FIELD OF AM

2015

DEVELOPMENT

CONCLUSION: FUTURE VISION

Techniques

Initiatives

FDM technique
Contour crafting
Winsun new materials

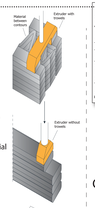
3D Concrete printing
Total custom

3DP technique
D-Shape

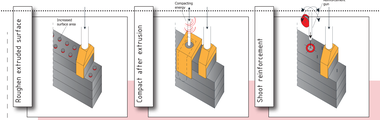
AM mould technique
EZCT
(moulds by Voxeljet)

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



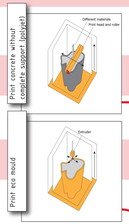
Concrete mortar



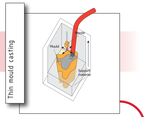
Concrete consistency and interlayer strength

Reinforcement

Binding agent

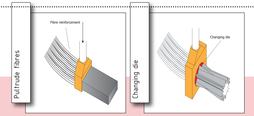


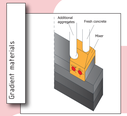
Freeform



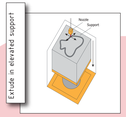
G-code

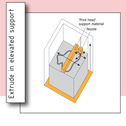
Could contain additional mixture information about;
Fibres
Aggregates
Retarders

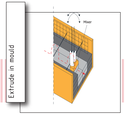




Mix extra aggregates before extrusion for efficient material usage







Implementation

3D-Print techniques that uses binders

Advanced (AM) moulds

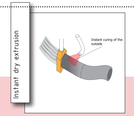
AM with a support material

Additive casting

Traditional concrete processing

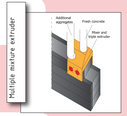
Mixture and composition

Pultrusion



Combining extrusion and curing

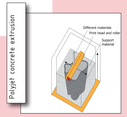
Extrusion



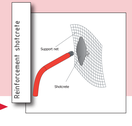
The multiple mixture extruder mixus to obtain the characteristics that optimise the mixture and material composition

Freeform and support

Resolution Curing



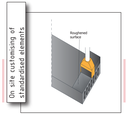
Polyjet in combination with elevated support printing increases the resolution



Shotcrete is used to cover the reinforcement with layers of concrete

Shotcrete

Customise



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

Related expertises

AM

Dr. Dipl.-Ing. Holger Strauss (Hochschule OWL)
Emo Langenberg (printing ceramic)
OLIS Architecten (Canal House)
MX3D
NOTRANT

Concrete

Werner Sobek gradient beton
Stuttgart University
Mw. dr. ir. S.A.A.M. Fennis (CiTG TU-Delft)

Companies

Winsun new materials
EZCT / Voxeljet
BetaBram
Skanska

Moulds

ir. Seibe Bakker
Voxeljet

Concrete processing

Sascha Hickert (Hochschule OWL)
Prof. Dipl-Ing. Matthias Michel
ir. Roel Schipper (CiTG TU-Delft)
dr.ir. Karel Vollers (BK TU-Delft)
Adapa (DK) MSc Eng Thomas Henriksen
Reider Group (AT)

AM Concrete research

TU Eindhoven concrete printing
- prof.dr.ir. T.A.M. (Theo) Salet - support material
- Rob Wolfs - Parameters and concrete properties

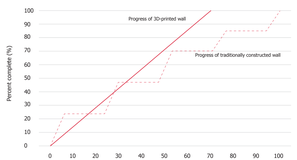
TU Delft
- Evaluating techniques and searching matching products
- Experiments with new concepts for AM of concrete

Saxion
Breakthrough in 3D printing

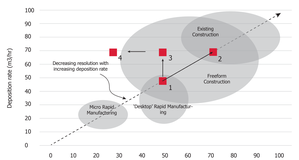
Developments

Inter layer strength
Aggregates & reinforcement
Isotropy
Surface quality
Material usage

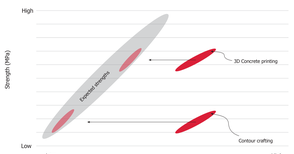
Mechanism	Constituent material	Composite
Phase change	Steel	
	Plastics	
Drying	Clay	
Chemical bonding	Gypsum	
Instant chemical reaction	Cement	Concrete



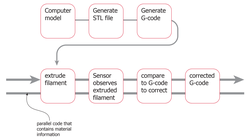
Adapted from Buswell, et al., 2007, p.278



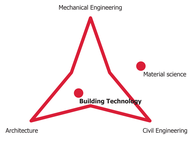
Adapted from Buswell, et al., 2007, p.279



G-code



Interdisciplinarity

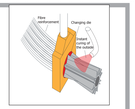


Hybrid techniques description

Instant dry extrusion/pultrusion

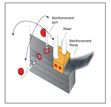
High furface quality elements with reinforcement that do not need to be finished.

e.g using a non newtonian fluid



Orientated fibre reinforced concrete

The extrusion head is used to mix, extrude and reinforce. Reinforcement is used for inter layer strength and for load distribution.



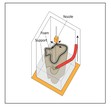
Print mill sand

Print with a low resolution the desired form and use milling (or lasers) as subtractive technique to finish the element.

(Mixed extrusion with) elevated support printing

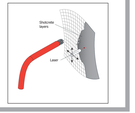
Use a (advanced) extrusion head to print a layer and add / cover the area around with loose support material after the extruded layer has been covered with a protection layer. The process is repeated till the element is finished.

The protection layer prevents dehydration of the concrete



Support net spraying

Print or weld a support frame that can be used as reinforcement and to define the geometry of the AM element. It is the method that builds a layer around a core. The net is covered with concrete using spray on.



Characteristics & Evaluation

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

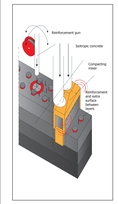
Orientated reinforcement
Controlled material composition
Less free form
More isotropic
Less material

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

Minimising printing time
Efficient support
Freeform
Controlled material composition

Build around the reinforcement
Freeform
Fast process
High surface quality due post processing

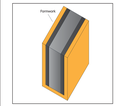
Advanced extruder



Aligned fibres
Controlled mixture
Inter layer strength
Smooth surface

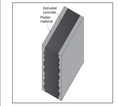
Advanced extruded elements with different densities are extruded at once due to multiple extrusion points in the die. The extruder head can be used for different process approaches

PRODUCTS



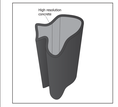
Gradient material

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



Core parts

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



Freeform

Freeform, high resolution elements,
Joints of standarized systems, and
3D refurbishment elements

ROADMAP: future vision

CONCRETE IN AN AM PROCESS

Freeform concrete processing

This report examines the additive manufacturing (AM) of concrete, its possibilities, feasibility and advantages over existing techniques. Traditional processing techniques are adapted to the characteristics of concrete and concrete does not let itself dictate how to behave. The possibilities for products made with an additive process are endless, but just replacing existing production methods with additive ones is still impossible. Although improved freeform production techniques are the aim of this research, this does not mean that more freedom in form is by definition the largest improvement that AM can offer at the moment. From another point of view the implementation of additional functions in traditional products can be of great value.
A roadmap envisions how the technique has to evolve in order to implement the characteristic properties of concrete. Product ideas and an evaluation of the techniques shown in the roadmap are related to the developments to achieve an increase in speed, surface quality and strength in the AM production technique, next to the requirements that have to be set regarding a matching fresh concrete mixture.

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