

Building Beyond Limits

Making the Case for Propelling Towards 3D Printed Concrete Structural Code

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THE WORLD'S GATHERING PLACE FOR ADVANCING CONCRETE

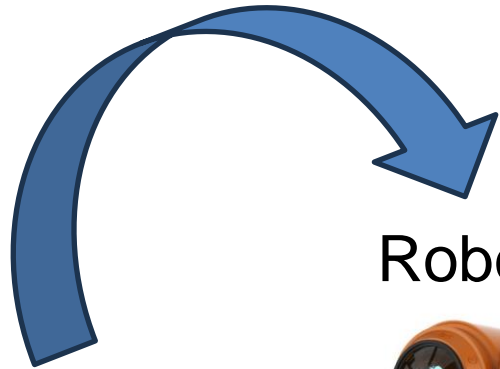


Introduction

How is 3D printing technology used in construction?

Specialized
Concrete
Mixture

- Strength
- Durability
- Workability



Robotic Arm



Source: xometry.com

Gantry System



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The Promise of 3D Printer in Construction



- Design flexibility and customization

- Speed and efficiency
- Reduced wastage
- Possibility of utilizing recycled materials
- Cost savings

Earliest Notable Implementation of 3D Printed Structures



2013: "Villa Urbe" in Shanghai, China



2014: "Canal House" in Amsterdam, Netherlands



2018: "3D Printed Castle" in Austin, USA



2016: "Office of the Future" in Dubai

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Companies/Designers that Successfully Implement 3D Printed Concrete Structures



ICON



Emergent



Printed Farms



Mighty Buildings



Larsen and Toubro, IIT Madras



University of Nantes, TICA



Apis Cor, Yves Behar



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Current Limitations

- Regulatory Hurdles
- Lack of Standardization
 - IBC 2021: Section 104.11 (alternative materials, design and methods of construction and equipment)
 - IRC Sections R301.1.3, R104.11
 - UFC 3-301-01 Section 1903.5
 - Acceptance Criteria (AC509) developed by ICC-ES
 - Firm patents
- Material Properties
- Quality Control



ICC-ES Evaluation Report


ESR-4623

Reissued October 2023

Subject to renewal October 2024

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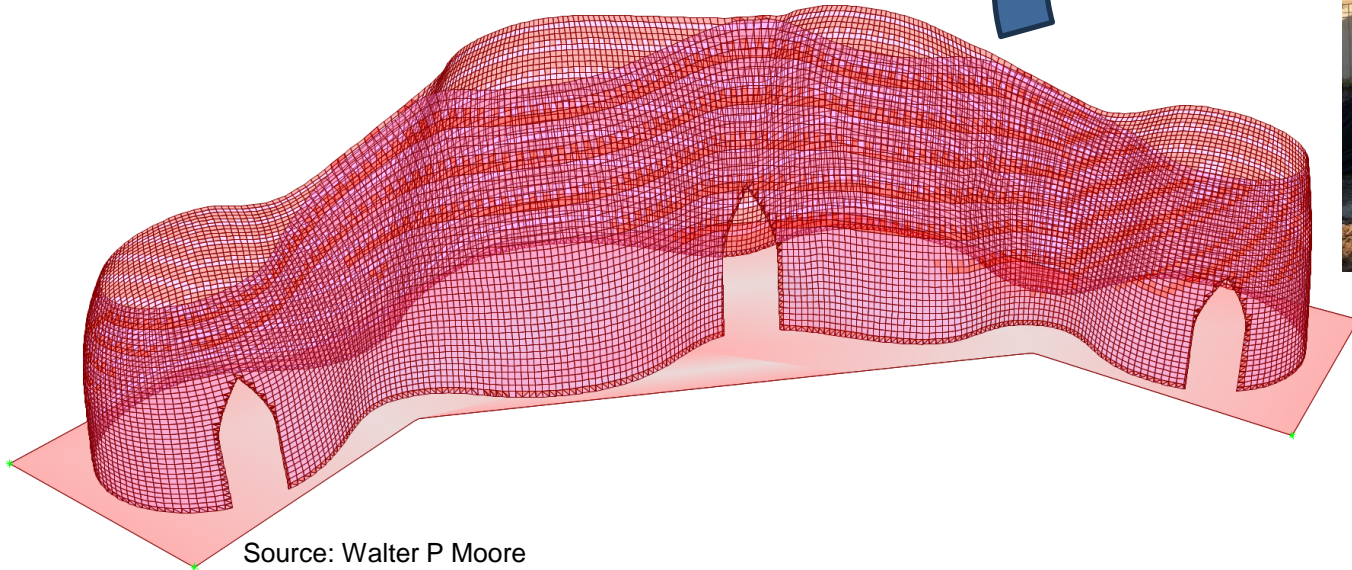
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DIVISION: 03 00 00 — CONCRETE Section: 03 37 00 — Specialty Placed Concrete	REPORT HOLDER: BLACK BUFFALO 3D CORPORATION	EVALUATION SUBJECT: BLACK BUFFALO 3D CONCRETE WALLS	
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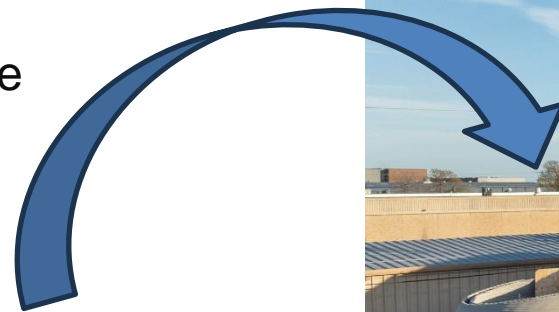


Current Challenges

Per IBC/IRC, non-conventional structural elements shall be designed in accordance with accepted engineering practice.

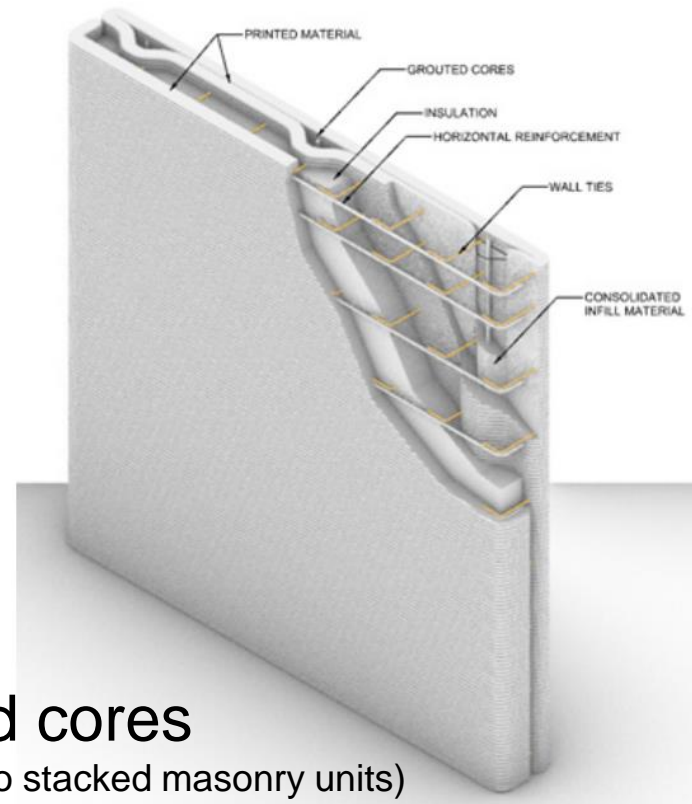


Source: Walter P Moore



Source: ATX Today, Image provided by ICON

Current Challenges



Stay-in-place formwork



GROUTED CORES

(analogous to stacked masonry units)



ACI 318 vs TMS402

- System proportioning Limitations
- Minimum Vertical Reinforcement
 - For most 3D wall configurations, ACI 318 provisions are stringent
 - However, TMS 9.3.4.2.2.1 requirement could drive required reinforcing above ACI limits
- Minimum Horizontal Reinforcement
- Tie Spacing
- Cover
- Development Length
- Anchorage to foundation
 - Only ACI 318 covers shear friction model which can be limiting in case of in-plane shear capacities

Need for Structural Code

Safety Assurance

- To ensure structural integrity and safety of 3D printed buildings

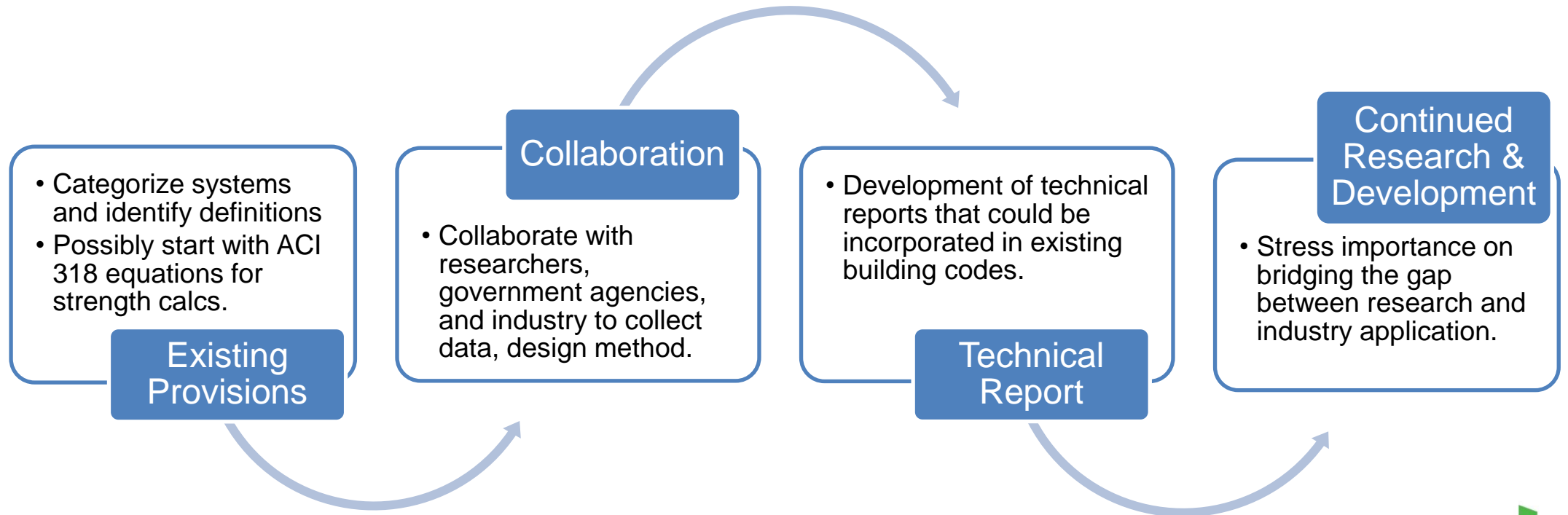
Industry Acceptance

- Foster confidence among architects, engineers, and investors

Innovation Catalyst

- Spur further research and development

Proposed Steps Forward



Thank You !!!