Digital fabrication: Think different – Build different

Prof. Dr. Robert J. Flatt, Institute for Building Materials, ETH Zurich
Overview of the talk

National Centre for Competence in Research (NCCR)
« Digital Fabrication in Architecture »

Inspiration
Cool projects
Design quality and potential

Potential
Where does it lie?

Excitation
Technological challenges

… and some thoughts on insurance
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:
- 13 Professors, (+3 associated)
- 8 Postdocs
- 24 PhD researchers (+17 associated)
- MAS teaching program
- Industry collaboration programme

Robotic Fabrication Lab, Institute for Technology in Architecture, ETH Zurich
Robotic Fabrication Research in Architecture

2005 - 2013

2005 ETH Zürich
2006 TU Vienna
2007 Harvard GSD
2008 RMIT Royal Melbourne Institute of Technology
2008 Yale
2009 Carnegie Mellon
2009 TU Graz
2010 University of Stuttgart
2010 American University of Sharjah
2010 University of Michigan
2010 IAAC Barcelona
2011 MIT
2011 SCI-Arc Los Angeles
2011 Singapore ETH Future Cities Laboratory
2012 Delft University of Technology
2012 University of Innsbruck
2012 McGill University
2013 Universidad Técnica Federico Chile
2013 The Bartlett School of Architecture
2013 Princeton
2013 ...

Profs. M. Kohler and F. Gramazio
(ETH Zürich)
Concrete 29 %
Formwork 53 %
Steel 18 %

Source: E. Lloret
Conventional Non Standard Formwork

Formwork of EPFL Rolex Learning Centers

Gramazio Kohler Research
ETH Zurich
3D Printed concrete

Gramazio Kohler Research
ETH Zurich
Smart Dynamic Casting
Fabrication

Includes standard Reinforcement!
Innenansicht Dachkonstruktion, Institut für Technologie in der Architektur (ITA), ETH Zürich, Dezember 2015
Dach Design von Gramazio Kohler Research, ETH Zürich
Konzept und Planung bei Gramazio Kohler Research, ETH Zürich
Research in Practice:
Applied Projects of the Architecture and Building Systems (A/S) Group

3for2@UWCSEA
New construction: 2015

Designed and managed by the A/S team, 3for2@UWCSEA is a 600 m² office space which hosts the administrative staff of UWCSEA. It is one of the first commercial-scale applications of passive chilled beams and displacement ventilation for offices in the tropics. It is set to become Singapore’s most energy-efficient office by 2018.
The 3for2 concept:
Achieving space, material, and energy savings through integrated systems

- Radiant ceiling panels for sensible cooling
- Dedicated Outdoor Air System (DOAS) with decentralized Ventilation units
- Slanted façade for shading with Low U-Value / Low SHGC glazing
- Building Integrated Photovoltaics
- Automation system with room / component sensors
- Slab integrated, meshed duct network for air distribution, diffusors
3D Printing – Powder beds

Enrico Dini

D-Shape
Digital Grotesque II

Imprimer le Monde, Centre Pompidou, 2017
dfab house: EMPA NEST
NEST – dfab house

- Robotically fabricated timber units
- Smart Slab (3D Printed)
- SDC facade mullions
- Mesh Mould wall
- Unit backbone
- Base
Mesh Mould:
Robotically produced Meshes as formwork AND reinforcement

Formwork + Reinforcement

Formwork = Reinforcement
Mesh Mould: Key advance and resulting material challenge

Steel $\rightarrow$ Adequate quantity for ductile behavior

Rate limiting step: weld points

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

Increase $d \rightarrow$ decrease weld points $\rightarrow$ increase $D$

Special mix design needed:
Self compacting concrete that stays in the mesh
«Mesh Mould» Receives Swiss Technology Award 2016
Layered based printing
Concrete / mortar / paste extrusion
What about reinforcement?

Do not bother us with that question …

Traditional
• Place after and infill
• Consider printed material as a lost formwork
• Limited (probably insufficient) amounts of steel

Fiber reinforcement
• Limited interconnection between layers
• Gets worse at high speeds that avoid cold joints

*Mats*
• Place *ad hoc* during production
• Efficiency ???
Operating window

There is an upper and a lower bound for the production rate

- Too low rates give cold joints
- Too high rates collapse under their own weight

Important factors are

- Thixotropic build up
- Contour length
- Layer height
- Linear rate

Contour length is a crucial factor when discussing whether or not cold joints form
What about the environment?
1st RILEM International Conference on Concrete and Digital Fabrication

http://digitalconcrete2018.ethz.ch/

Extended abstract
Deadline:
15 October 2017
Conclusions

Think different – Build different!

Despite the norms, but not despite safety, economy or ecology

Doing the exact same thing digitally, will rarely pay off

Added value, functionality or integration will pay off

New horizon for design tools informed by new construction methods
Acknowledgements

Mesh Mould

3D Printing

Digital Concrete Processing

Smart Dynamic Casting

Extrusion
Thank you for your attention

image is by AndrewRae.org.uk
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