ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

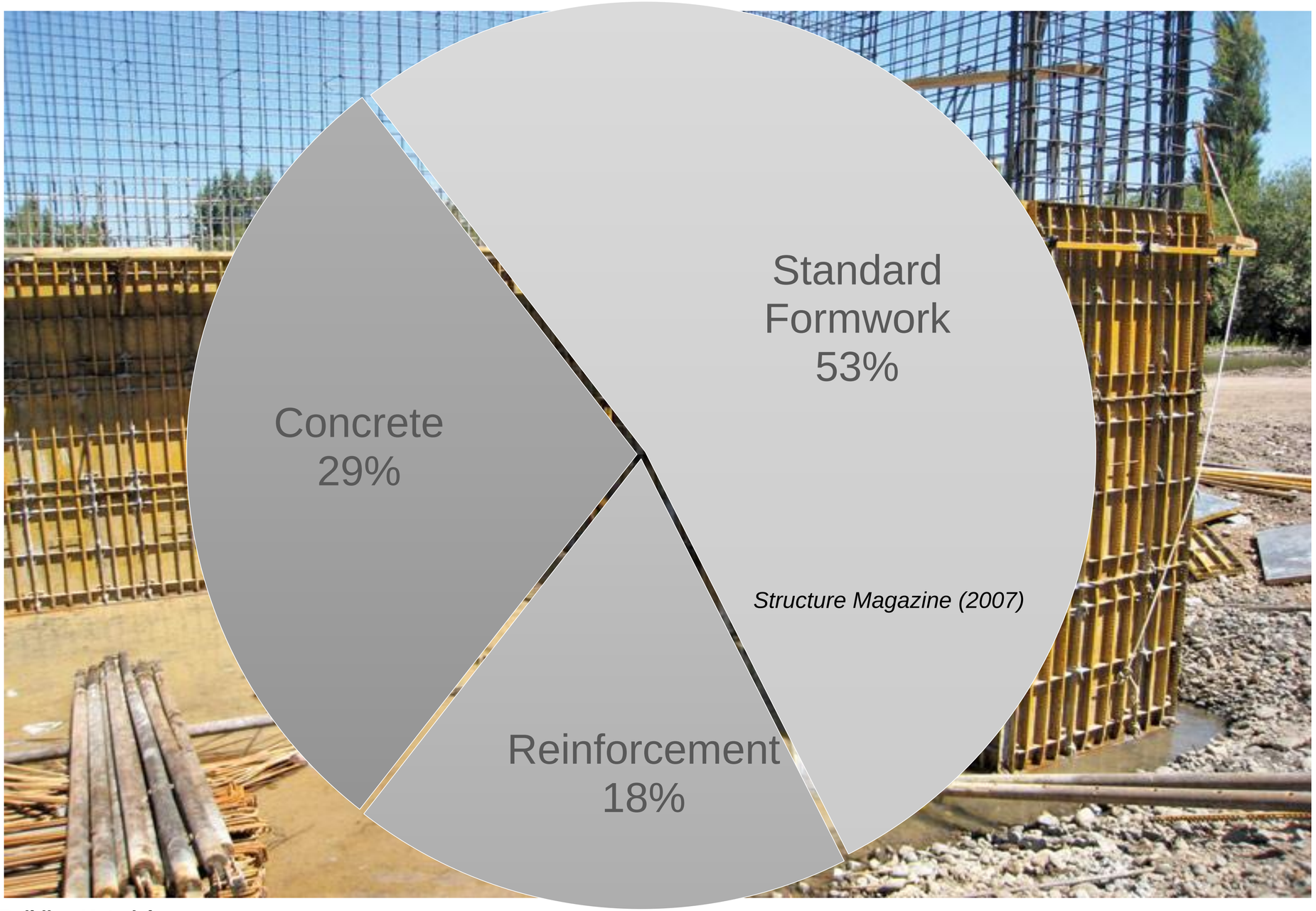
IfB
Institut für Baustoffe
Institute for Building Materials

Digital Concrete at ETH Zurich

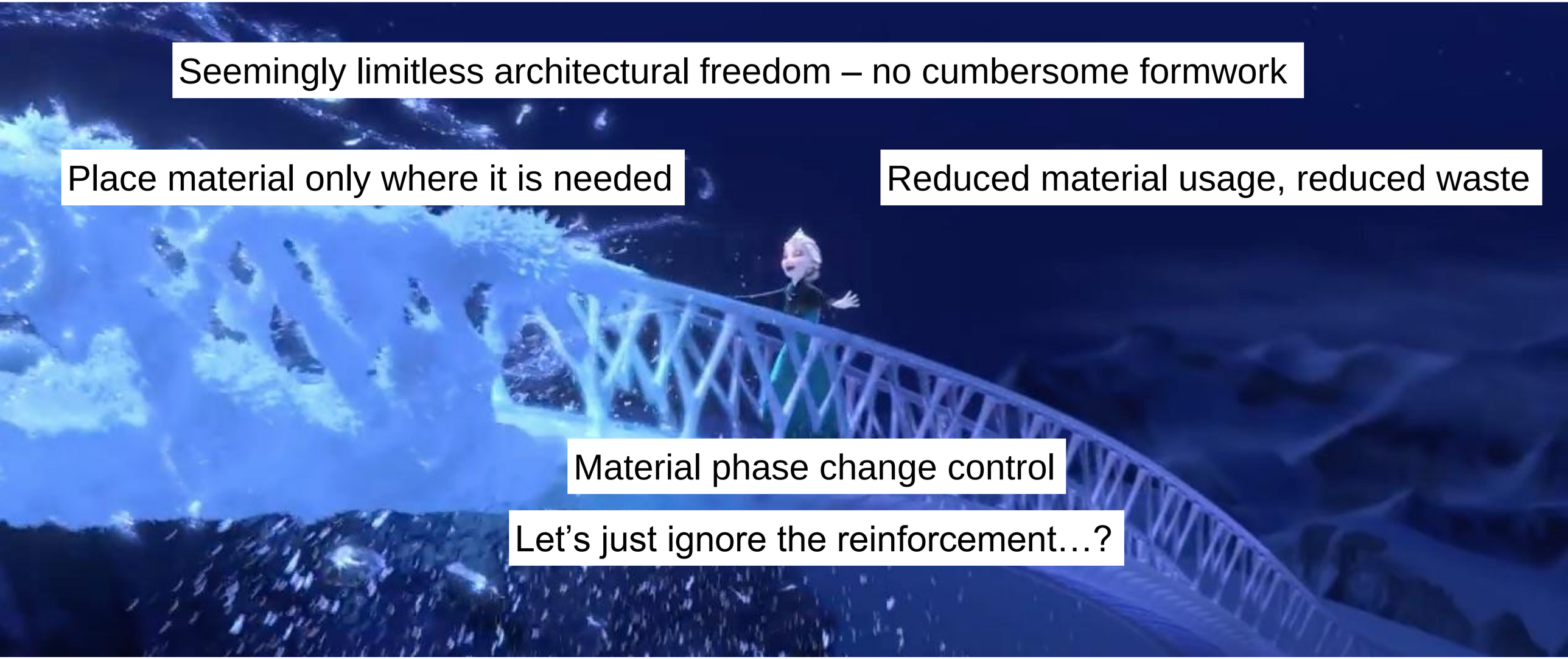
Tim Wangler, Ena Lloret, Lex Reiter, Norman Hack, Hannes Heller, Nicolas Ruffray, Mathias Bernhard, Konrad Graser, Fabio Gramazio, Matthias Kohler, Benjamin Dillenburger, Nicolas Roussel, Robert Flatt

ACI Convention, Anaheim, California

16 October 2017


Standard Formwork 53%
Concrete 29%
Reinforcement 18%
Structure Magazine (2007)

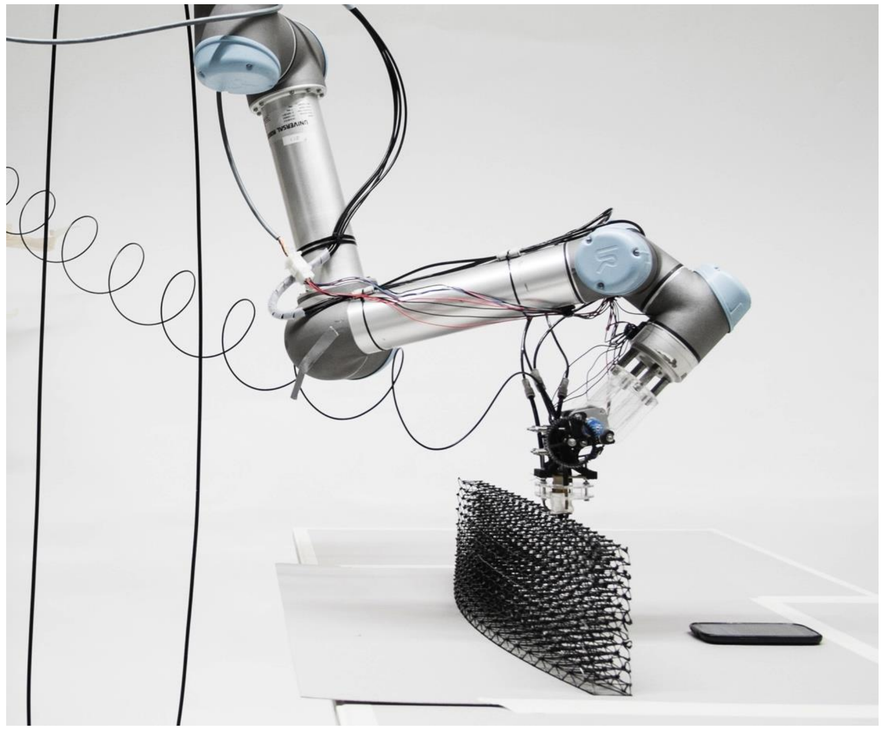

Non standard formwork
Concrete
Reinforcement


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…?


The Economist
Keynesynomics explained
The euro crisis: back after its siesta
Argentina's oil grab
The science of guerrilla warfare
America's kingpin king
The third industrial revolution
A 24-PAGE SPECIAL REPORT


The Economist
Obama v Obamacare
How to make a chromosome
Will Japanese women rebel?
Marine Le Pen woos France
Understanding the first world war
RISE OF THE ROBOTS
A 14-PAGE SPECIAL REPORT

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**

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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

1st RILEM International Workshop on Digital Fabrication with Concrete: 13 January 2017

Strong Interest in International Workshop on Digital Fabrication with Concrete

~140 attendees, 1/3 industry

Keynotes:

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

1st RILEM International Conference on Concrete and Digital Fabrication

DigitalConcrete 2018

RobIArch 2018

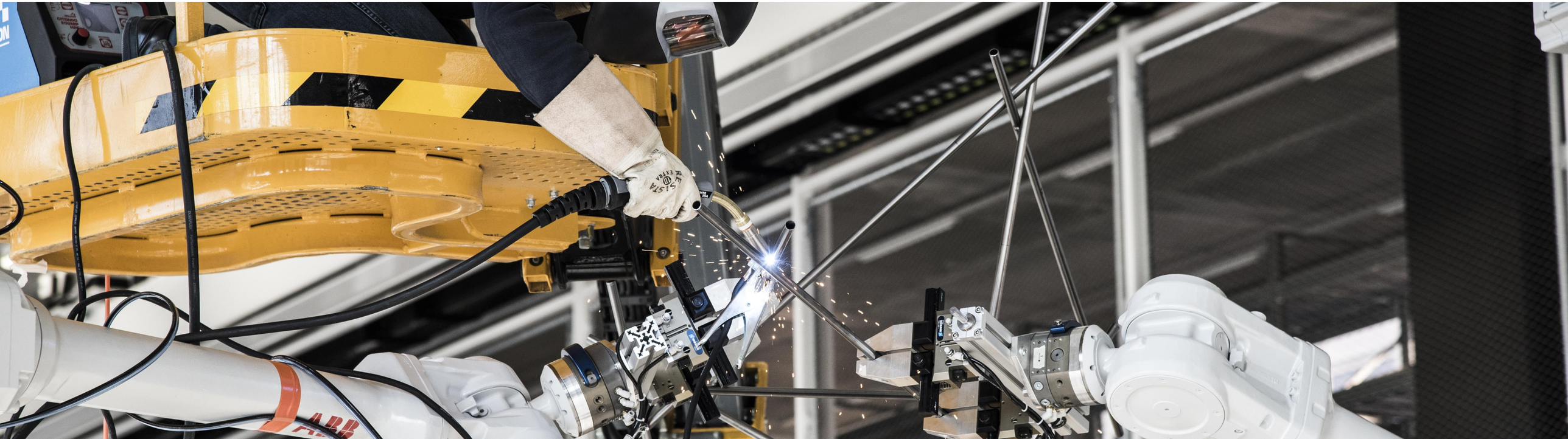
Robotic Fabrication in Architecture, Art, and Design

10th–15th SEPTEMBER 2018, ETH ZURICH

National Centre of Competence in Research Digital Fabrication

ETH zürich

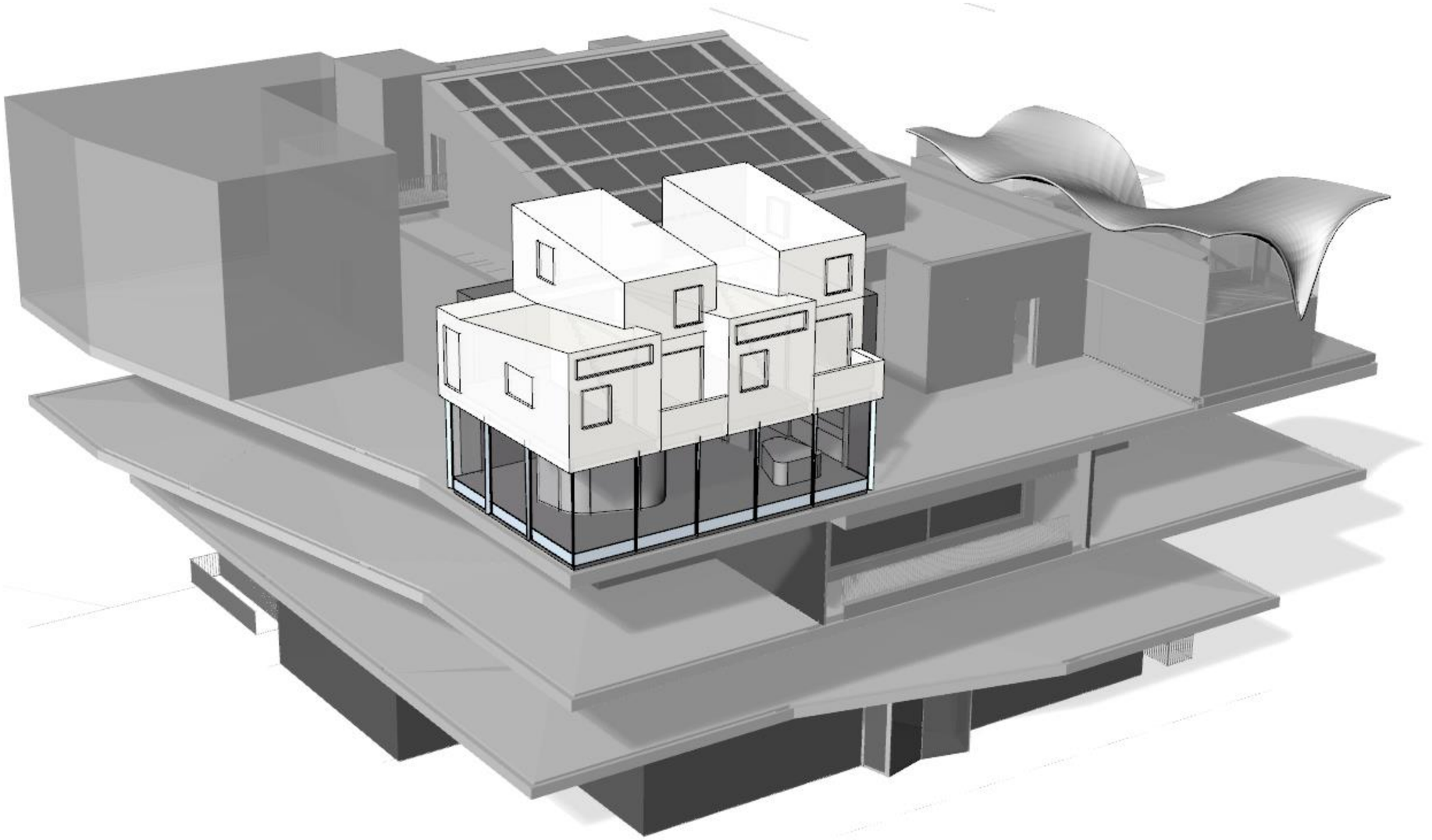
DARCH Department of Architecture



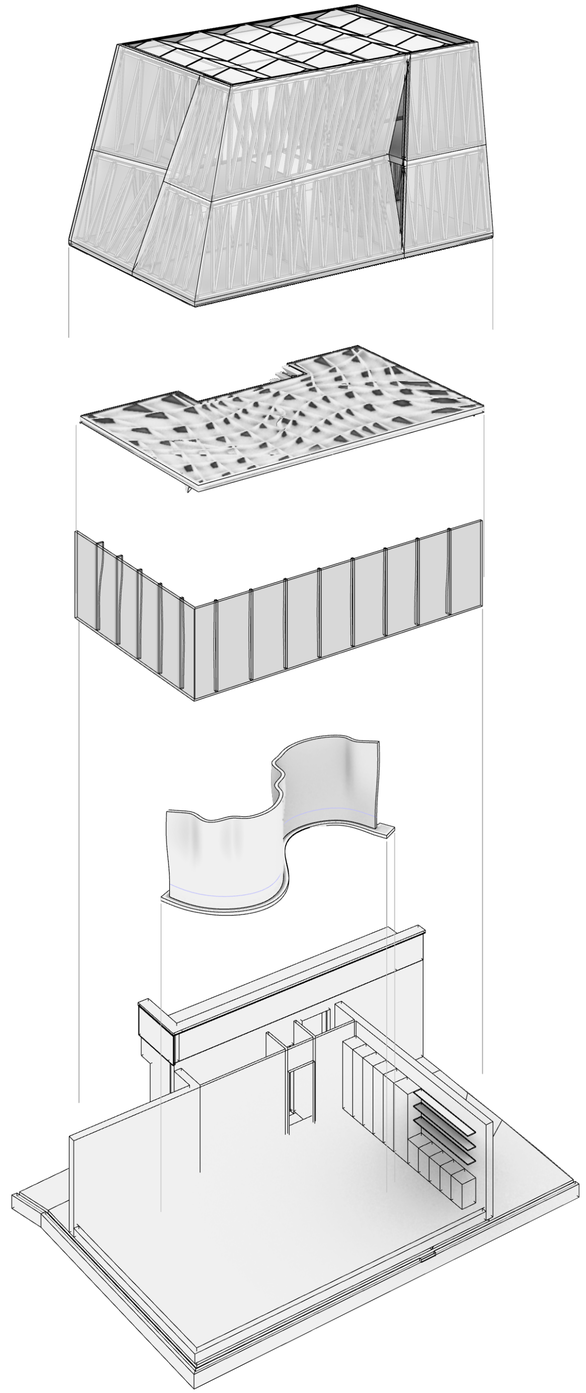
Robotic Fabrication Laboratory

NEST
Dübendorf, Switzerland

NEST – dfab house

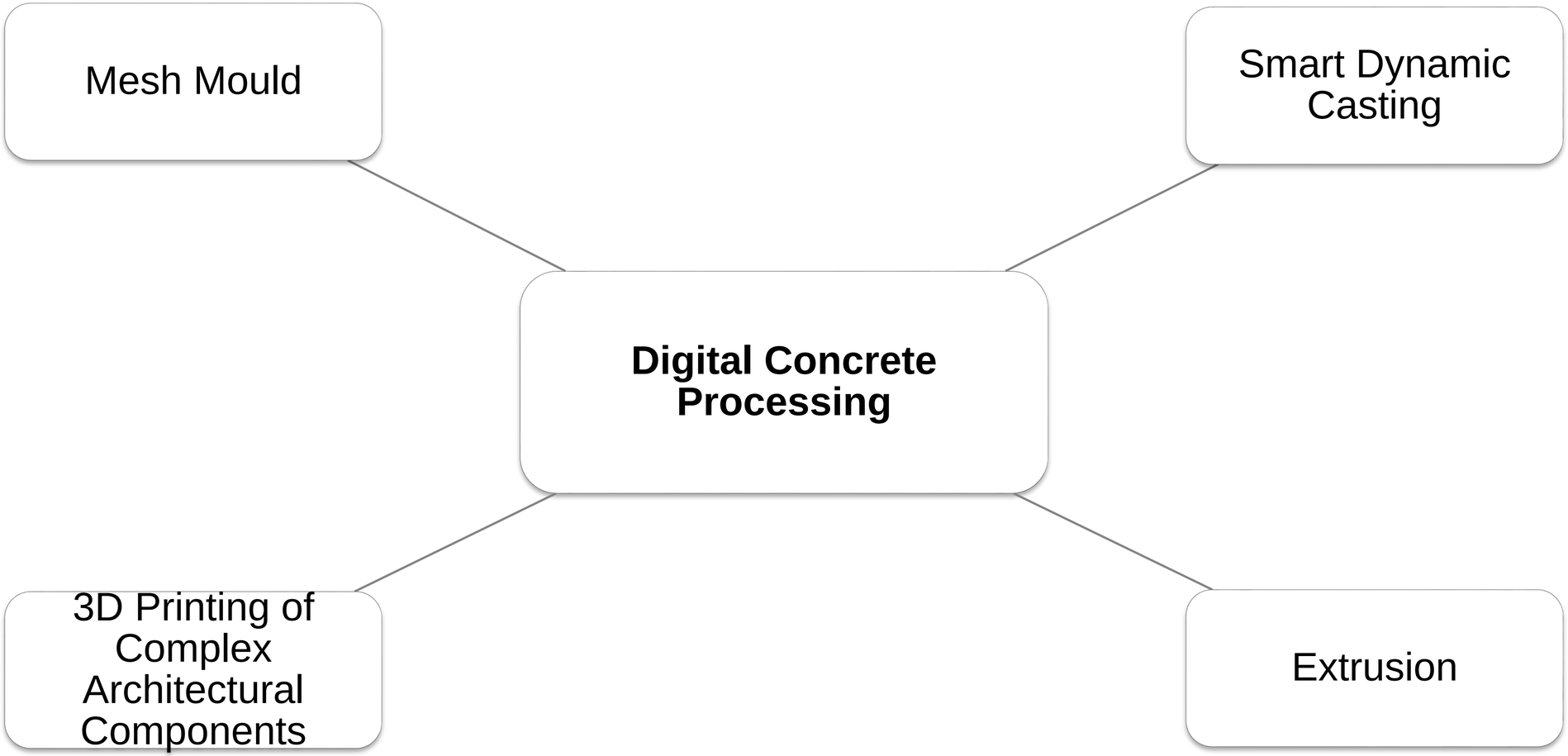


NEST – dfab house



- Robotically fabricated timber units
- **Smart Slab (3D Printed)**
- **SDC facade mullions**
- **Mesh Mould wall**
- Unit backbone
- Base

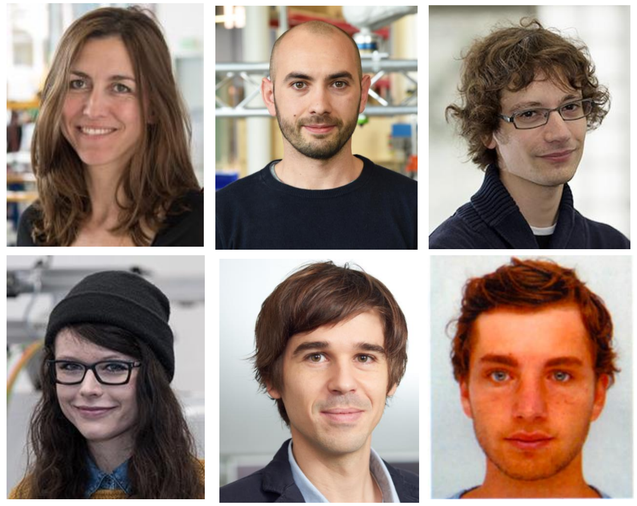
Digital Concrete at ETH Zurich



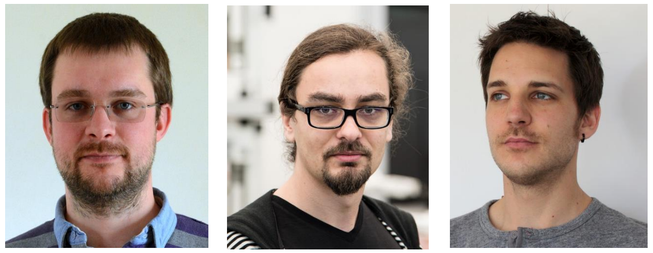
Digital Concrete at ETH Zurich

Mesh Mould

Digital Concrete Processing



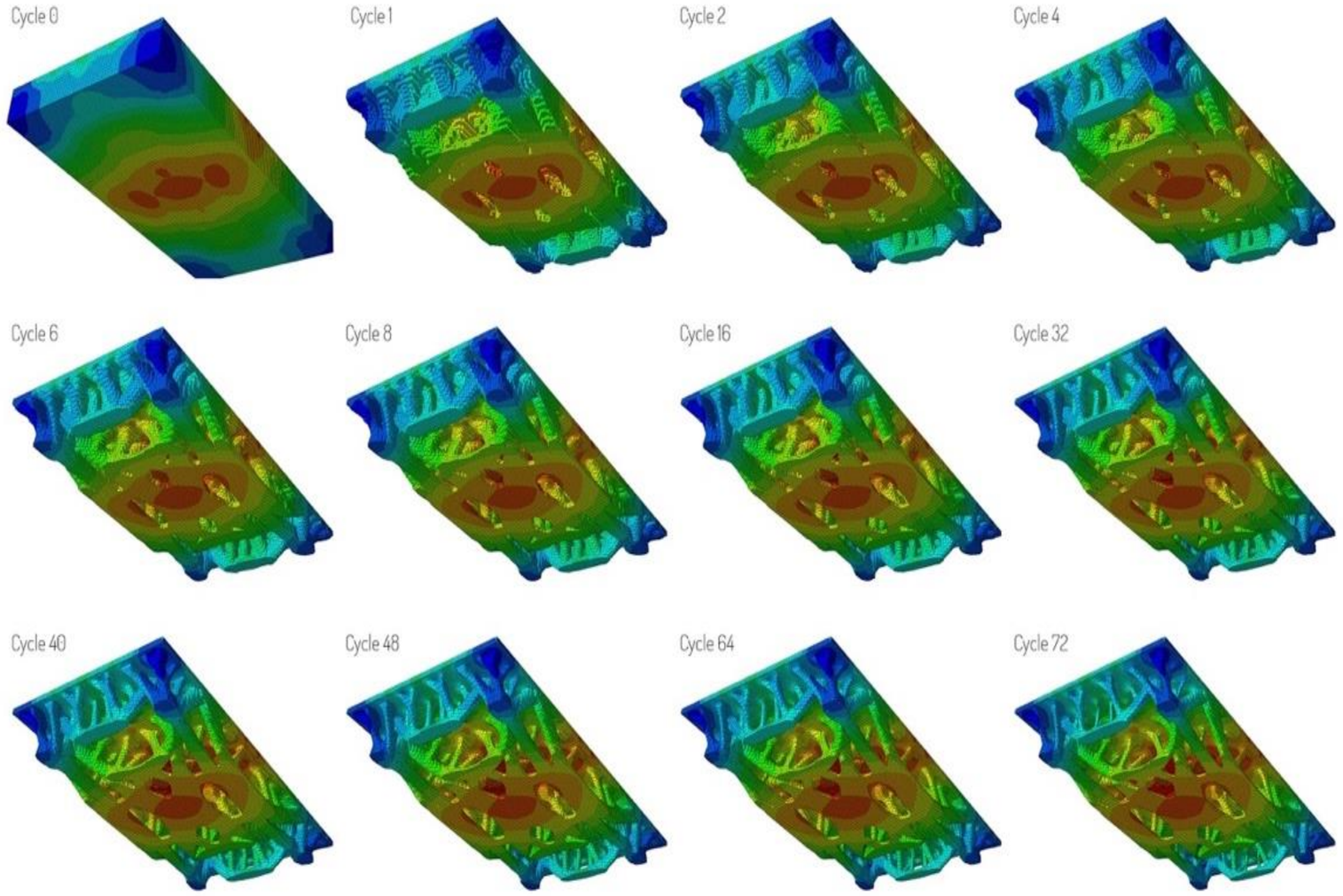
Smart Dynamic Casting



3D Printing

Extrusion

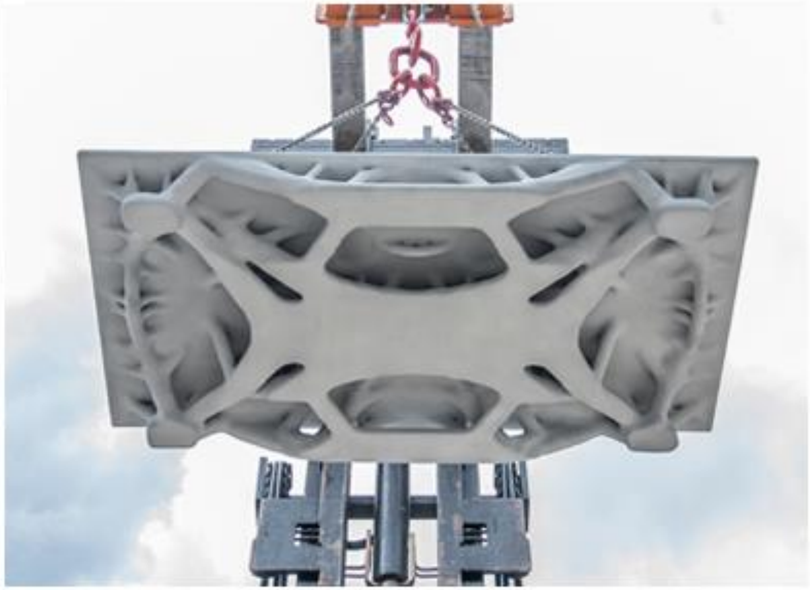
3D Printing of Complex Architectural Components

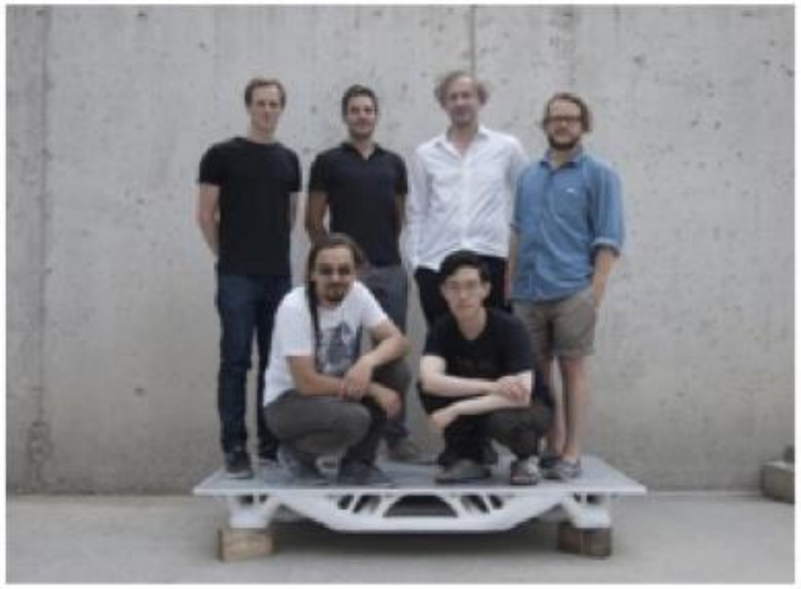


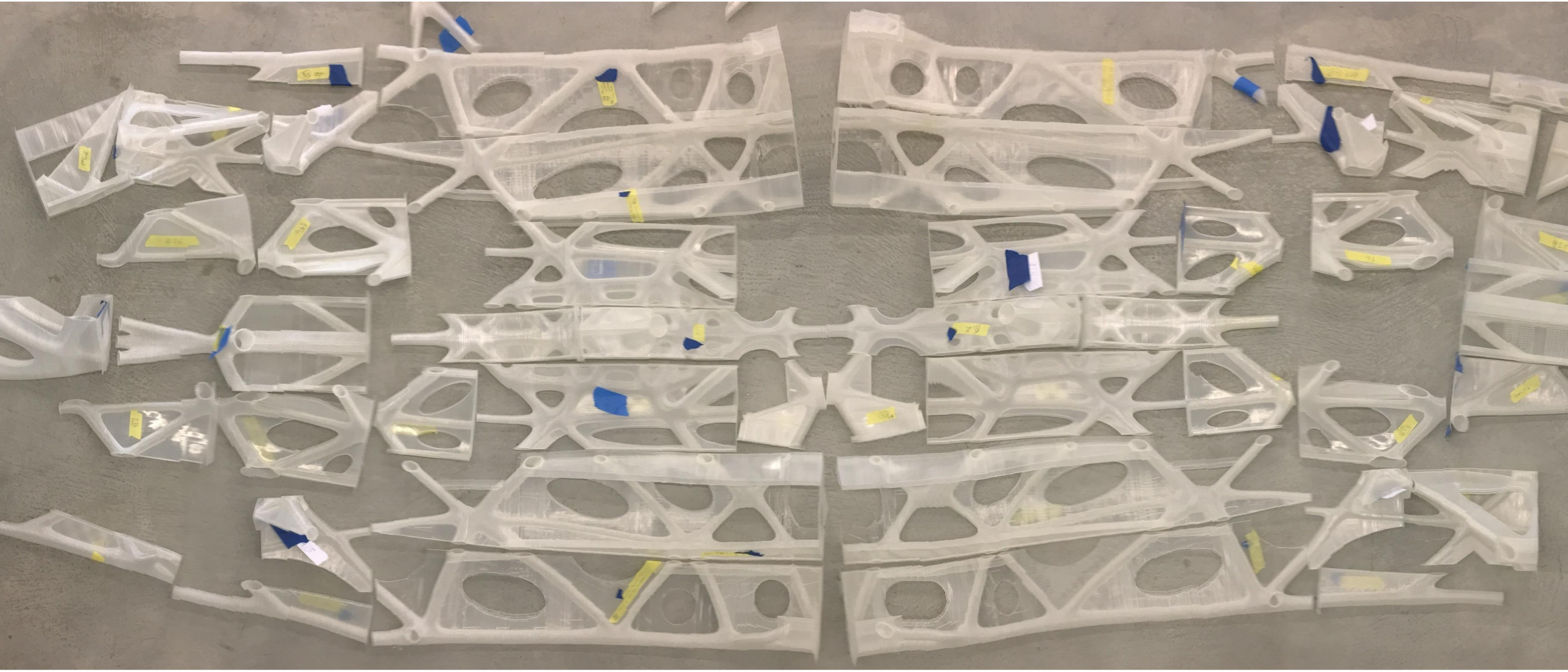
Slab element

Optimized to reduce material for specific loading case

Ruffray et al, (accepted UHPFRC 2017)





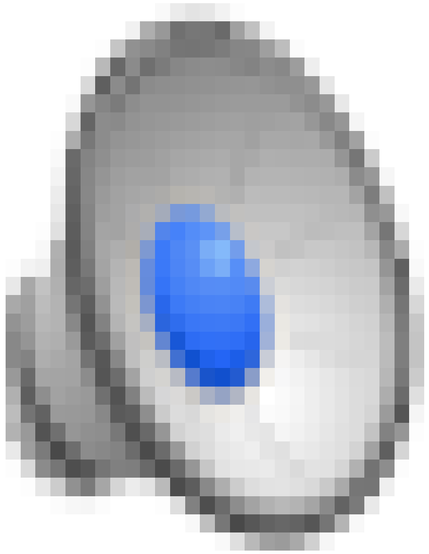


Winner,
2017 Construction Prize

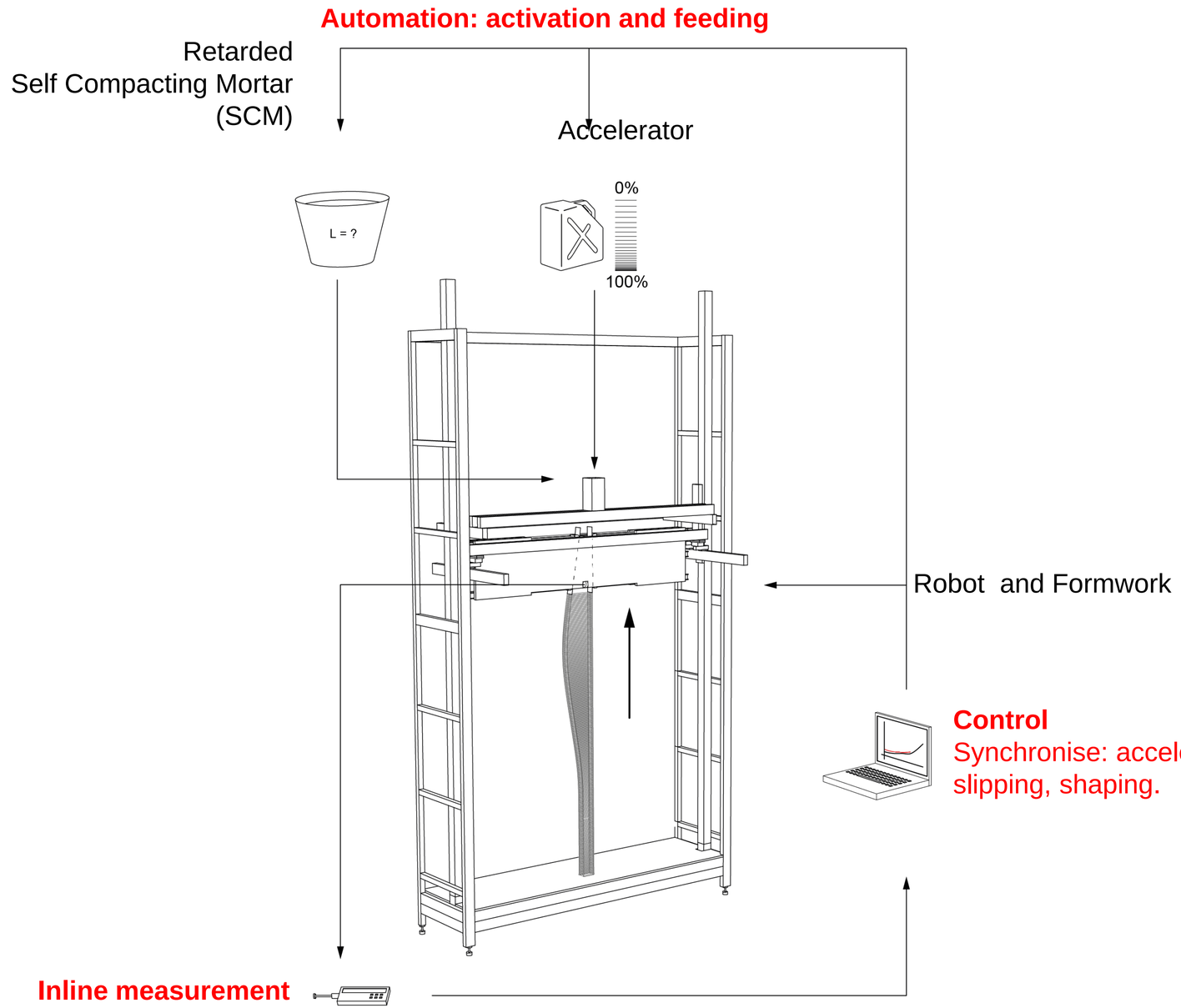
Smart Dynamic Casting

Smart Dynamic Casting

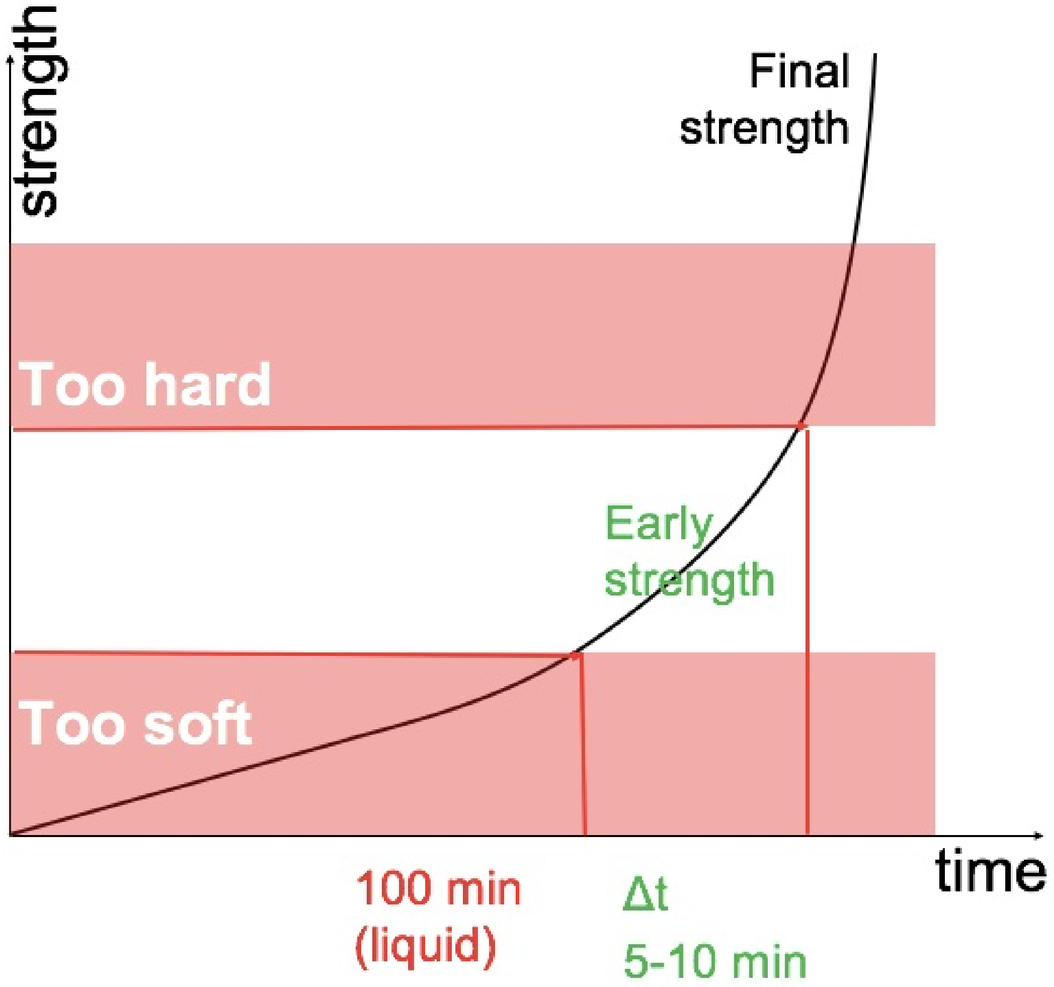
- Scaled down slipforming
- Complex shapes
- Elements>>formwork
- Self compacting, highly retarded material
- Accelerated at casting point
- Hardened (hardening) material comes out
- Hydration control through admixtures



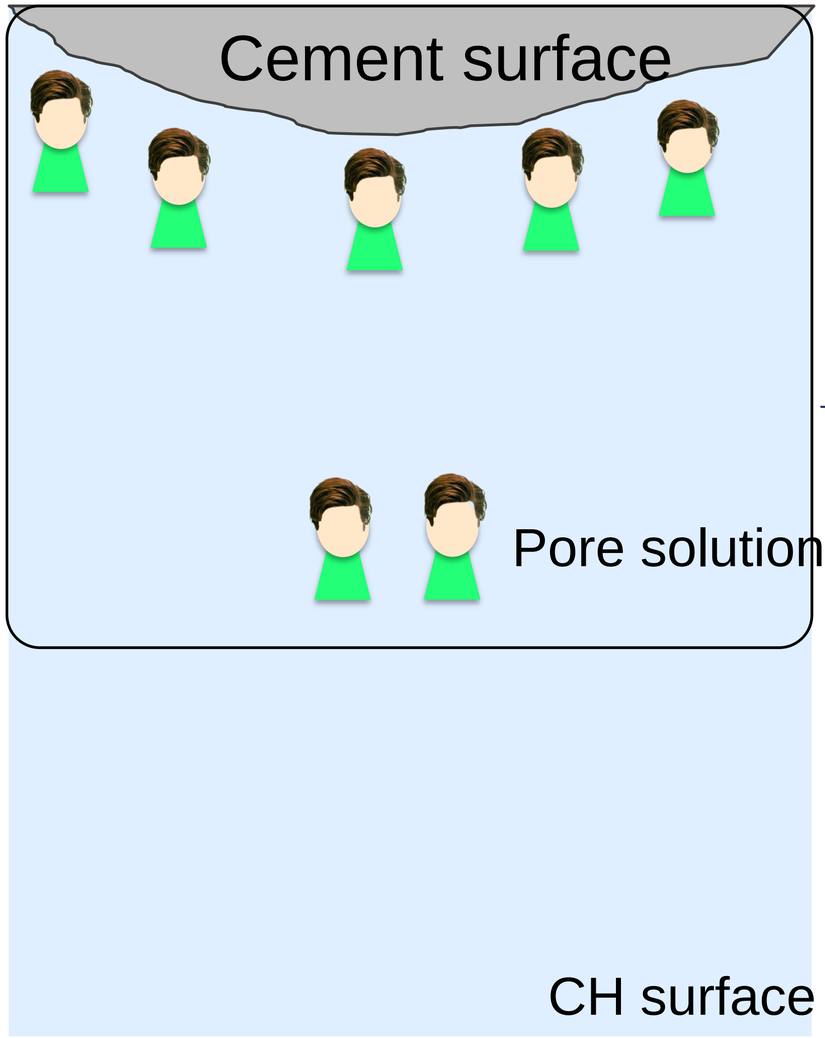
Process setup

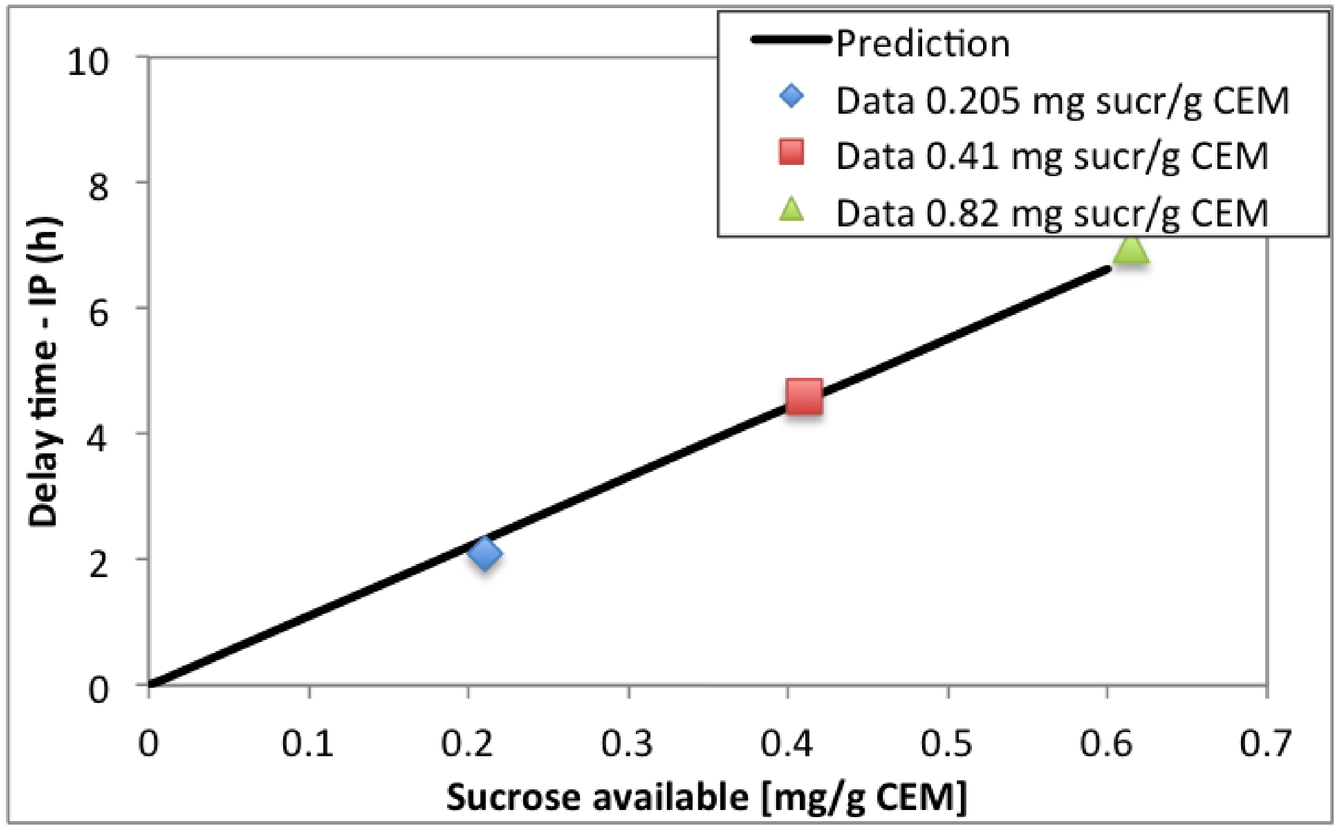


Gramazio Kohler Research & Physical Chemistry of Building Materials
ETH Zurich


strength
Final
strength
Too hard
Early
strength
Too soft
time
100 min
(liquid)
Δt
5-10 min

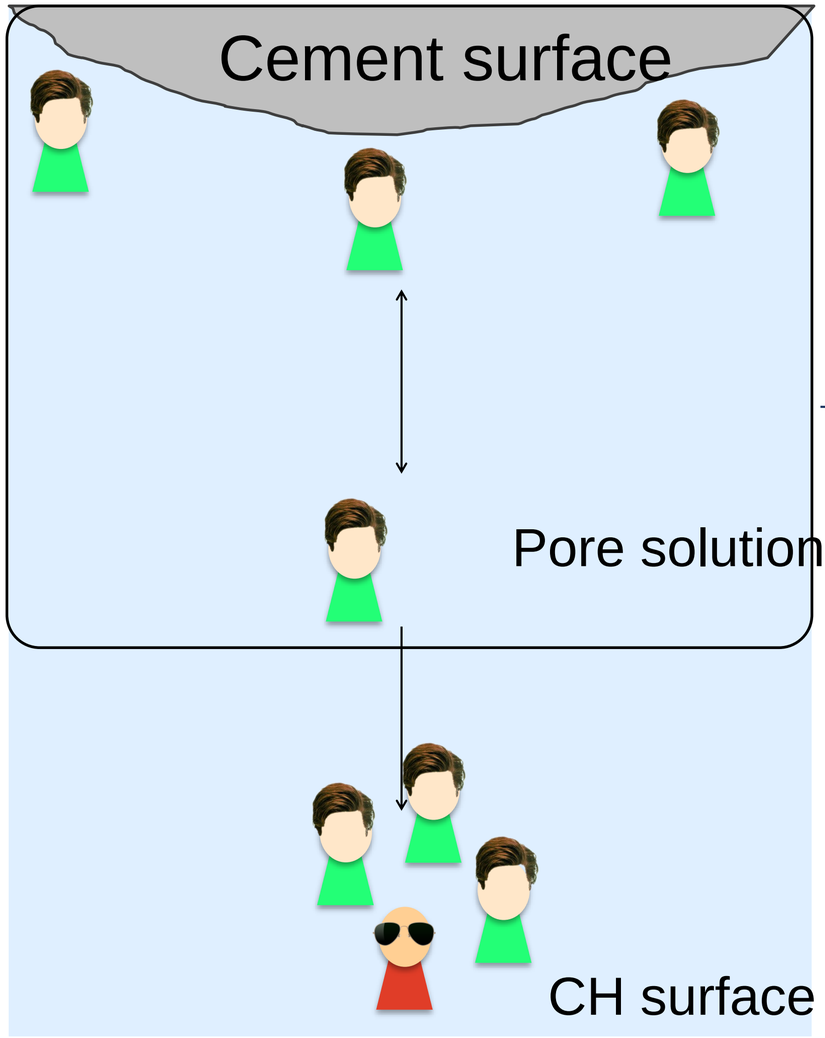
”Putting concrete to sleep and waking it up”

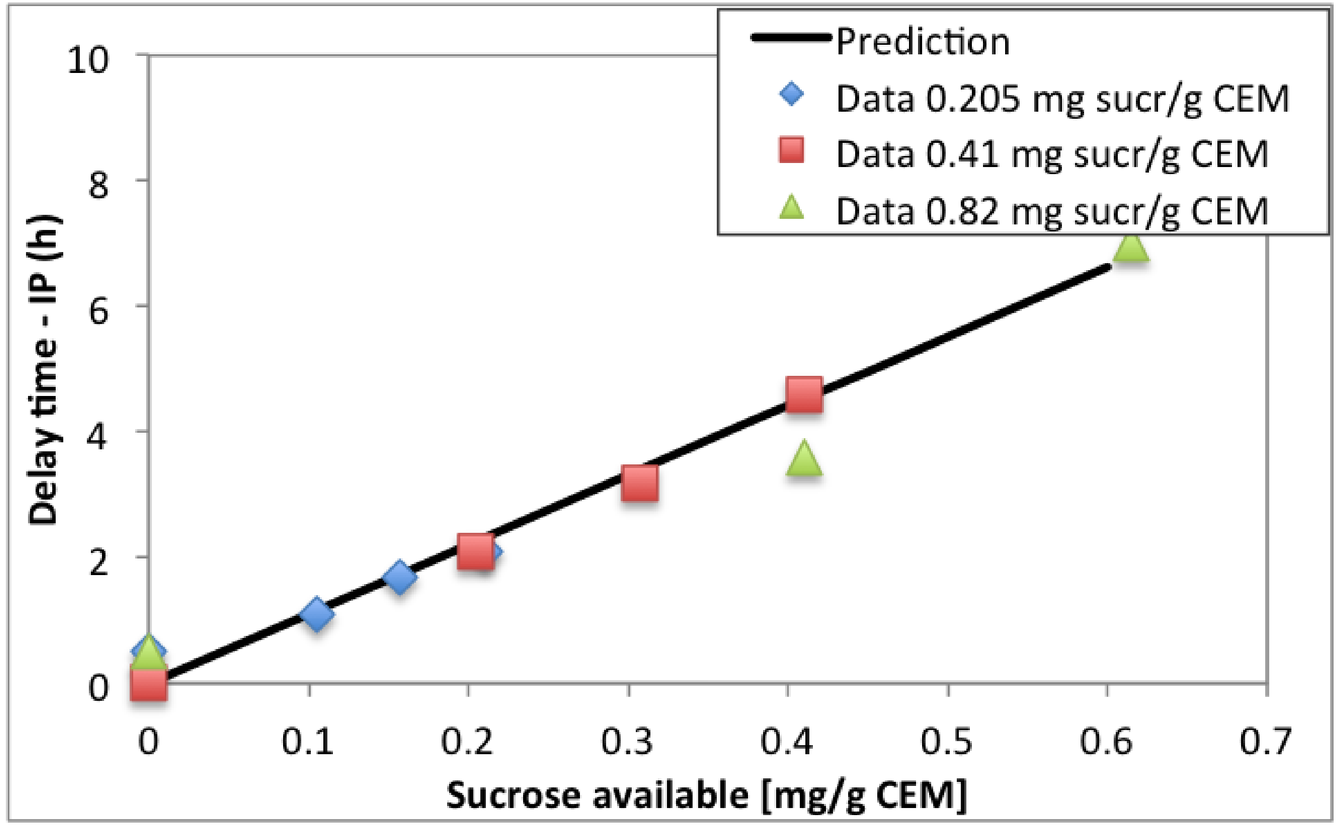




Reiter et al., ACI Int. Conf. SPs (2015)

”Putting concrete to sleep and waking it up”





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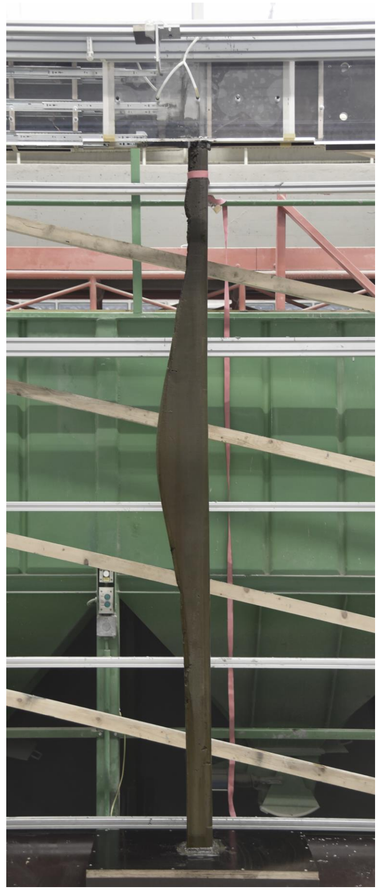
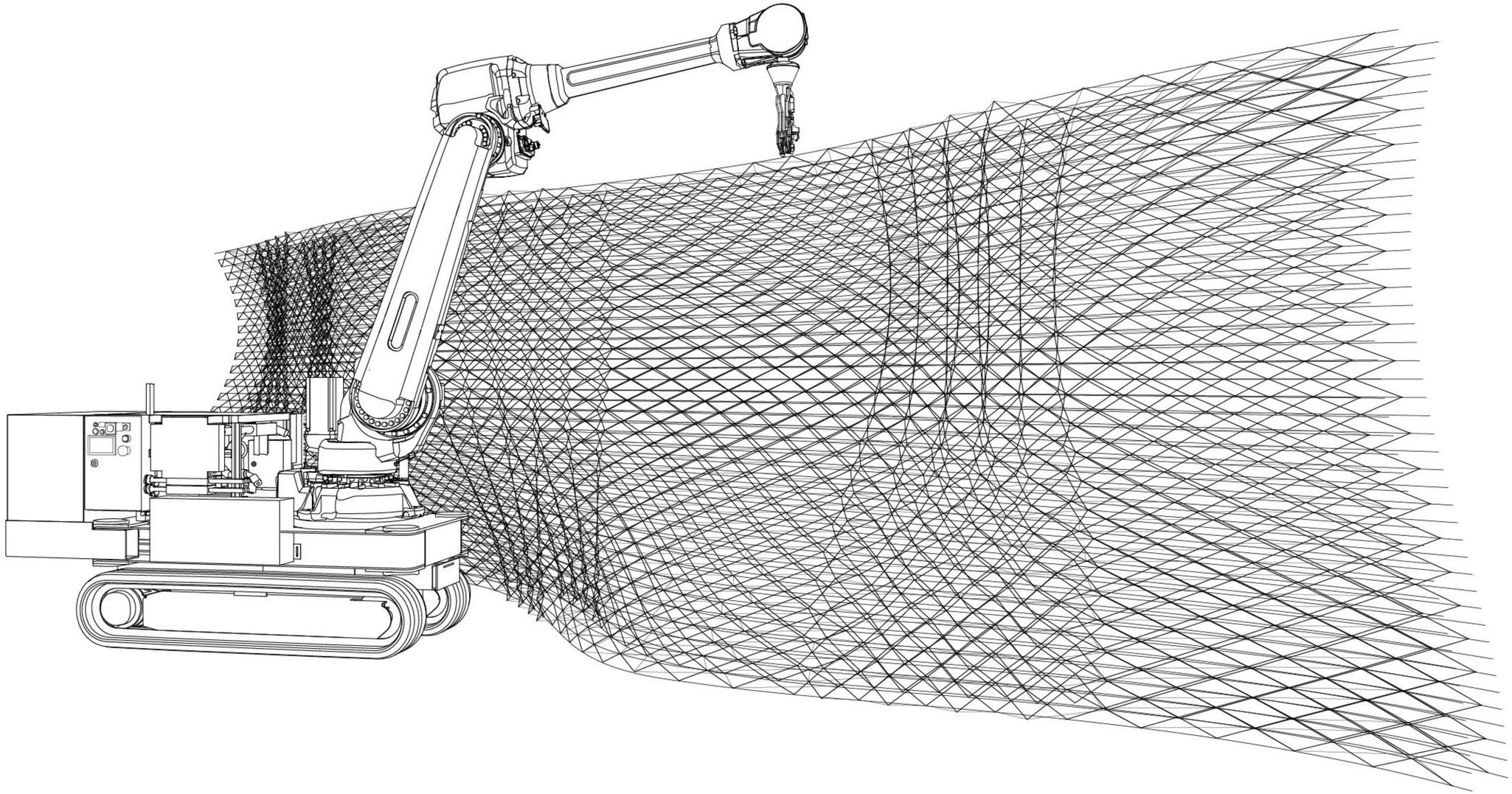
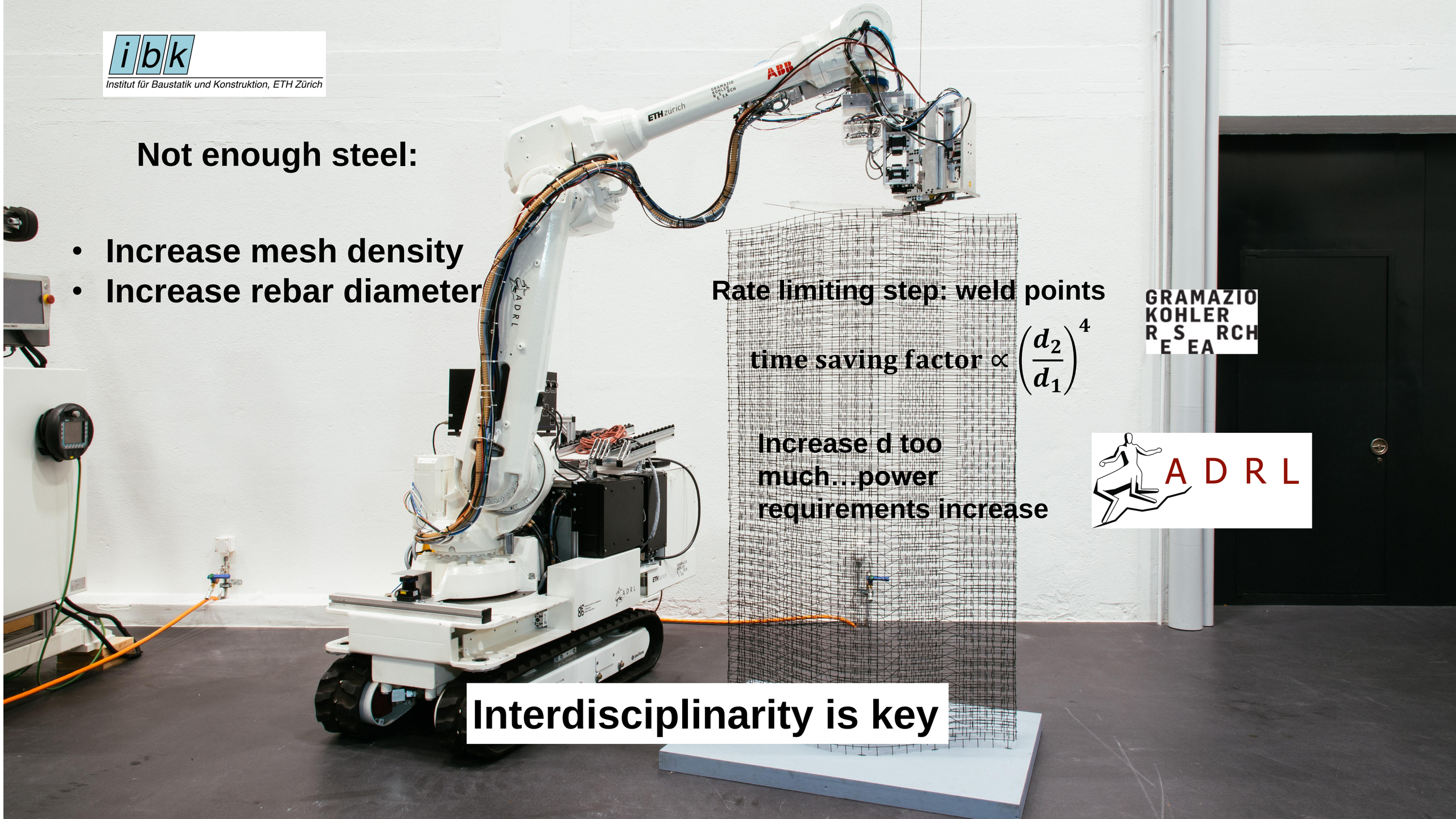


Mesh Mold





Institut für Baustatik und Konstruktion, ETH Zürich

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

GRAMAZIO KOHLER RESEARCH

ADRL

Interdisciplinarity is key

«Mesh Mould» Receives Swiss Technology Award 2016

READ MORE

Gramazio Kohler Research
ETH Zurich

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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INTERDISCIPLINARITY

Thank you for your attention

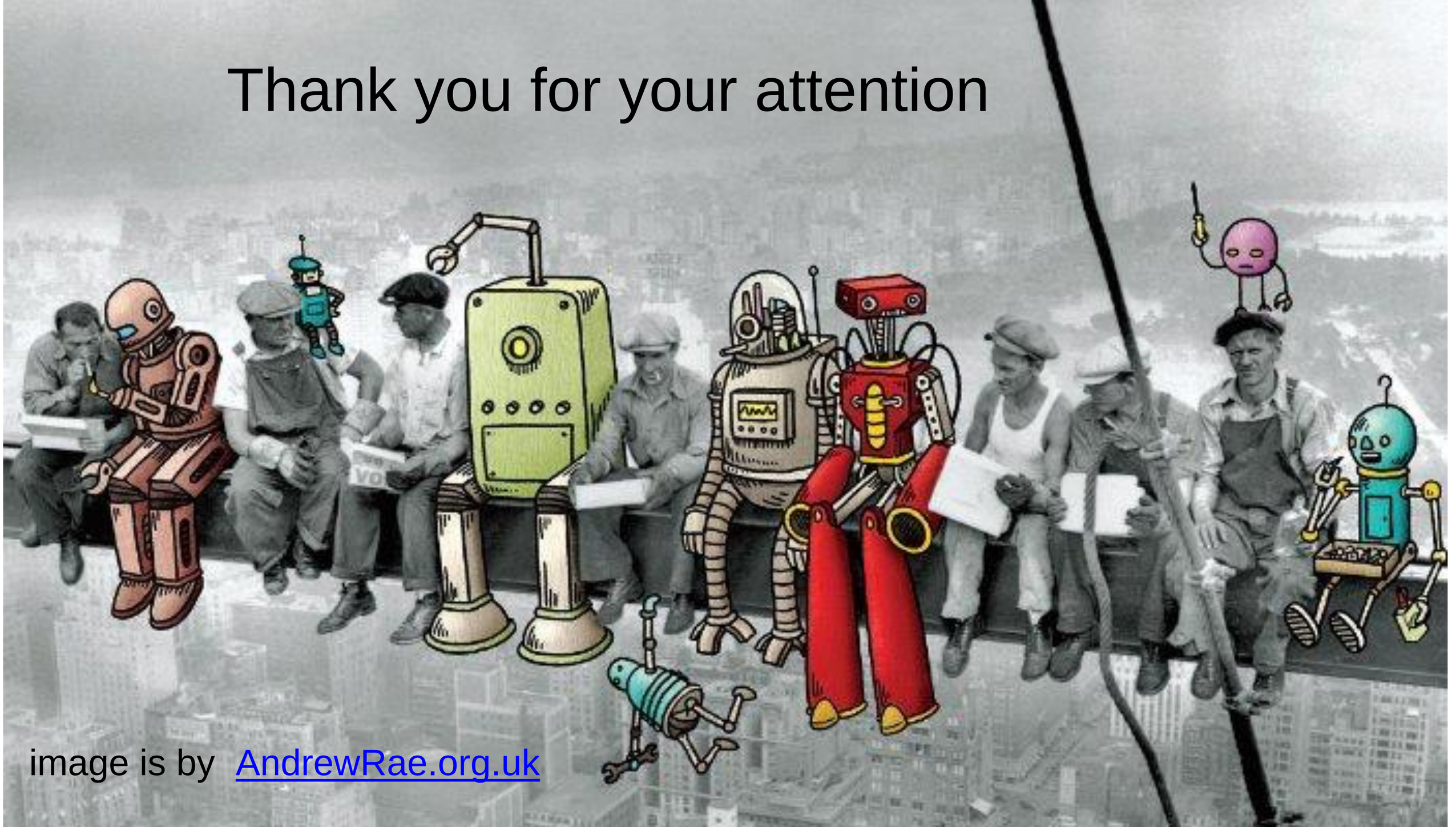

image is by AndrewRae.org.uk

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