CONCRETE in an AM process

Freeform concrete processing

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P5 presentation

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CONCRETE in an AM process

Freeform concrete processing

Introduction
Research
AM of concrete
Roadmap
Conclusions & recommendation
Additive manufacturing

A production technique that builds objects by adding material layer by layer
Additive manufacturing

Strengths and weaknesses

Geometric freedom
Hybrid structures
File to factory
No tooling
Sustainability
Mass customisation

Production time
Material behaviour
Accuracy
Limited size
Print houses

Concrete AM
Research question

"What are the conditions, regarding production techniques and form, to benefit optimally of an AM process for producing façade elements?"
Sub-questions

Material characteristics
Processing techniques
Development
FIELD OF AM

Initiatives

FDI technique
Contour crafting
Winsun new materials

3D Concrete printing
Total custom

3DP technique
D-Shape

AM mould technique
EZCT (moulds by Voxeljet)

Characteristics

- Anisotropic
- Surface quality differs
- No internal reinforcement
- No aggregates
- Compact concrete low air bulbs
- Missing support material

- Not concrete
- Strong
- Freeform

- Isotropic concrete
- Lost mould

Related expertises

AM
- U. Holger Strauss (Hochschule Stuttgart University)
- Winfried Siebke (Beton)
- I. Siebke Balcker (Voxeljet)

Concrete
- Sascha Hickert (Hochschule OWL)
- Prof. E. H. E. M. Schubert (TU Delft)
- Dr. R. Kampp (TU Delft)
- D. C. M. Eng. M. Haefliger (Rieder Group AG)

Moulds
- TU Delft - Support material
- U. Holger Strauss (Hochschule Stuttgart University)
- I. Siebke Balcker (Voxeljet)
- Sascha Hickert (Hochschule OWL)
- Prof. E. H. E. M. Schubert (TU Delft)
- Dr. R. Kampp (TU Delft)

Concrete processing
- TU Eindhoven concrete printing
- TU Delft - Parameters and concrete properties

AM Concrete research
- TU Eindhoven concrete printing
- TU Delft - Support material
- U. Holger Strauss (Hochschule Stuttgart University)
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DEVELOPMENT

G-code
Could contain additional mixture information about Fibres Aggregates Retarders

Concrete consistency and interlayer strength
Reinforcement

Concrete mortar

Binding agent

Freeform
Thin mould casting

it techniques binders
<table>
<thead>
<tr>
<th>Mechanism</th>
<th>Constituent material</th>
<th>Composite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase change</td>
<td>Steel, Plastics</td>
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<tr>
<td>Drying</td>
<td>Clay</td>
<td></td>
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<tr>
<td>Chemical bonding</td>
<td>Gypsum</td>
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<tr>
<td>Instant chemical reaction</td>
<td>Cement</td>
<td>Concrete</td>
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</tbody>
</table>
**AM mould technique EZCT** (moulds by Voxeljet)

- Freeform
- Isotropic concrete
- Lost mould

**Related expertises**

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<th>Concrete</th>
<th>Moulds</th>
<th>Concrete processing</th>
<th>AM Concrete research</th>
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</thead>
</table>
| Dr. Dipl.-Ing. Holger Strauss (Hochschule OWL) | Werner Sobek gradient beton Stuttgart University | Ir. Siebe Balder Voxeljet | Sascha Hickert (Hochschule OWL) Prof. Dipl.Ing. Matthias Michel | TU Eindhoven concrete printing - prof.drr.t.A.M. (Theo) Saelens - support material
- Rob Wolfs - Parameters and concrete properties |
| Enzo Langenberg (printing ceramic) DUS Architecten (Canel House) MIXO | Mw. dr. ir. S.A.A.M. Fennis (CITG TU-Delft) | | | |
| NSTRMNT | | | | |

**Companies**

- Winsum new materials
- EZCT / Voxeljet
- BetaBram
- Skanska

**Developments**

- Interlayer strength
- Aggregates & reinforcement

**Progress of 3D-printed wall**

Progress: 100%
Inter layer strength
Reinforcement
Material composition
Anisotropy
Process
Additive manufacturing

Print houses

Sub-questions

Research question

Characteristics of process

Additive manufacturing

Additive manufacturing

Characteristics

Sub-questions

Research question

Characteristics of process

Prezi
G-code
Could contain additional mixture information about:
Fibres
Aggregates
Retarders

Pultrude fibres

Fibre reinforcement

Changing die

Mix extra aggregates before extrusion for efficient material usage

Gradient materials

Additional aggregates

Fresh concrete

Nozzle Support
Combining extrusion and curing

The multiple mixture extruder mixus to obtain the characteristics that optimise the mixture and material composition

Polyjet in combination with elevated support printing increases the resolution
Concrete consistency and interlayer strength

Concrete mortar

Binding agent

Print concrete without complete support (polyjet)

Print eco mould

Different materials, print head and roller

Moulds

Concrete processing

AM Concrete research
Mixture
Extrusion
Multiple mixtures e.
Polyjet in combination with elevated support printing increases the resolution
Extrude in elevated support
Nozzle Support
Resolution
Curing
Extrude in elevated support
"Print head" support material layers
Reinforcement shotcrete
Support net
Shotcrete
Supporting shotcrete
Stillcrete
Rising of elements
Roughened surface
Standardized elements can be customised on site when the surface binding is strong
Shotcrete is used to cover the reinforcement with layers of concrete
Freeform and support
the characteristics that optimise the mixture and material composition
Extrude in elevated support
"Print head" support material layers
Freeform and support

Resolution
Curing

Polyjet concrete extr.
with elevated support
printing increases the
resolution

Support material
Print head and roller

Shotcrete is used
to cover the reinforcement
with layers of concrete

Extrude in elevated
support

`print head`
support material
Nozzle

Support net

Reinforcement shotcrete

Extrude in elevated
support

Extrude in mould

Shotcrete

Standardized elements
can be customised on
site when the surface
binding is strong
enough by e.g.
roughening it
mechanically

On site customising of
standardised elements

Customise

G-code
**CONCLUSION: FUTURE VISION**

**Hybrid techniques description**

**Combining extrusion and curing**
- Instant dry extrusion/pultrusion
  - High throughput quality elements with reinforcement that do not need to be finished
  - E.g. using a non-reinforcement null

**Orientated fibre reinforced concrete**
- The extrusion head is used to mix, extrude and reinforce.
- Reinforcement is used for layer strength and load distribution.

**Print mill sand**
- Print with a low resolution the desired form and use milling or laser to add structure to the form element.

**Mixed extrusion with elevated support printing**
- Use a subtractive extrusion head to print a layer and weld it to the previous layer, adding support material after the extruded layer has been formed with a protection layer. The process is repeated till the element is finished.

**Support net spraying**
- Print or weld a support frame that can be used in reinforcement and to control the geometry of the four elements. It is the method that can be used in a layer at a time. The net is covered with concrete using spraying.

**Characteristics & Evaluation**

- Fast
- Reinforced
- Can be automated easily
- High quality concrete (extruded at once)

- Orientated reinforcement
- Controlled material composition
- Less free form
- More isotropic
- Less material

- High surface quality
- Less resolution needed
- Faster printing needed
- Faster overall process

- Minimising printing time
- Efficient support
- Freestyle
- Controlled material composition

- Build around the reinforcement
- Freestyle
- Fast process
- High surface quality due to post-processing

**CONCRETE IN AN AM PROCESS**

This report examines the additive manufacturing (AM) of concrete. It does so by outlining the processes and techniques that are adapted to the characteristics of concrete material.
High-dosed concrete

Oriental Construction
Less time
More efficiency
Less material

Prezi
Elevated support

The protection layer prevents dehydration of the concrete.
CONCLUSION: FUTURE VISION

Advanced application

Concretemaking
- Large scale components
- Production of infrastructure
- High quality concrete structures

Products

- Decorative components
- Architectural elements
- High performance concrete

Concrete in an AM process

Freeform concrete processing

This representation shows the advantages of using 3D printing for concrete, highlighting its suitability for complex and repetitive structures. The technique allows for the creation of intricate designs and the production of large-scale components, suitable for infrastructure projects. Advanced applications in the construction industry are shown, emphasizing the potential for high-quality concrete structures and decorative architectural elements. The process of forming concrete using 3D printing is depicted, illustrating the transition from digital design to physical construction. This innovation provides a new avenue for concrete fabrication, offering opportunities for creativity and efficiency in the construction sector.
Advanced extruder

Aligned fibres
Controlled mixture
Inter layer strength
Smooth surface

Advanced extruded elements with different densities are extruded at once due to multiple extrusion points in the die. The extruder head can be used for different process approaches.
G-code

Computer model -> Generate STL file -> Generate G-code

extrude filament -> Sensor observes extruded filament -> compare to G-code to correct -> corrected G-code

parallel code that contains material information
Gradient material

Large structural elements with different distribution of aggregates and composition. With or without formwork.

Core parts
Core parts

Print in low resolution, to increase production speed. These elements will be covered or finished afterwards.

Freeform
Freeform

Freeform, high resolution elements, Joints of standarized systems, and 3D refurbishment elements
ROADMAP: future vision
Recommendations

Collaboration between faculties
  Architecture
  Civil engineering
  Material science
  Mechanical engineering

Build a printer to test and validate theoretical research
Conclusions

Concrete differs a lot from other AM materials
Processes need to be adapted to the material
Premature to look only at products
Multiple stage or combined techniques are important
Next steps in research

In depth research regarding feasibility of the future visions
Keep observing the competition to keep ahead of them
Publish results
Questions?

CONCRETE
in an AM process

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