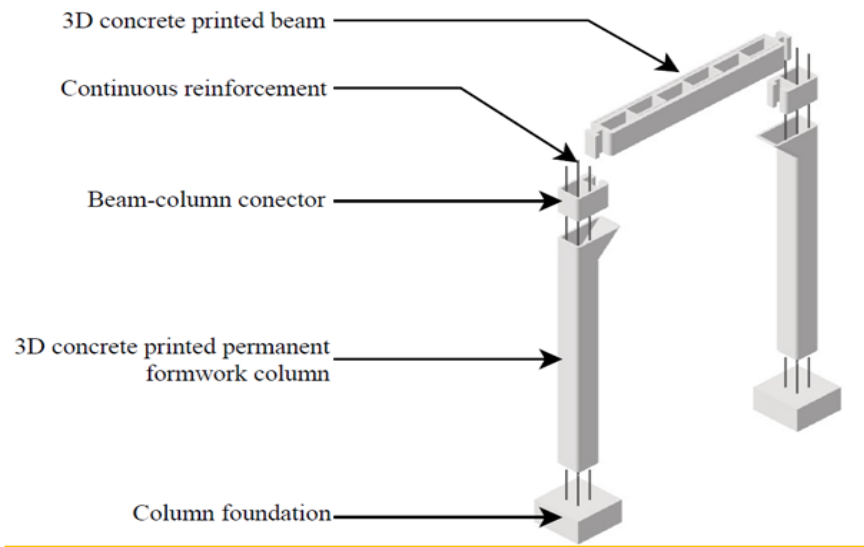
Durability Tests / Carbonation

Research: Building Level



Thermal Conductivity / Insulation





Off-Site Construction / Prefabrication

Construction Model

Two Options

- Prefabrication / Off-Site
- On-Site (Walls & Roof)

Conventional Methods

1x /Time Period

3DCP

3x /Time Period

Speed

Higher Productivity = Lower Turnaround Time
Affordable = Keeping up with Population Growth (≠ Cost)

What's Next?

3D Print Full Scale House [±40-60 m^2] in 2025 by Partnering with Industry and Statutory/Regulatory Entities

Aim?

1. Demonstrate Technology Readiness Level (TRL) in RSA Context [6 to 9] (Show)
2. Facilitate Industry Adoption of 3DCP Technology (Grow)
3. Ensure Safe and Sustainable Implementation (Lead)

Our aim is to unlock the true potential of Additively Manufactured Concrete Technologies and transform the largely unindustrialized global construction sector into a smart, sustainable and lucrative industry.

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Thank you
Dankie
Enkosi

Photo by Stefan Els