Digital Concrete at ETH Zurich

Tim Wangler, Ena Lloret, Lex Reiter, Norman Hack, Hannes Heller, Nicolas Ruffray, Mathias Bernhard, Konrad Graser, Fabio Gramazio, Matthias Kohler, Benjamin Dillenburger, Nicolas Roussel, Robert Flatt

ACI Convention, Anaheim, California

16 October 2017
Concrete 29%

Standard Formwork 53%

Reinforcement 18%

Structure Magazine (2007)
Non standard formwork

Concrete

Reinforcement
Seemingly limitless architectural freedom – no cumbersome formwork

Place material only where it is needed

Reduced material usage, reduced waste

Material phase change control

Let’s just ignore the reinforcement…?
National Centre of Competence in Research: Digital Fabrication in Architecture

Interdisciplinary initiative to foster the innovation capacity of architecture and construction

Launch: June 2014

Duration: 3 x 4 year phases = 12 years

Composition:
• 14 Professors,
• 10 Postdocs,
• 36 PhD researchers
• MAS teaching program
• Industry collaboration program
Digital Concrete: Opportunities and Challenges

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Abstract
Digital fabrication has been termed the “third industrial revolution” in recent years, and promises to revolutionize the construction industry with the potential of freeform architecture, less material waste, reduced construction costs, and increased worker safety. Digital fabrication techniques and cementitious materials have only intersected in a significant way within recent years. In this letter, we review the methods of digital fabrication with concrete, including 3D printing, under the encompassing term “digital concrete”, identifying major challenges for concrete technology within this field. We additionally provide an analysis of layered extrusion, the most popular digital fabrication technique in concrete technology, identifying the importance of hydration control in its implementation.

Keywords: Concrete; Digital Fabrication; Rheology; Set on Demand; Thixotropy
~140 attendees, 1/3 industry

Keynotes:

- Richard Buswell
- Enrico Dini
- Theo Salet
- Domenico Asprone, Costantino Menna
- Viven Esnault
- Norman Hack
- Ena Lloret
- Benjamin Dillenburger

Strong Interest in International Workshop on Digital Fabrication with Concrete
Extended abstract deadline:
31 October 2017
Rob|ARCH 2018
Robotic Fabrication in Architecture, Art, and Design

10th–15th SEPTEMBER 2018, ETH ZURICH
Robotic Fabrication Laboratory
NEST
Dübendorf, Switzerland
NEST – dfab house
NEST – dfab house

- Robotically fabricated timber units
- Smart Slab (3D Printed)
- SDC facade mullions
- Mesh Mould wall
- Unit backbone
- Base
Digital Concrete at ETH Zurich

- Mesh Mould
- Smart Dynamic Casting
- 3D Printing of Complex Architectural Components
- Extrusion
Digital Concrete at ETH Zurich

Mesh Mould

3D Printing

Digital Concrete Processing

Smart Dynamic Casting

Extrusion
3D Printing of Complex Architectural Components
Slab element

Optimized to reduce material for specific loading case

Ruffray et al, (accepted UHPFRC 2017)
3D Printing of Complex Architectural Components
Winner, 2017 Construction Prize
Smart Dynamic Casting
Smart Dynamic Casting

- Scaled down slipforming
- Complex shapes
- Elements>>formwork
- Self compacting, highly retarded material
- Accelerated at casting point
- Hardened (hardening) material comes out
- Hydration control through admixtures
Process setup

Retarded Self Compacting Mortar (SCM)

Automation: activation and feeding

Accelerator

Robot and Formwork

Control
Synchronise: acceleration, filling, slipping, shaping.

Inline measurement
"Putting concrete to sleep and waking it up"

Reiter et al., ACI Int. Conf. SPs (2015)
"Putting concrete to sleep and waking it up"

Graph:
- Prediction line
- Data points for 0.205 mg sucr/g CEM
- Data points for 0.41 mg sucr/g CEM
- Data points for 0.82 mg sucr/g CEM

Reiter et al., ACI Int. Conf. SPs (2015)
Mesh Mold
Not enough steel:

- Increase mesh density
- Increase rebar diameter

Rate limiting step: weld points

\[
\text{time saving factor} \propto \left( \frac{d_2}{d_1} \right)^4
\]

Increase \(d\) too much...power requirements increase

Interdisciplinarity is key
Physical Chemistry of Building Materials

ETH Zurich
«Mesh Mould» Receives Swiss Technology Award 2016
The ETH Experience: key takeaways

- Rheology is key!
- Hydration control is essential
  - Monitoring of structural buildup, ideally on line
- Processing and processing windows will be paramount
  - Mixing and admixtures
  - Cold joints vs. collapse or buckling in layered processes
- How to provide the necessary reinforcement...if any?
  - Let’s rethink reinforcement
- Let’s not forget durability
The ETH Experience: key takeaways

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Thank you for your attention

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1st RILEM International Conference on Concrete and Digital Fabrication

http://digitalconcrete2018.ethz.ch/

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31 October 2017