CONCRETE
in an AM process

Freeform concrete processing

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Dennis de Witte
P5 presentation

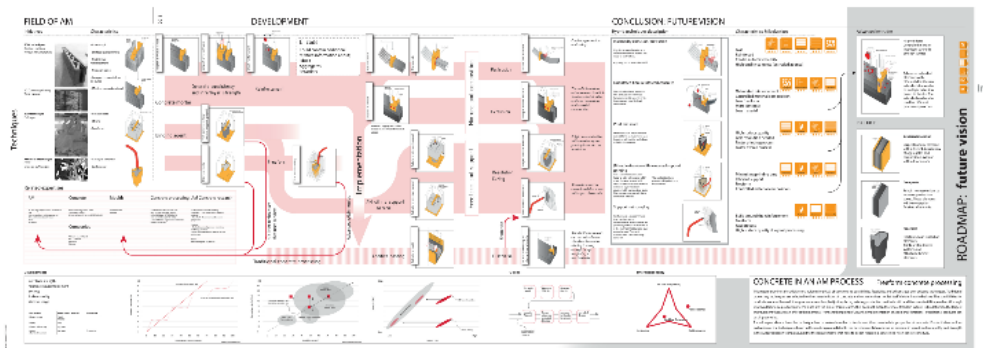
30 January 2015 16:00

CONCRETE
in an AM process

Freeform concrete processing

Introduction
Research
AM of concrete
Roadmap
Conclusions & recommendation

Inter layer strength
Reinforcement
Material composition
Anisotropy
Process



Process
Control
Implement

Threats
Add value

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

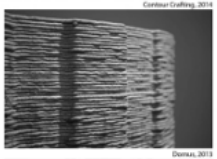
2015

DEVELOPMENT

Initiatives

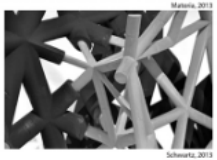
FDM technique
Contour crafting
Winsun new materials

3D Concrete printing
Total custom



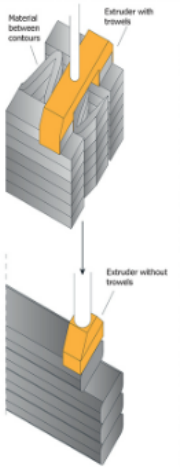
3DP technique
D-Shape

AM mould technique
EZCT
(moulds by Voxeljet)

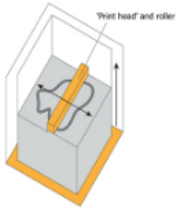


Characteristics

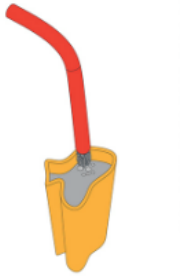
- Anisotropic
- Surface quality differs
- No internal reinforcement
- No aggregates
- Compact concrete low air bulbs
- Missing support material



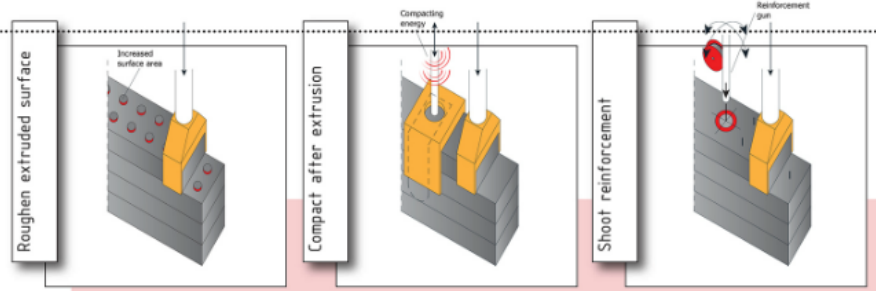
- Not concrete
- Strong
- Freeform



- Isotropic concrete
- Lost mould



Related expertises



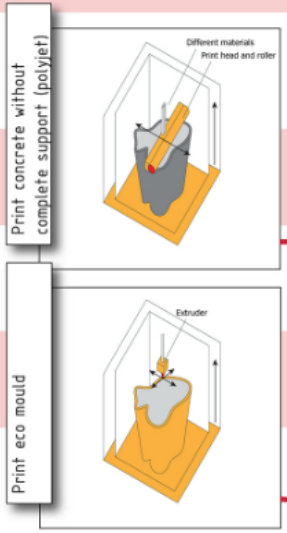
G-code
Could contain additional mixture information about;
Fibres
Aggregates
Retarders

Concrete consistency and interlayer strength

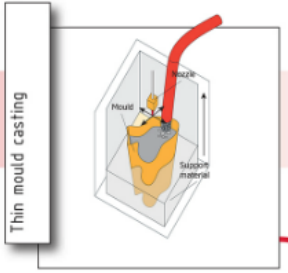
Reinforcement

Concrete mortar

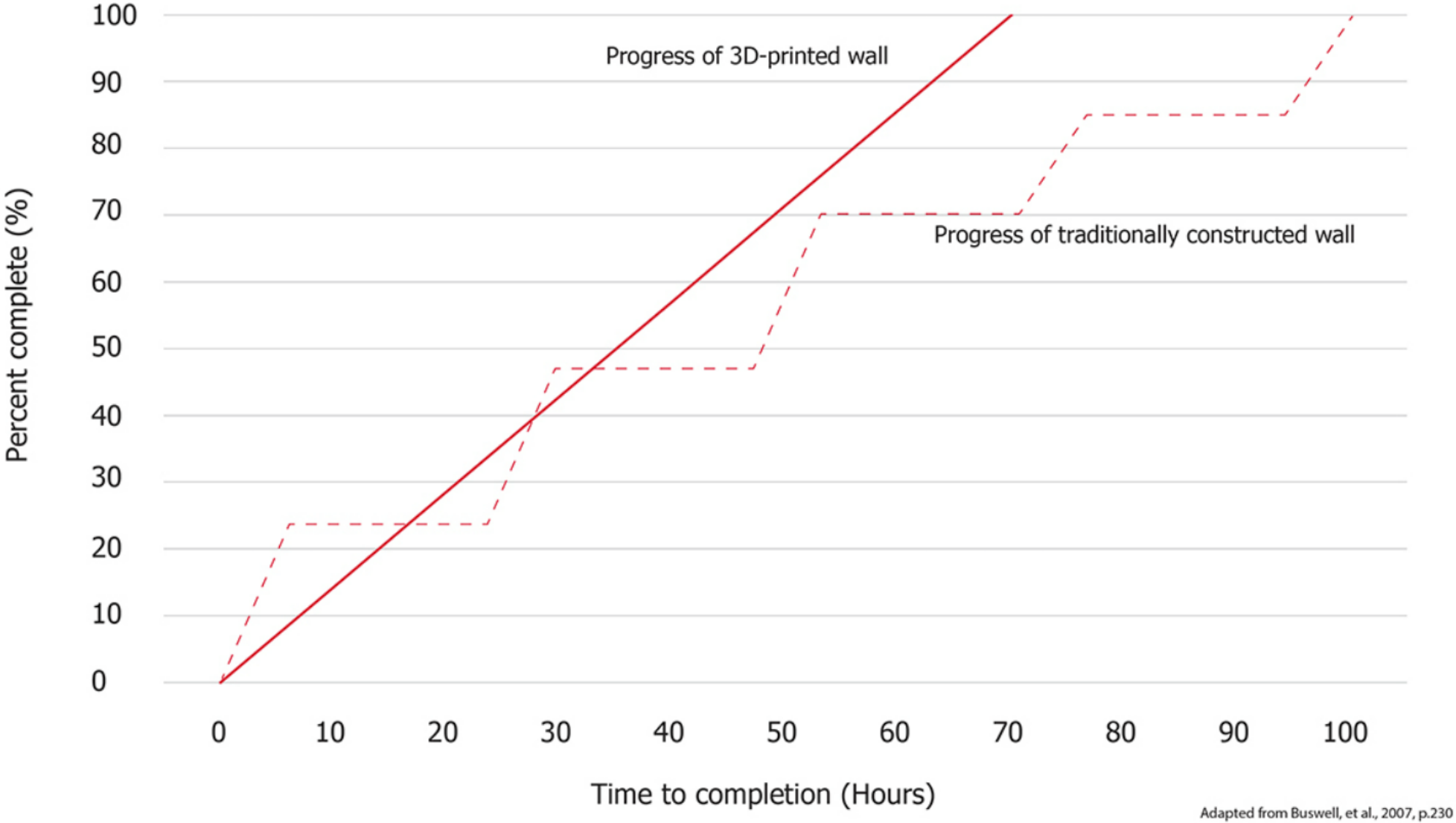
Binding agent



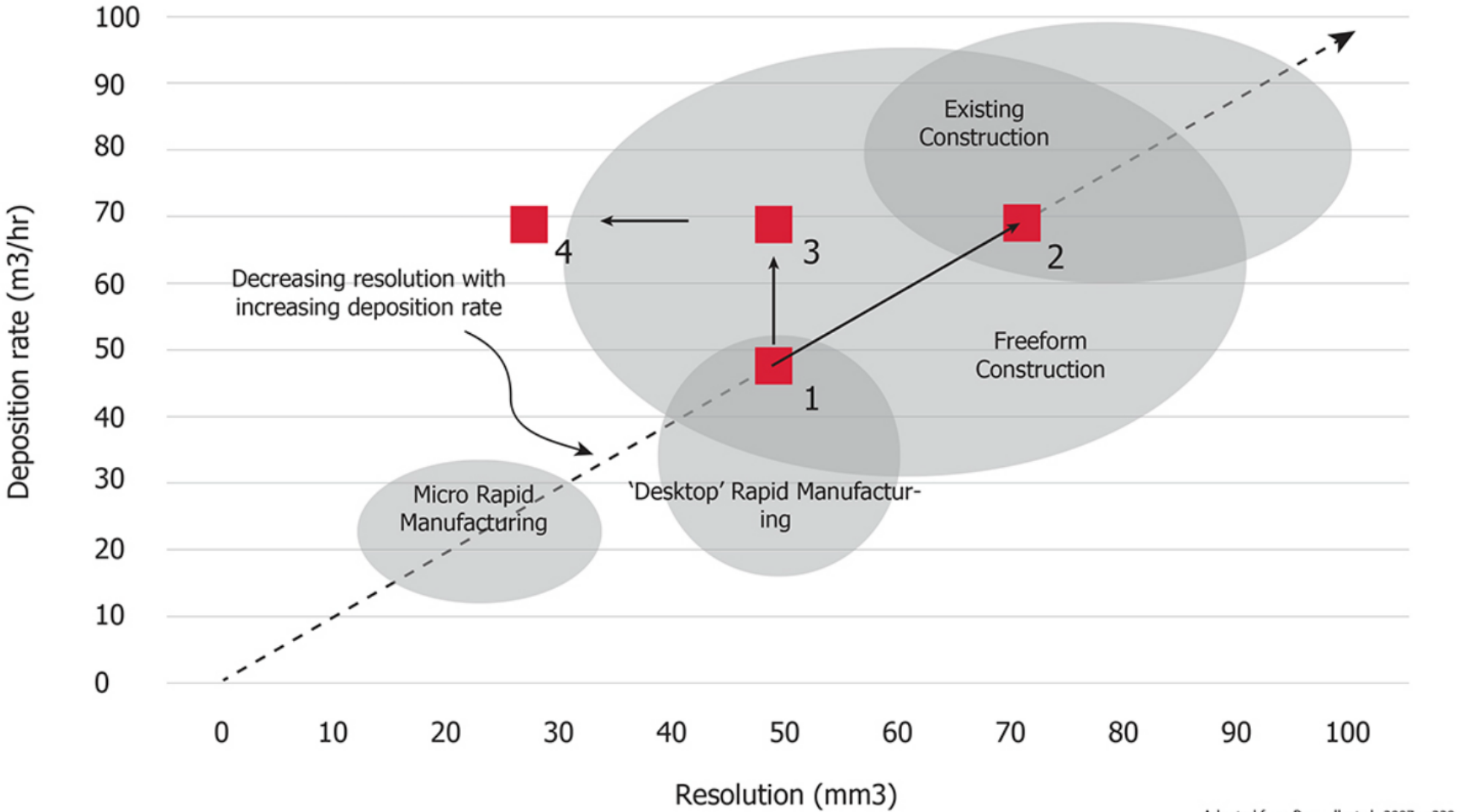
Freeform



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.230



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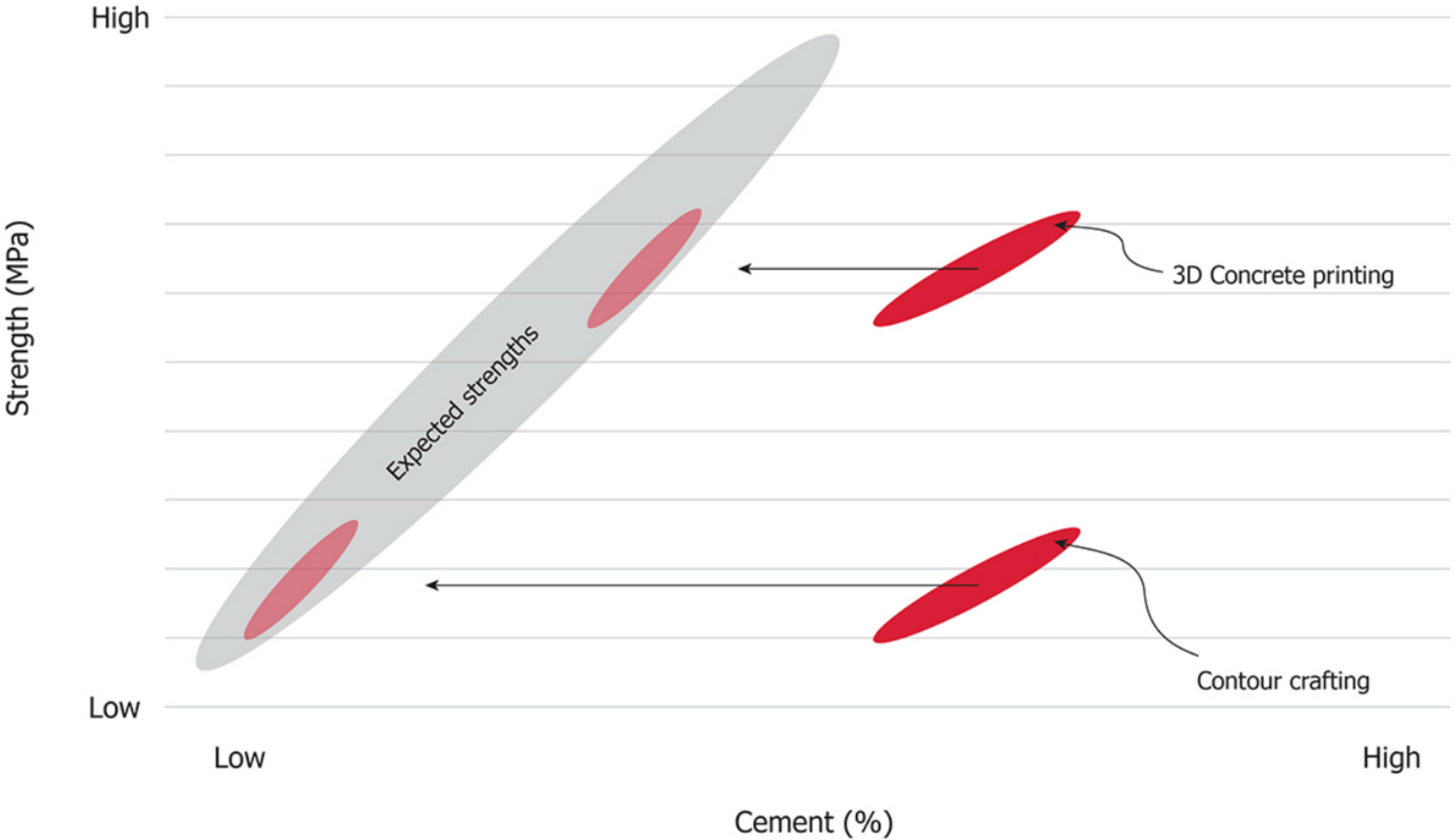
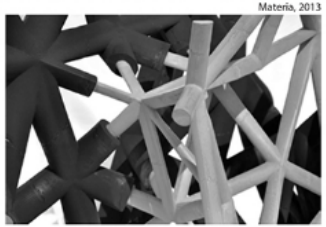

High
Strength (MPa)
Low
Low
High
Cement (%)
Expected strengths
3D Concrete printing
Contour crafting

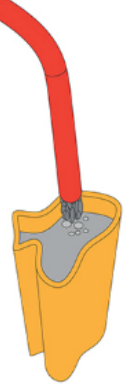

Materia, 2013

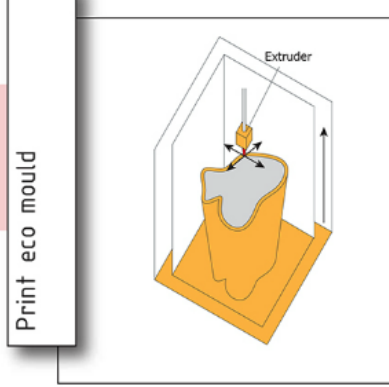
AM mould technique
EZCT
(moulds by Voxeljet)


Schwartz, 2013

- Isotropic concrete

- Lost mould





Related expertises

AM

Dr. Dipl.-Ing. Holger Strauss (Hochschule OWL)
Erno Langenberg (printing ceramic)
DUS Architecten (Canel House)
MX3D
NSTRMNT

Concrete

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

Moulds

ir. Siebe 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
Rieder 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

Companies

Winsum new materials
EZCT / Voxeljet
BetaBram
Skanska

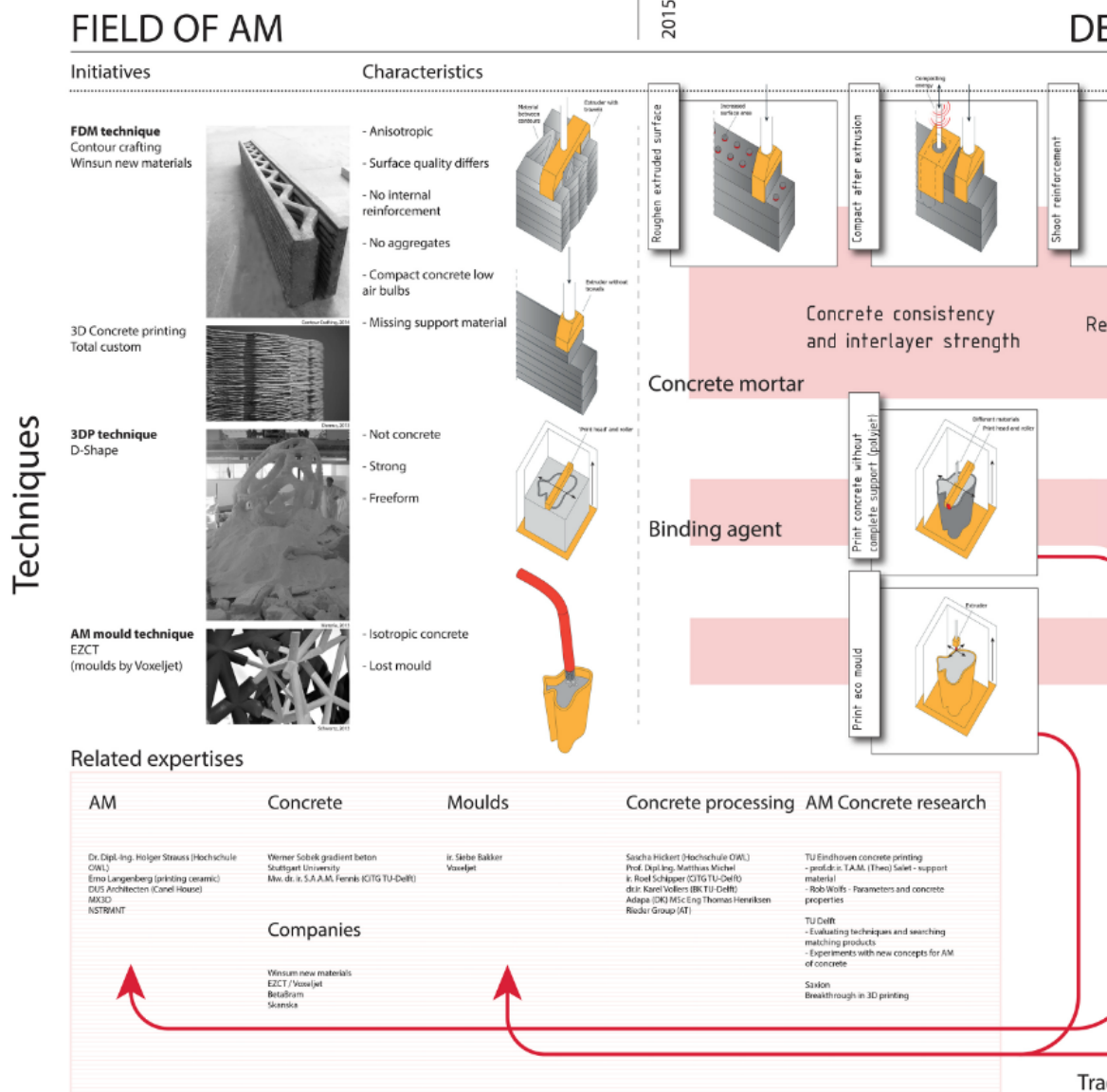
Inter layer strength

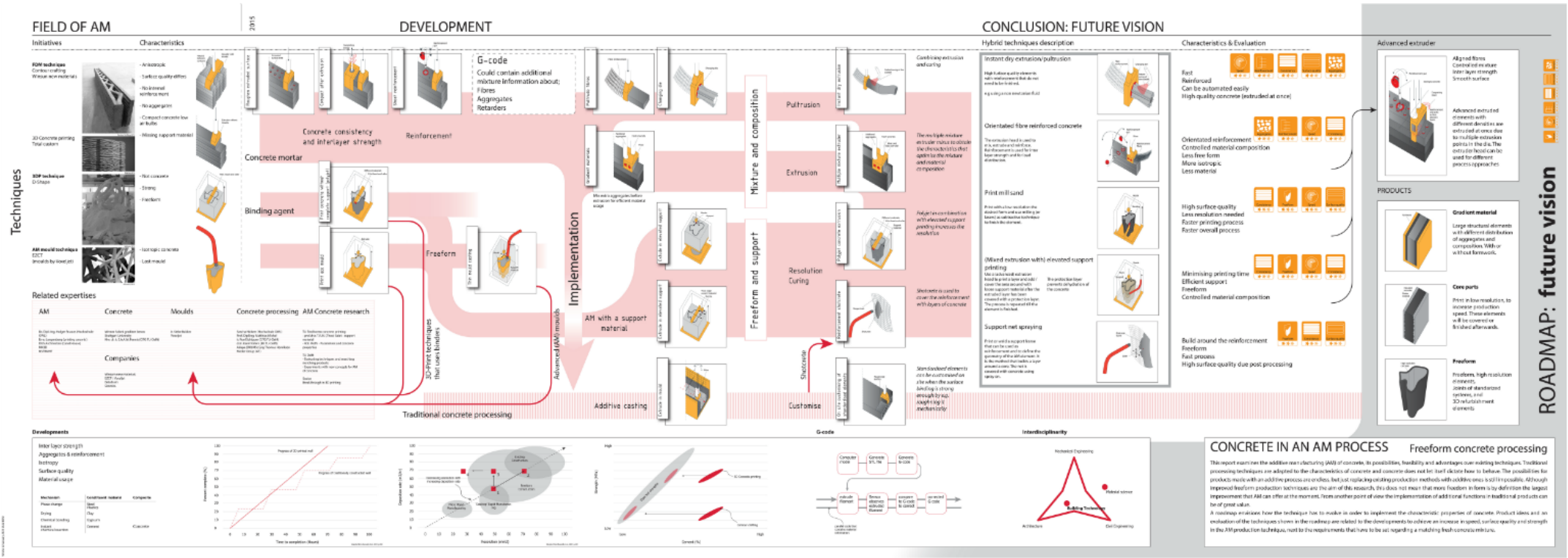
Reinforcement

Material composition

Anisotropy

Process





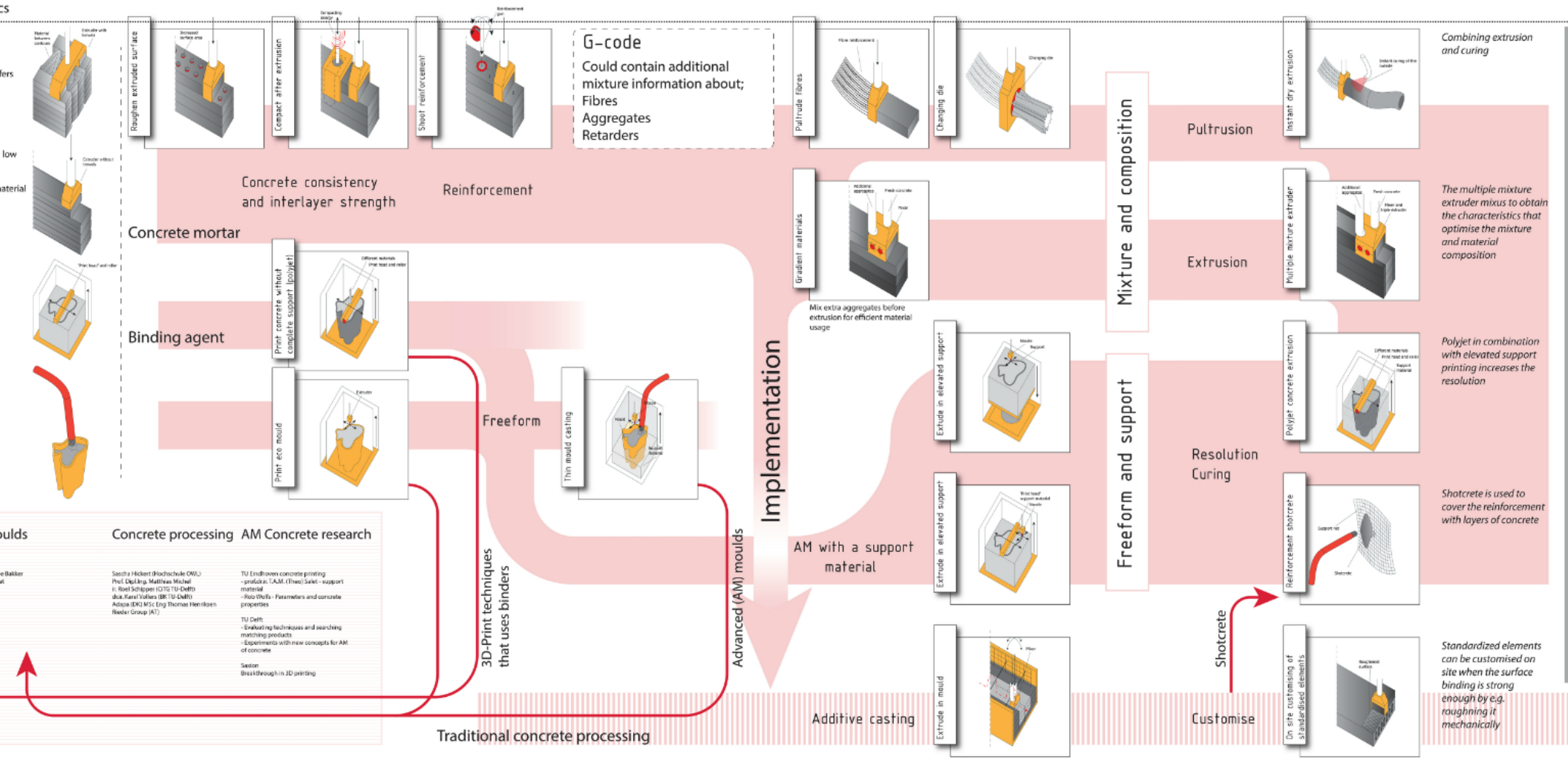
CONCRETE IN AN AM PROCESS

Freeform concrete processing

This report examines the additive manufacturing (AM) of concrete, its possibilities, feasibility and advantages over existing techniques. Traditional processing techniques are adopted 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.

DEVELOPMENT



Concrete processing

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dhuk.Karel Vollers (BK TU-Delft)
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- Evaluating techniques and searching matching products
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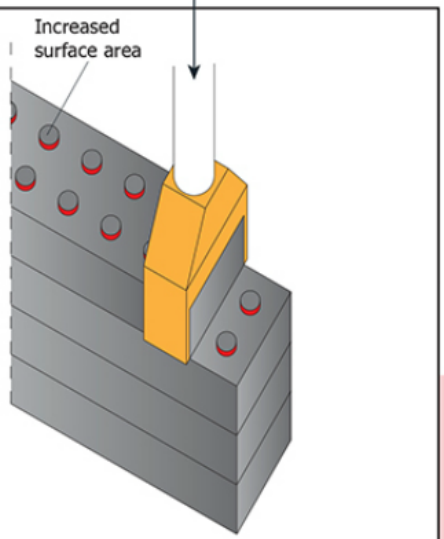
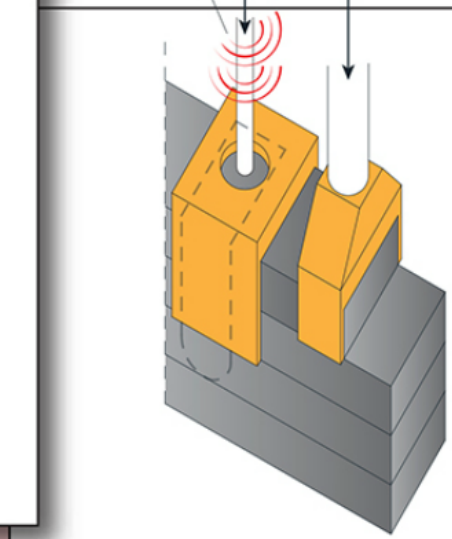
Saxion
Breakthrough in 3D printing

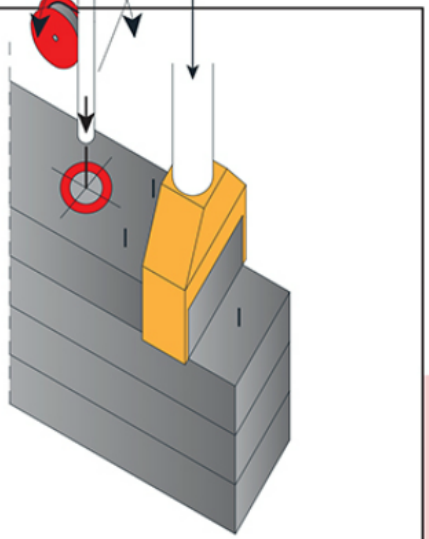
Roughen extruded surface



Compact after extrusion



Shoot reinforcement



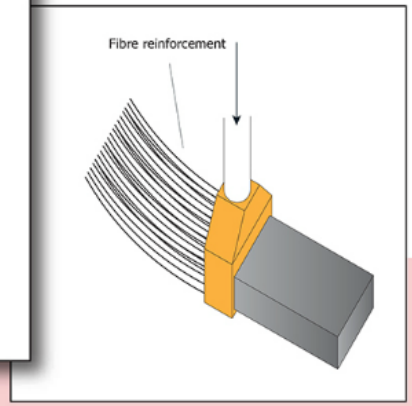
Concrete consistency
and interlayer strength

Reinforcement

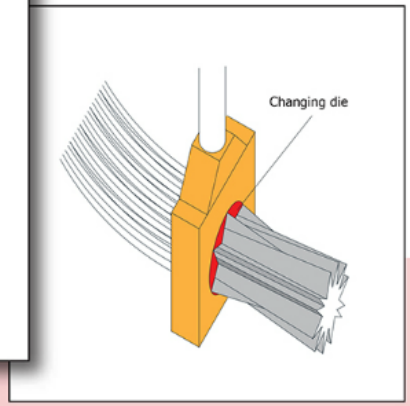
G-code

Could contain additional mixture information about;
Fibres
Aggregates
Retarders

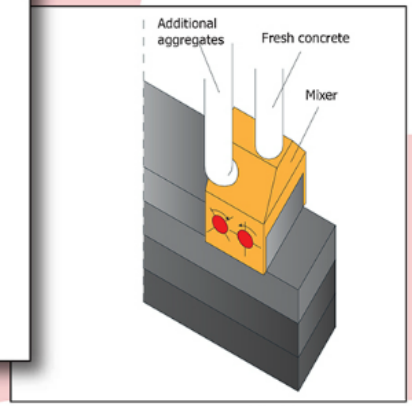
Pultrude fibres



Changing die



Gradient materials



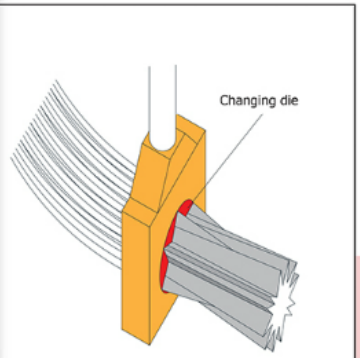
Mix extra aggregates before extrusion for efficient material usage

Mixture and composition

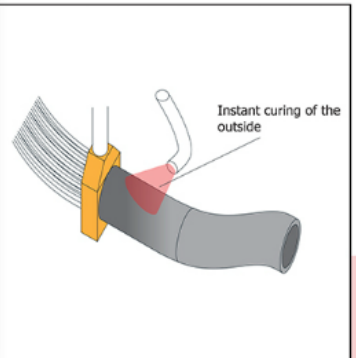
Mixture and composition

Pultrusion

Changing die



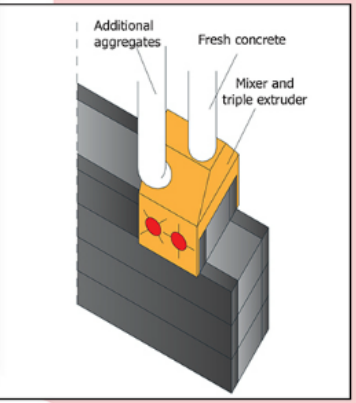
Instant dry extrusion



Combining extrusion and curing

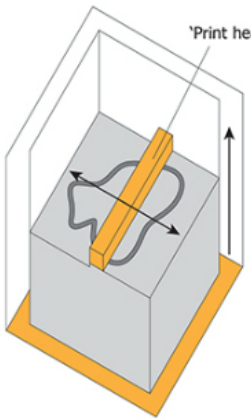
Extrusion

Multiple mixture extruder



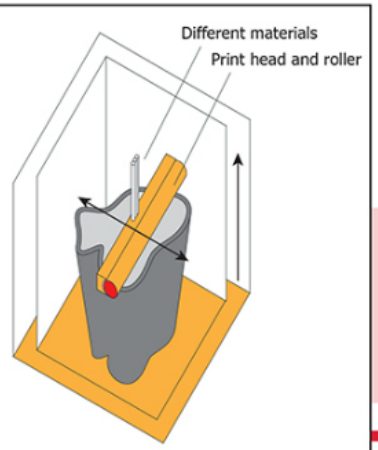
The multiple mixture extruder mixus to obtain the characteristics that optimise the mixture and material composition

Concrete mortar

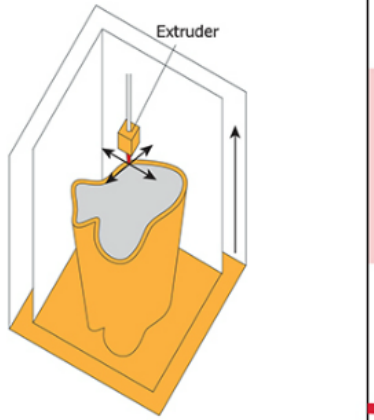


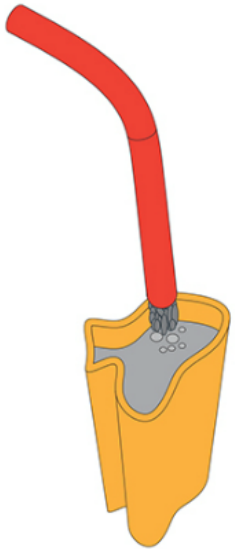
Binding agent

Print concrete without complete support (polyjet)



Print eco mould





ete

Free

Mixt

Freeform and support

Resolution
Curing

Extude in elevated support

Extrude in elevated support

Polyjet concrete extrusion

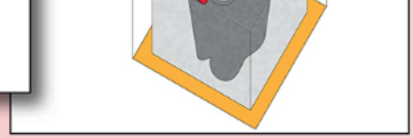
Polyjet in combination with elevated support printing increases the resolution

Reinforcement shotcrete

Shotcrete is used to cover the reinforcement with layers of concrete

Extrude

Polyje

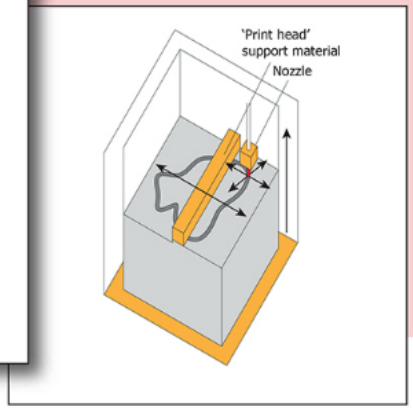


Freeform and supp

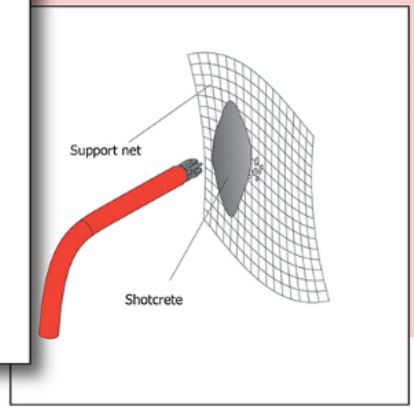
Resolution

Curing

Extrude in elevated support



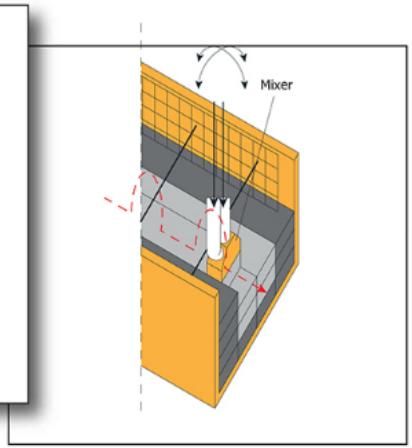
Reinforcement shotcrete



Shotcrete is used to cover the reinforcement with layers of concrete

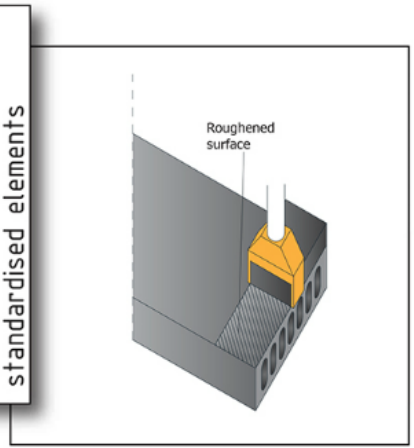
Shotcrete

Extrude in mould

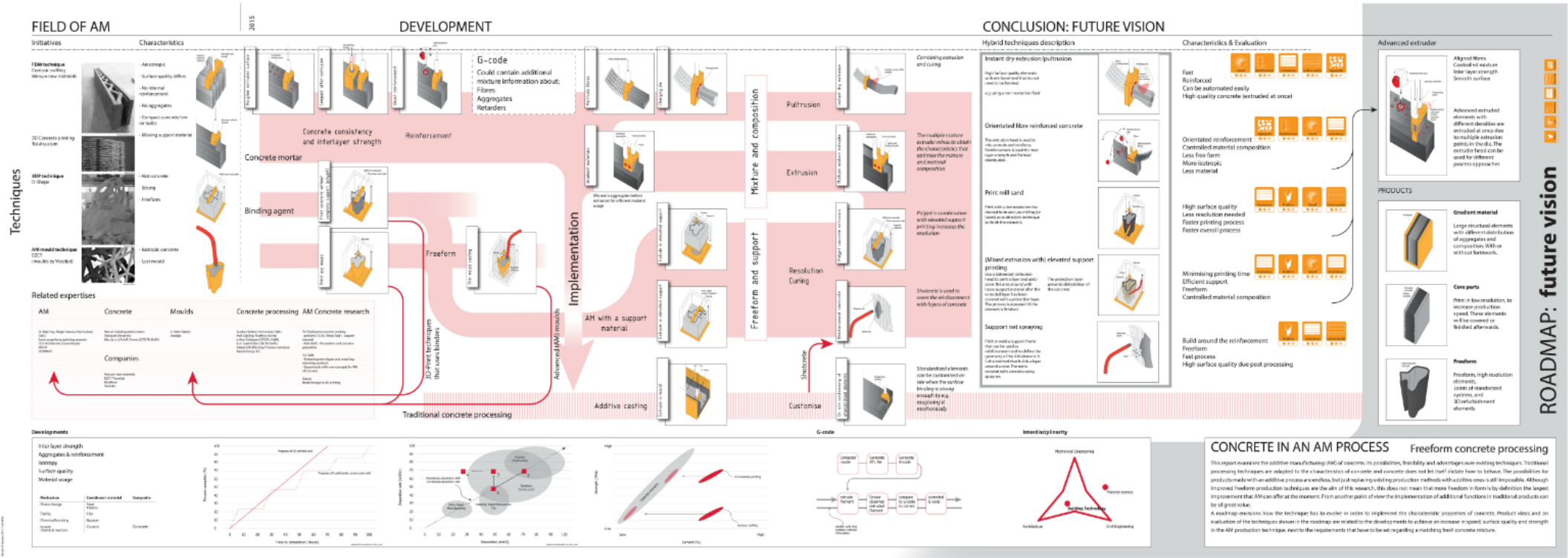


Customise

On site customising of standardised elements



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



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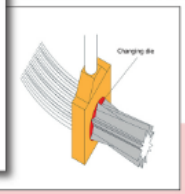
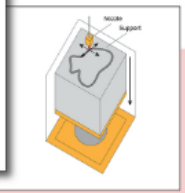
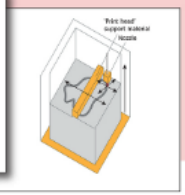
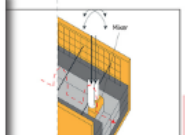
CONCLUSION: FUTURE VISION









Mixture and composition

Freeform and support

Pultrusion

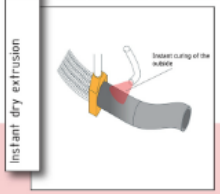
Extrusion

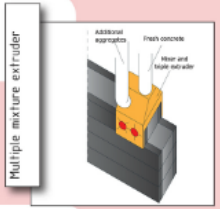
Resolution

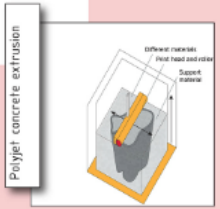
Curing

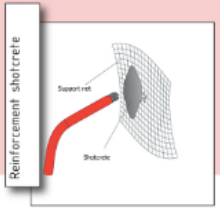
Shotcrete

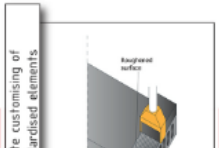
Customise











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

Shotcrete is used to cover the reinforcement with layers of concrete

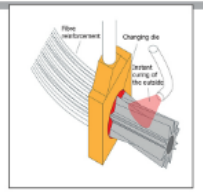
Standardized elements can be customised on site when the surface binding is strong enough by e.g. roughning it

Hybrid techniques description

Instant dry extrusion/pultrusion

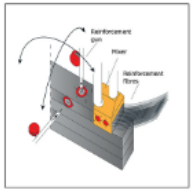
High furface quality elements with reinforcement that do not need to be finished.

e.g using a non newtonian fluid



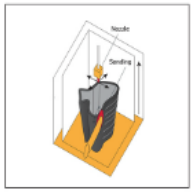
Orientated fibre reinforced concrete

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



Print mill sand

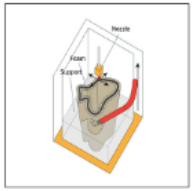
Print with a low resolution the desired form and use milling (or lasers) as subtractive technique to finish the element.



(Mixed extrusion with) elevated support printing

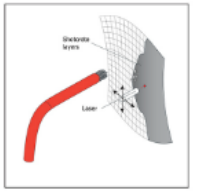
Use a (advanced) extrusion head to print a layer and add / cover the area around with loose support material after the extruded layer has been covered with a protection layer. The process is repeated till the element is finished.

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

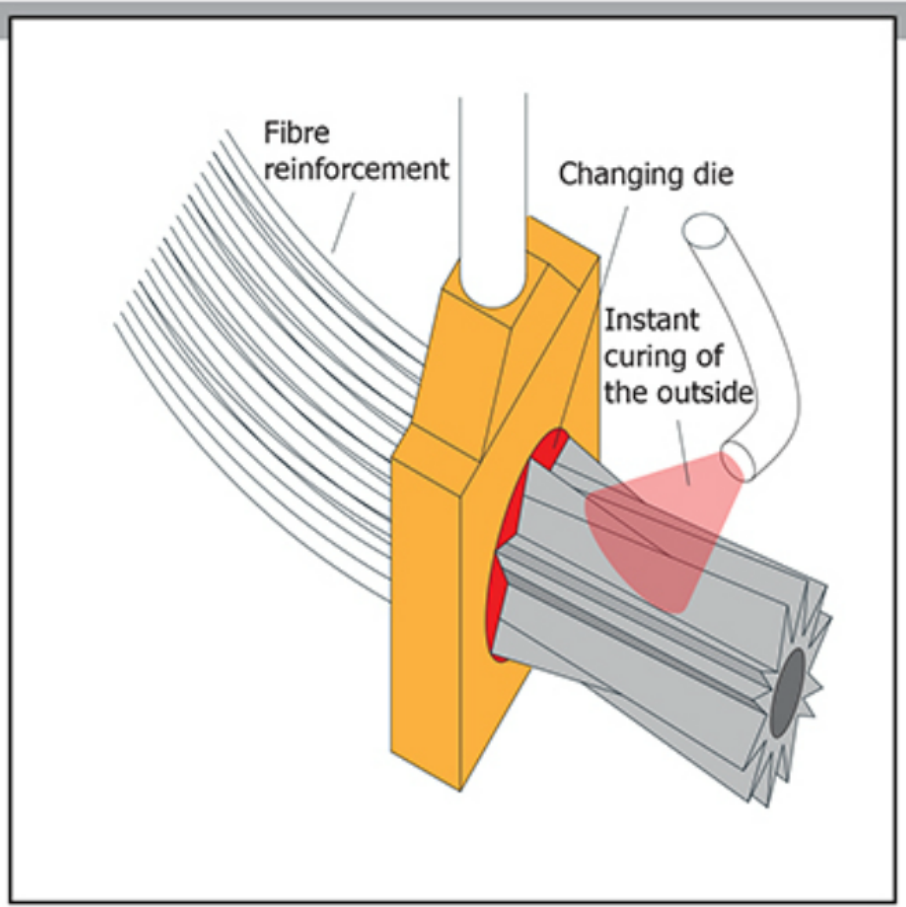
Minimising printing time
Efficient support
Freeform
Controlled material composition

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

scription

Char

ltrusion



Fast

Reinf

Can b

High

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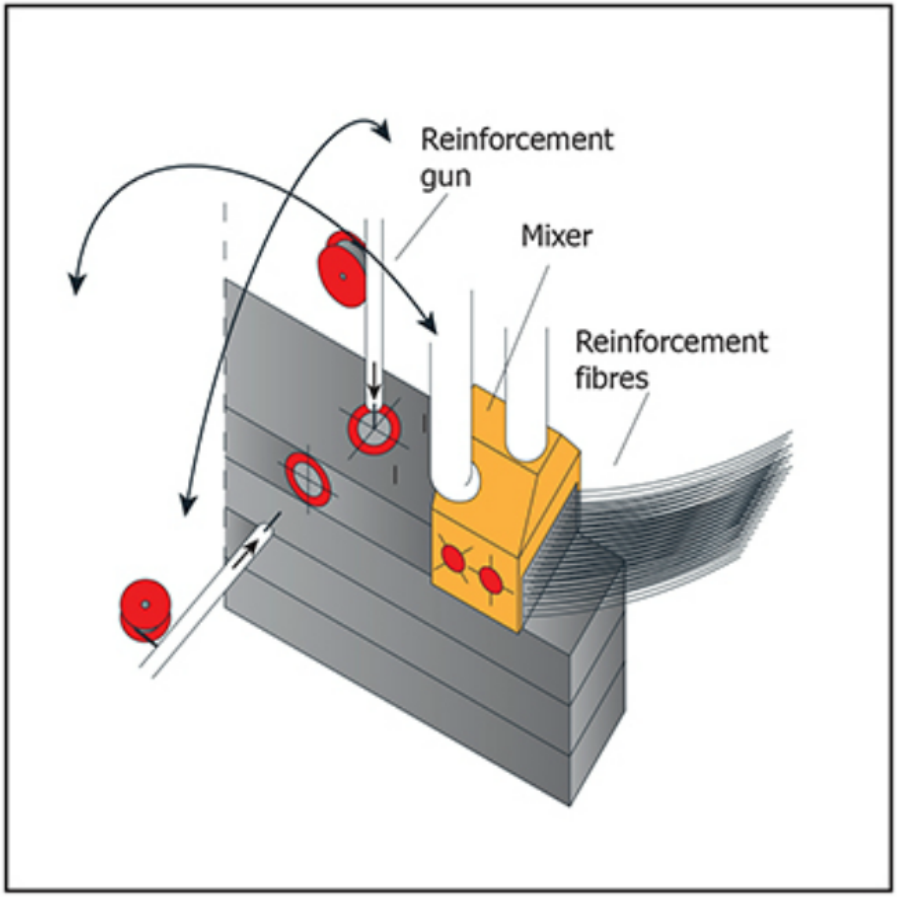
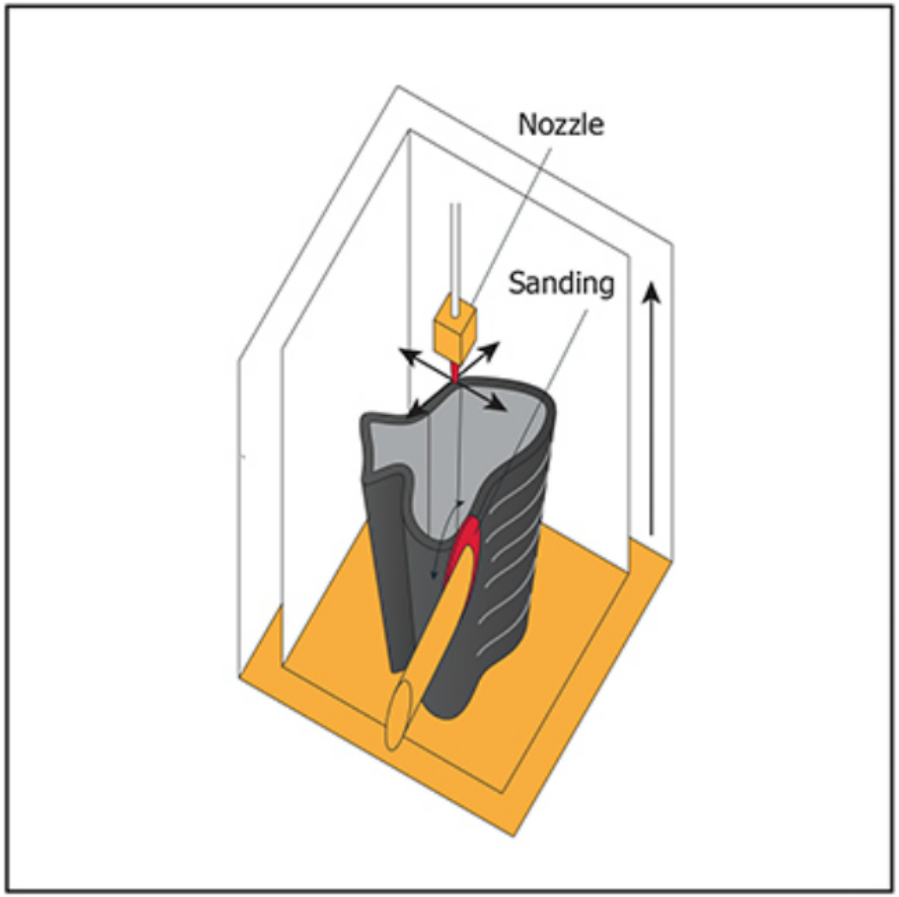


Orien
Contr
Less f
More
Less r

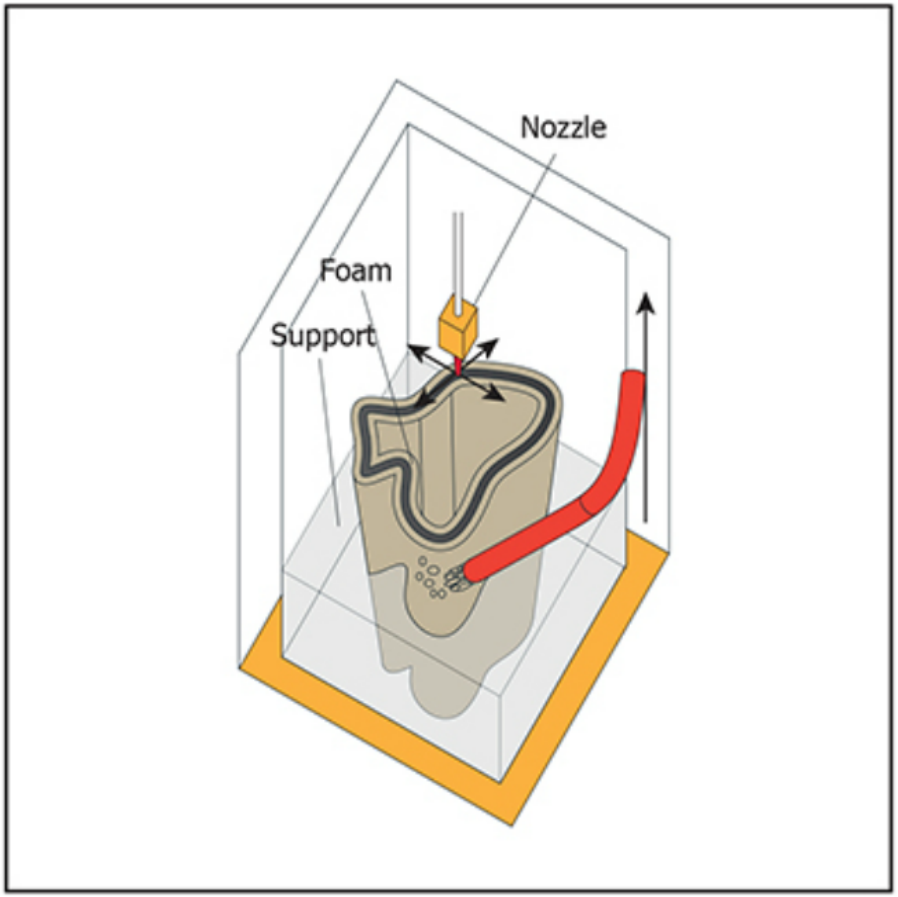


High
Less
Faste
Faste

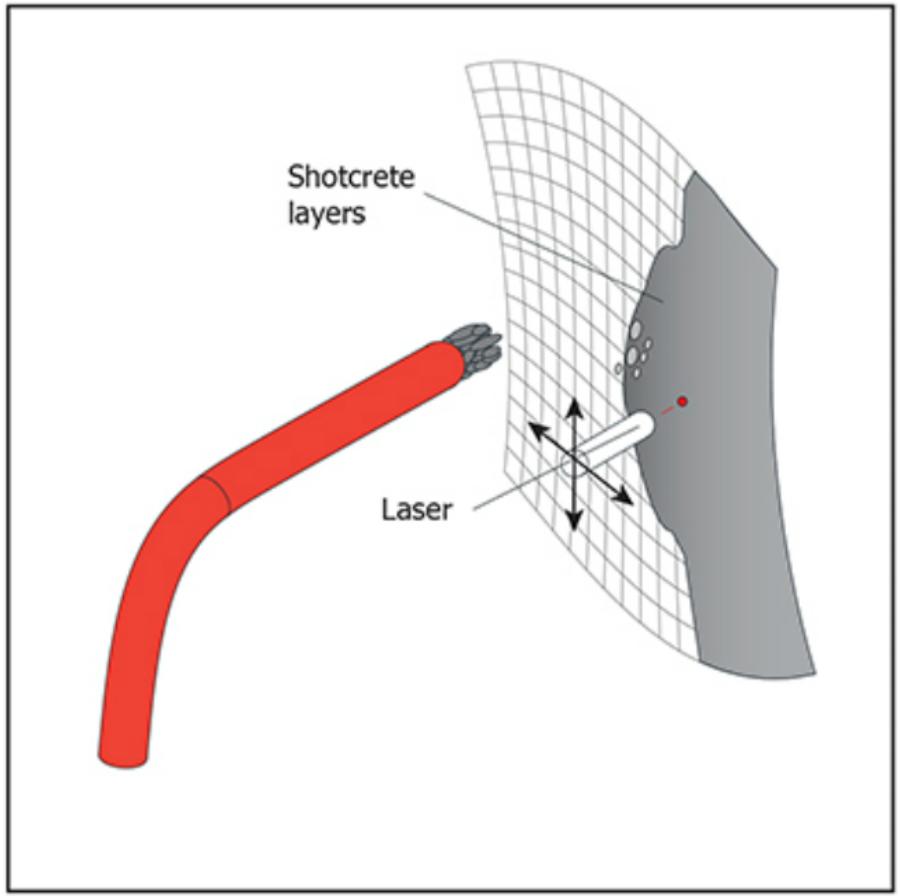
levated support

levated support

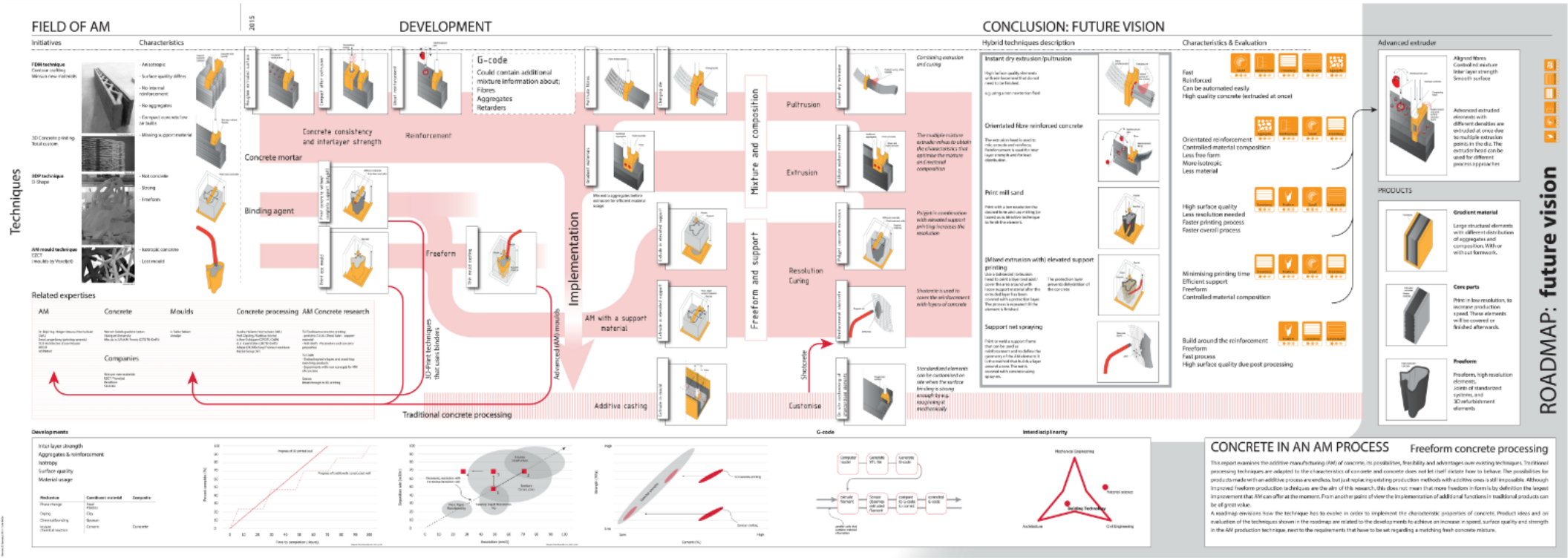
he protection layer
revents dehydration of
he concrete



Minir
Effici
Freef
Contr



Build
Freef
Fast p
High



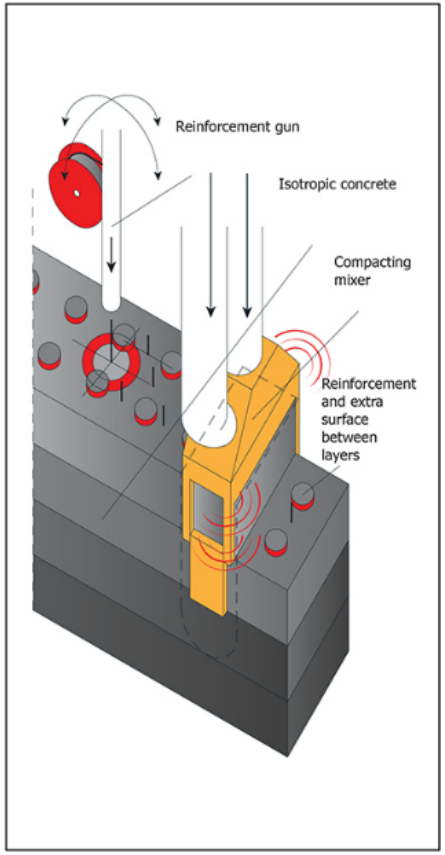
CONCRETE IN AN AM PROCESS

Freeform concrete processing

This report examines the additive manufacturing (AM) of concrete, its possibilities, flexibility 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.

Advanced extruder



Aligned fibres
Controlled mixture
Inter layer strength
Smooth surface

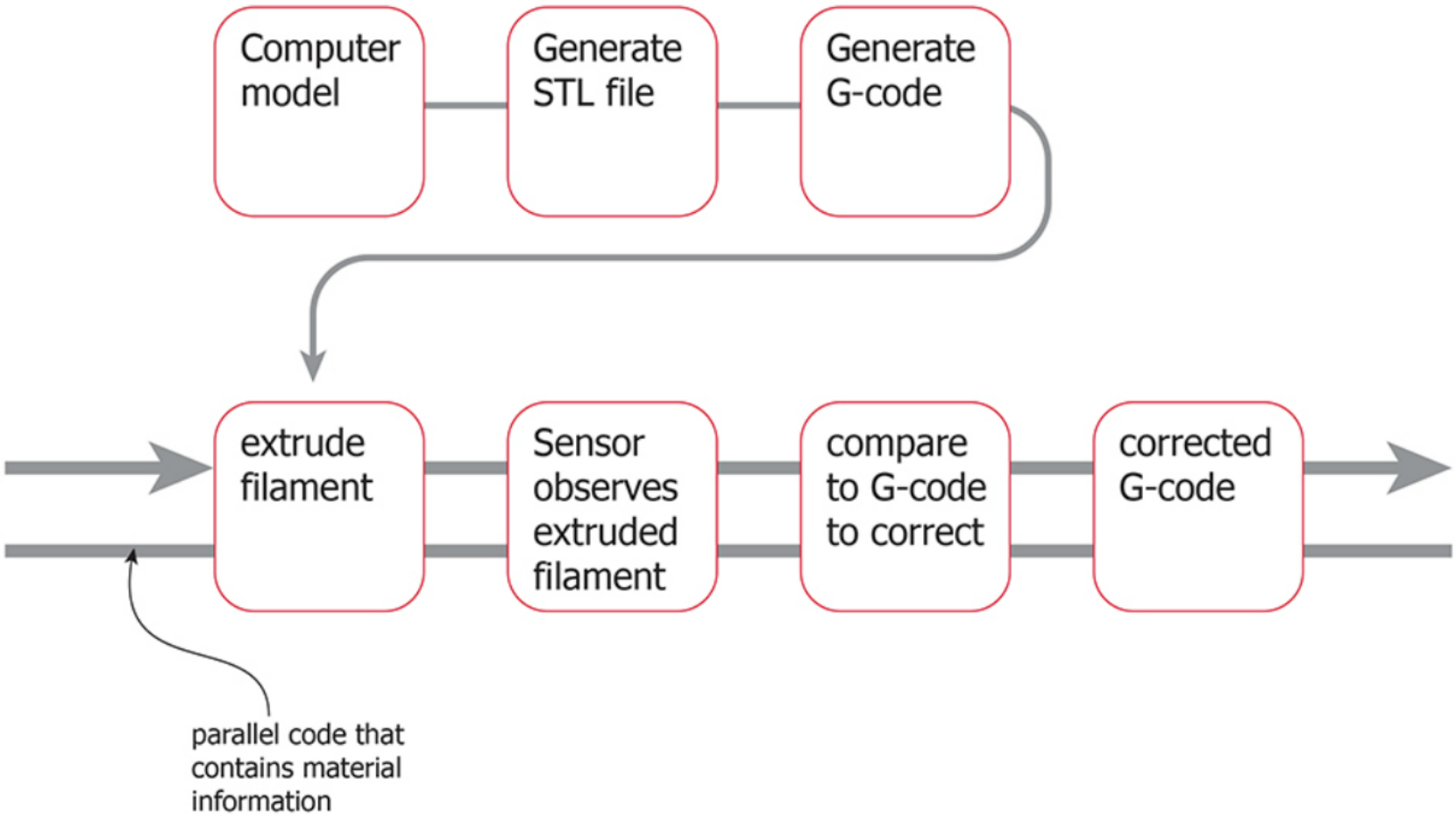
Advanced extruded elements with different densities are extruded at once due to multiple extrusion points in the die. The extruder head can be used for different process approaches

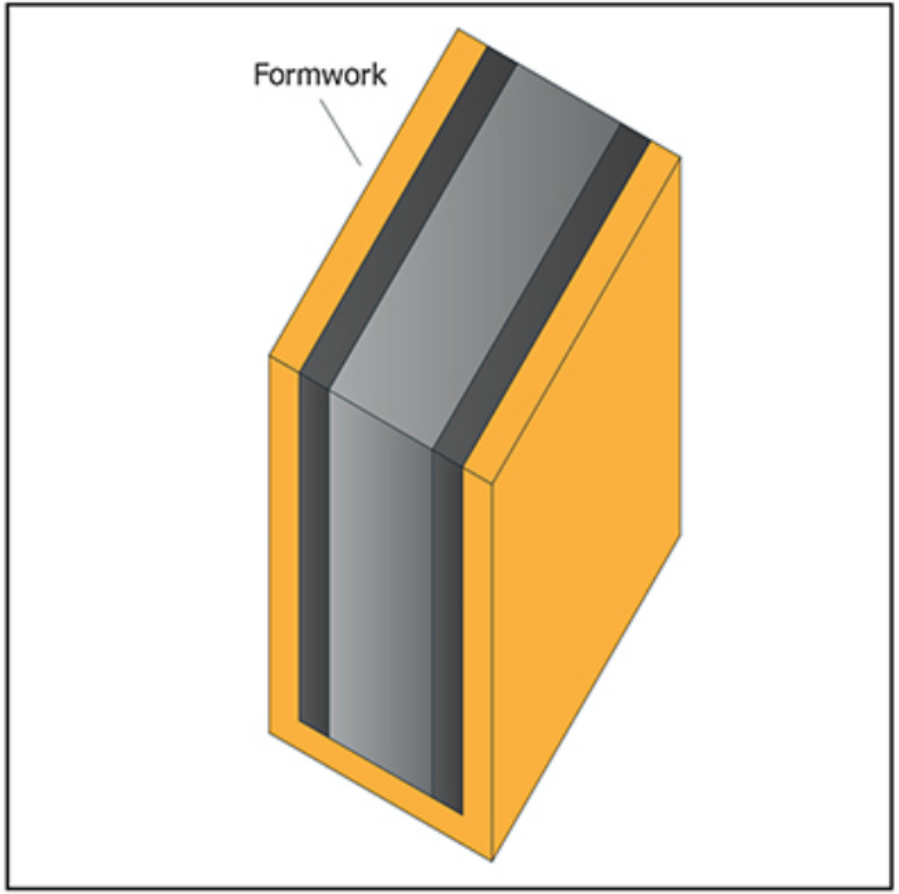
PRODUCTS

Process

Control

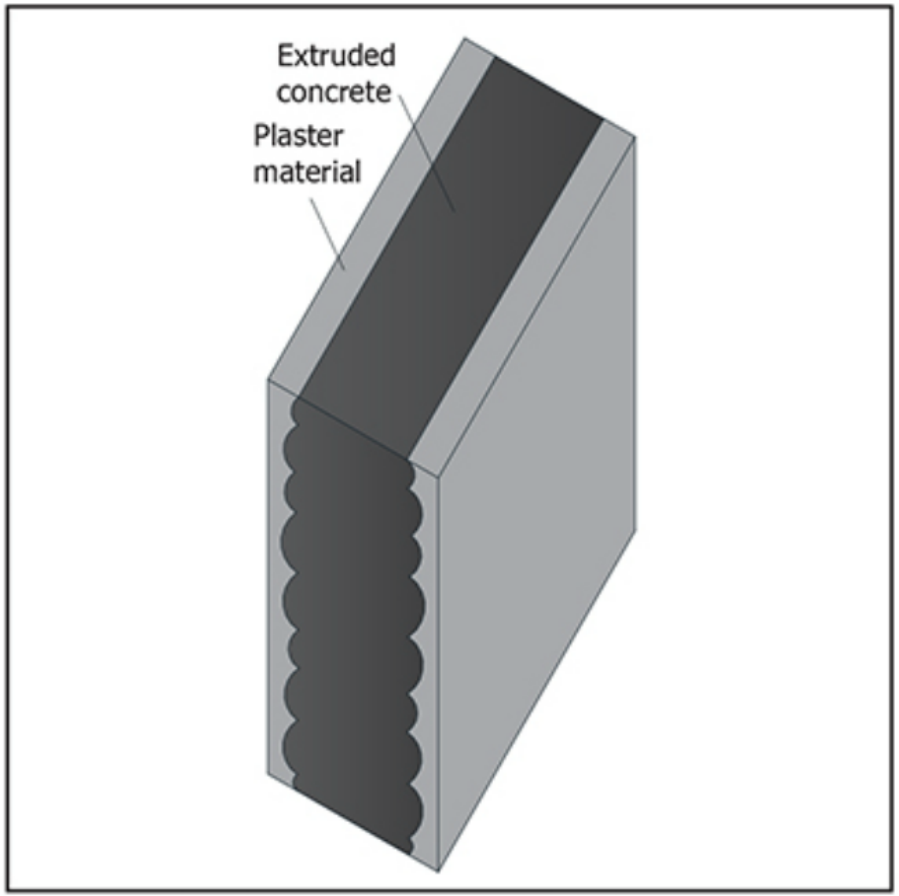
Implement


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



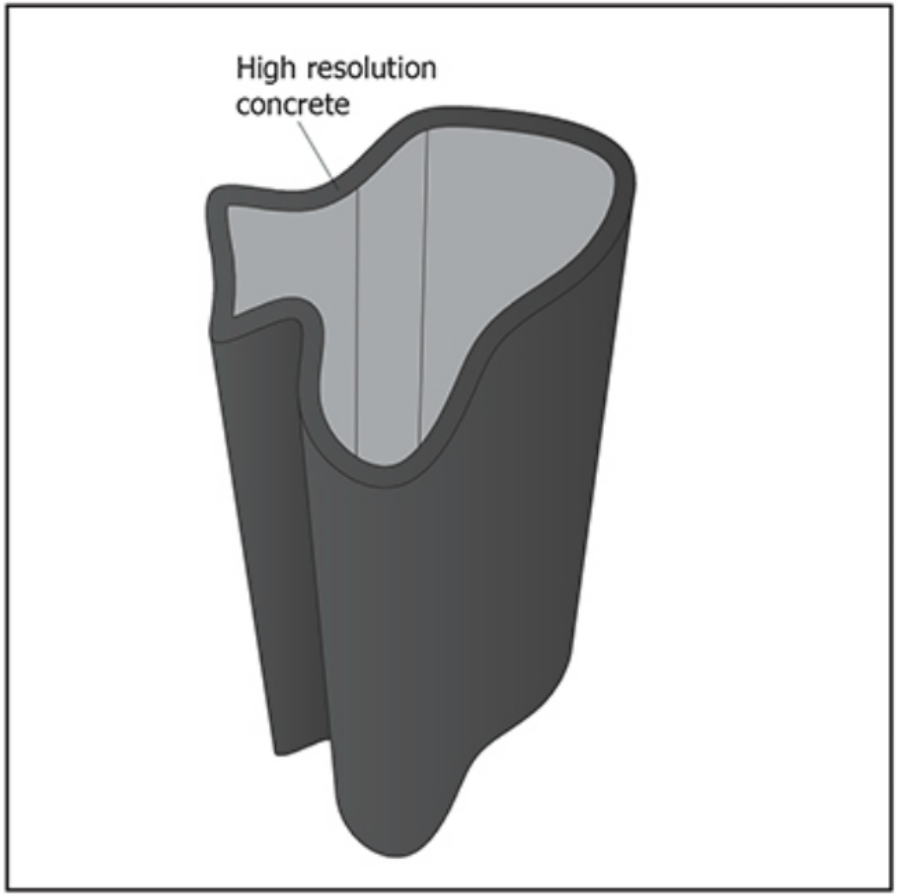
Gradient material

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



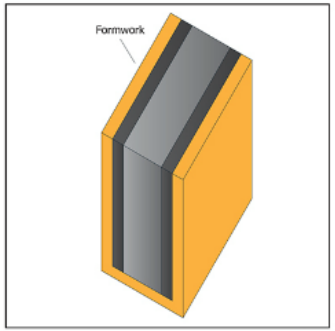
Core parts

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



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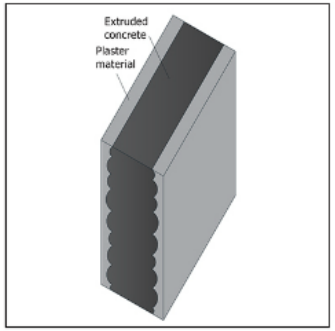

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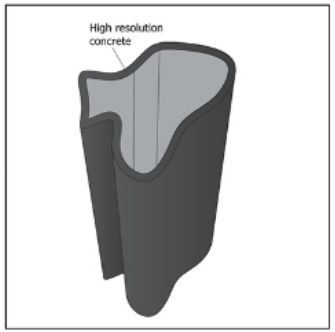


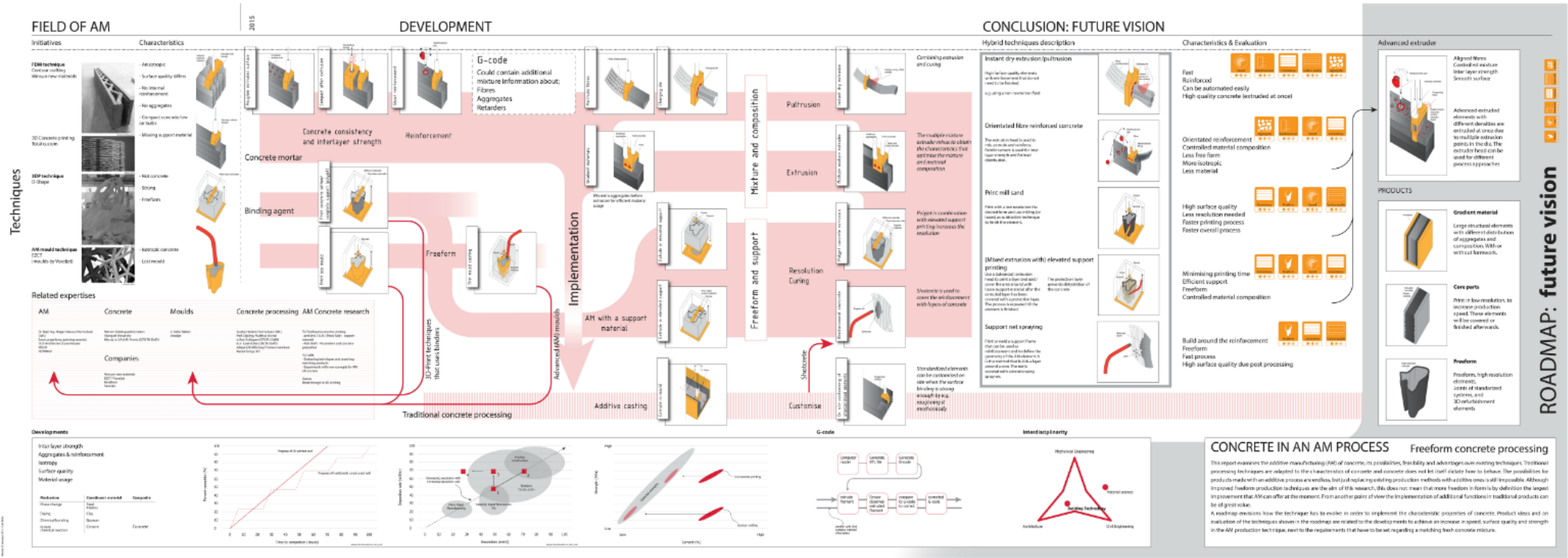
Freeform

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

ROADMAP: **future vis**

Threats

Add value



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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 feasilbility of the future visions
Keep observing the competition to keep ahead of them
Publish results

Questions?

CONCRETE in an AM process

Freeform concrete processing