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Department:
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The Viability of 3D Concrete Printing Technology in the Housing Sector

Tariro Ndarowa

School of Civil Engineering & The Built Environment

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UNIVERSITY OF JOHANNESBURG

Presentation Outline

- Project Objectives
- Research Questions
- Limitations of the Research
- Technology Uptake – International Perspective
- Technologies used for 3D Concrete Printing (3DCP) of Buildings
- Materials used for 3DCP
- The future of 3DCP in South Africa
- Conclusions and Way Forward

Project Objectives

The project objectives are to:

- Explore the potential of using 3D Concrete Printing (3DCP) technology to build houses in South Africa;
- Review availability of 3DCP in the market (Local & International);
- Review and analyze materials used for 3D printing and the availability thereof in SA; and
- Review potential challenges and the future of implementing 3DCP of houses in SA.
- 2.6 million backlog.

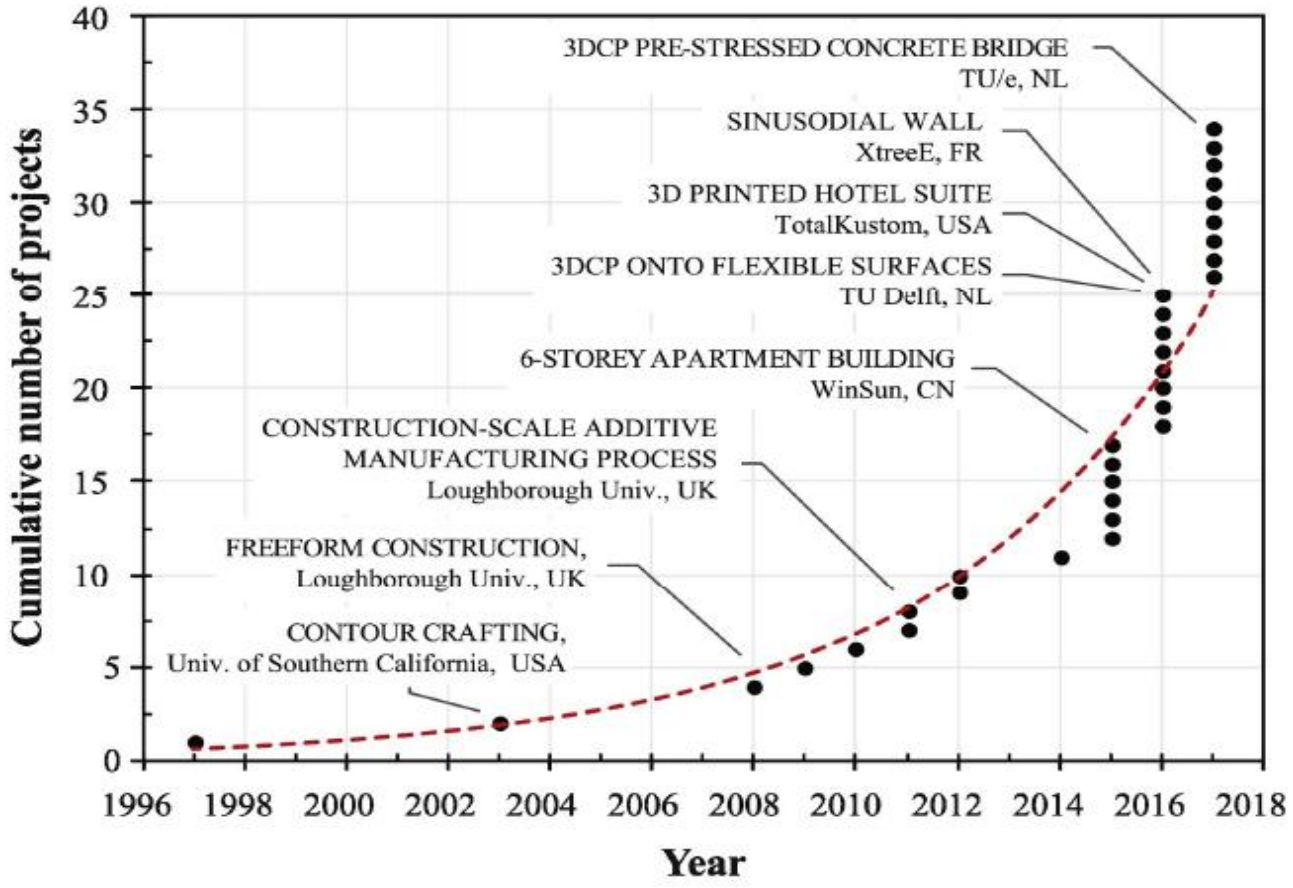
Research Questions

- Is 3D construction printing (3DCP) technology mature enough to be embraced by the industry?
- Has 3D printing of buildings, specifically houses, been implemented on a large scale elsewhere in the world and what technologies have been used?
- Is the house construction industry of South Africa ready for 3D printing of houses, and what could be the potential inhibitors?
- What are the materials used for 3D printing of buildings? Is there a potential of using re-cycled and or waste materials? What are the contributions of these materials to passive green homes and combating the negative effects on climatic change?
- Is it cost effective to use 3D Concrete printing?

Limitations of the Research

- 3D printing is currently limited to printing of walling elements
- Future research to extend to printing of other building elements (Foundations, roofs etc)
- However, pilot project implementation in KZN will focus on innovation of all construction elements (3D printed walls and other building elements using other forms of innovation)

Technology Uptake: International Perspective - 3DCP



Number of 3DCP projects since 1997 (Buswell et al., 2018)

Technologies used for 3DCP

- The following approach was used in identifying technologies:
  - Detailed desktop search on local and international suppliers of the printers;
  - Referrals by contacts obtained through previously attended conferences and workshops. Notably were contacts provided by the “founder” of 3D construction printer Prof Behrokh Khoshnevis (formerly with University of South Carolina); and
  - Enquiries through other academic institutions (e.g. University of Shandong, Republic of China)
- Our initial intent was to visit the suppliers of the 3DCP, but with the pandemic COVID-19, our studies were limited to internet search and video calls.

Technologies used for 3DCP (Cont…)

Approach used followed these principles:

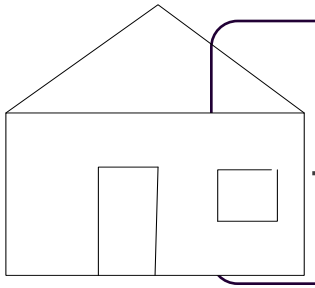
- Cost effectiveness
- Speed
- Customisable materials (Open source)
- Industrial scale
- Sustainability

Technologies used for 3DCP (Cont…)

Findings:

- 3DCP is still in its infancy stages
- Very few companies have managed to successfully establish a manufacturing plant and run “Real-life” projects
- Printers are manufactured on a request basis, and takes about 3 months to assemble
- 3DCP Printers generally use commonly available building materials (cement and sand), with special proprietary material (additive)
- As an emerging technology, there is reluctance to provide info by suppliers
- Opportunity to develop customised materials using local and waste materials

3D Printing Process



Housing typology

BIM or CAD Model

Slicing and layer combination

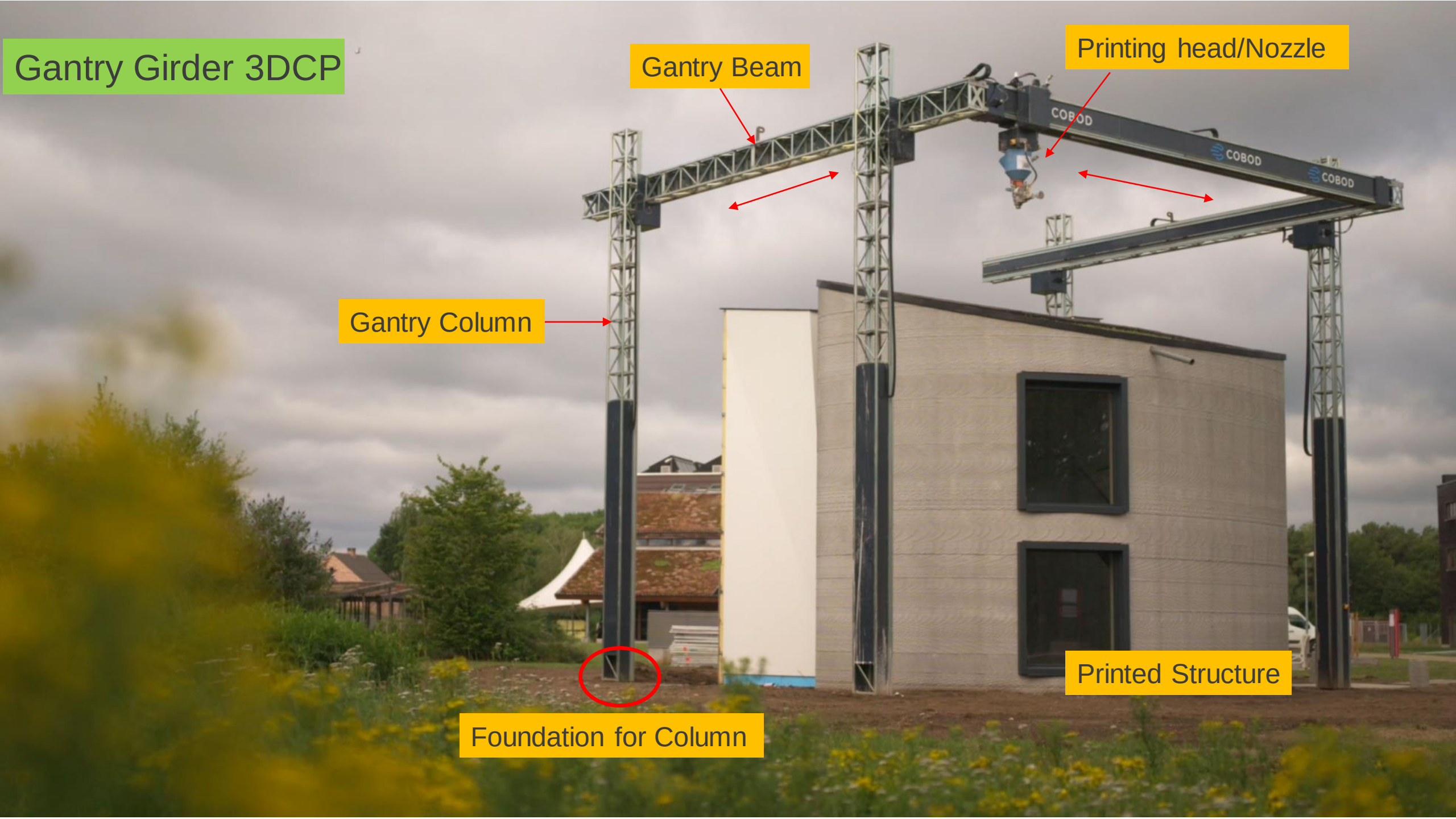
3D Printing

Physical 3D printed object

Technologies used for 3DCP (Cont…)

The following are the common 3DCP available:

- Robotic Arm System
- Gantry Girder System


Gantry Girder 3DCP
Gantry Beam
Printing head/Nozzle
Gantry Column
Printed Structure
Foundation for Column
COBOD
COBOD
COBOD

Example of House: Gantry Girder System

- The walls are curved, the only straight elements being the windows and doors.
- Non-straight shapes are expensive and difficult to construct when using the traditional methods

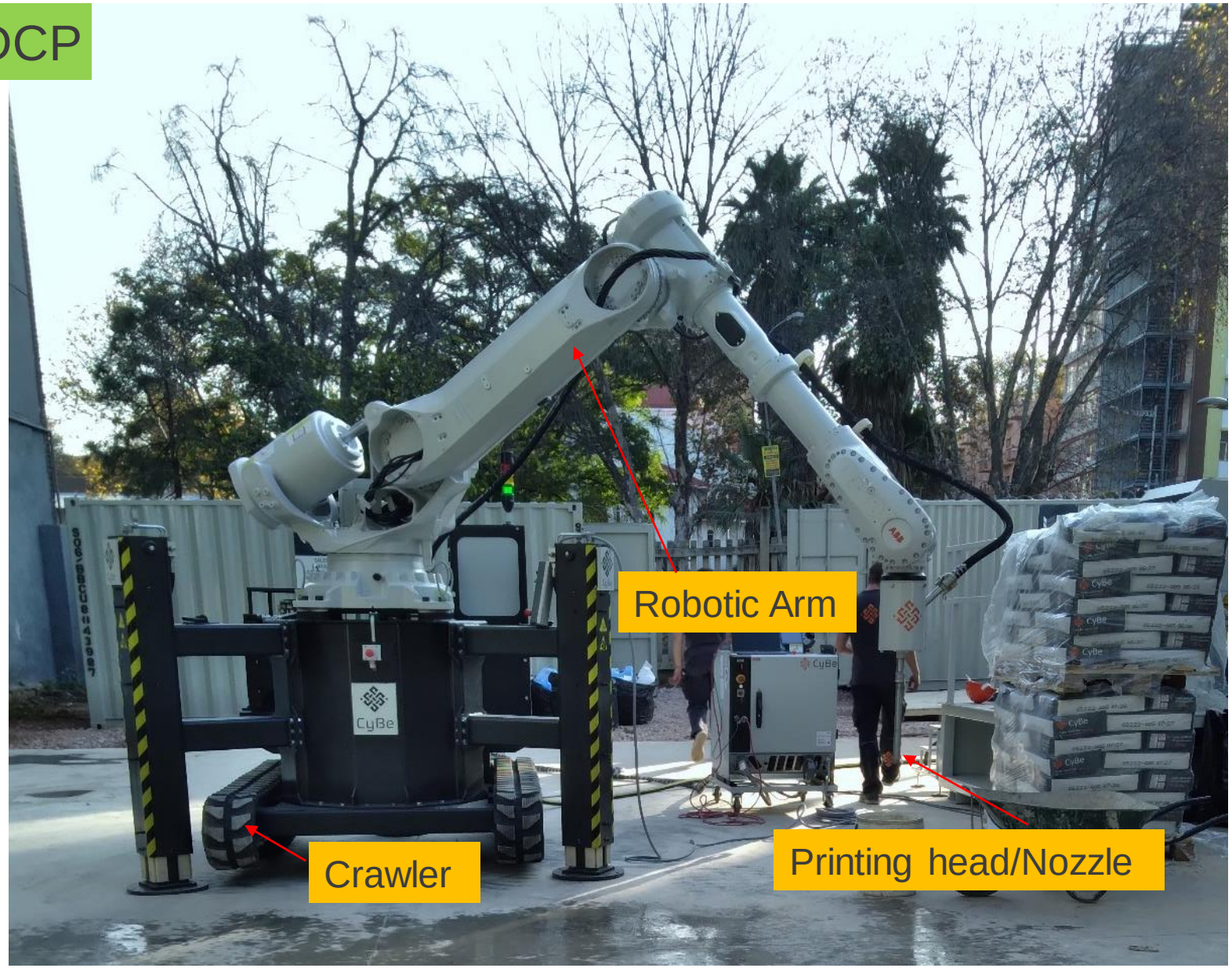
Gantry Girder System

Video of Gantry Girder

Advantages and Disadvantages of Gantry Girder 3DCP

Advantages	Disadvantages
• Generally stable structure for construction due to its weight.	• Big Structure – The printer has to be bigger than the structure it prints.
• Relatively inexpensive (Compared to Robotic systems)	• Difficult to move from one position to the other. Monolithic structure.
• Suitable for printing large structures at once. There is generally no need to move it around as it encloses the structure it is printing	• Long setup and calibration time (About 4 hours). The machine needs to be assembled first before printing can commence.
• High material flexibility. It uses open source materials and has limited restrictions from a materials point of view.	

Robotic Arm 3DCP



3D printed house at the University of Johannesburg, South Africa
House size – 40 sqm

Video of Robotic Arm

Advantages and disadvantages of Robotic Arm 3DCP

Advantages	Disadvantages
• Portable – Smaller in size as compared to the gantry system.	• Construct large buildings in parts as it cannot reach all areas of the house.
• Easy to move – It has a crawler system which assists with mobility.	• Relatively expensive – compared to gantry systems
• High material flexibility – It uses open source materials and has limited restrictions from a materials point of view.	

Materials Used for 3DCP

- Material used for 3D printing need to have following characteristics
  - Flowability:- Flow behaviour of fresh materials in the pumping system
  - Open Time:- Time elapsed between initial contact of dry mix and water and the time when the material is printable.
  - Extrudability:- Capacity of fresh paste to pass through the nozzle of the printer as a continuous and intact filament
  - Buildability:- Printed resistance to deformation under load
  - Hardened Properties: eg. Compressive, flexural, tensile, etc
- Following waste materials have been used internationally;
  - Copper tailings waste materials
  - Recycled glass
- Currently limited number of materials have been used for 3DCP. Experimentation is underway at UJ to investigate the use of multiple materials and locally produced waste materials to produce complex mix designs.

The Future of 3DCP in South Africa

- Transformative technology that will revolutionise and fast-track the delivery of houses in SA.
- Perceived high implementation costs of 3DCP. Life cycle costing of 3DCP compared to conventional construction being conducted;
- Potential in reducing on site health and safety risks;
- Potential of reducing waste materials, transportation costs, etc;
- Availability of local materials. Printers have provision for open source materials;
- Limited footprint. Most printers can print 40-100 sqm, 2 storey high;
- Pilot project to be implemented in KZN where 50 houses will be demonstrated will validate some of the preliminary findings

Conclusions and Way Forward

- Size of printers is huge and may be difficult to assemble and disassemble on-site leading to cost increases;
- Initial high capital cost (to be validated through the Life Cycle Cost)
- Disruptive impact on skills required on-site (more high tech skills as opposed to unskilled labour force). Complete value chain of housing delivery (from material acquisition to disposal) to be reviewed. Research in progress
- Huge potential to create more efficient and interesting designs as 3D printing can achieve shapes that conventional building techniques cannot (Typical “box match” houses)

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