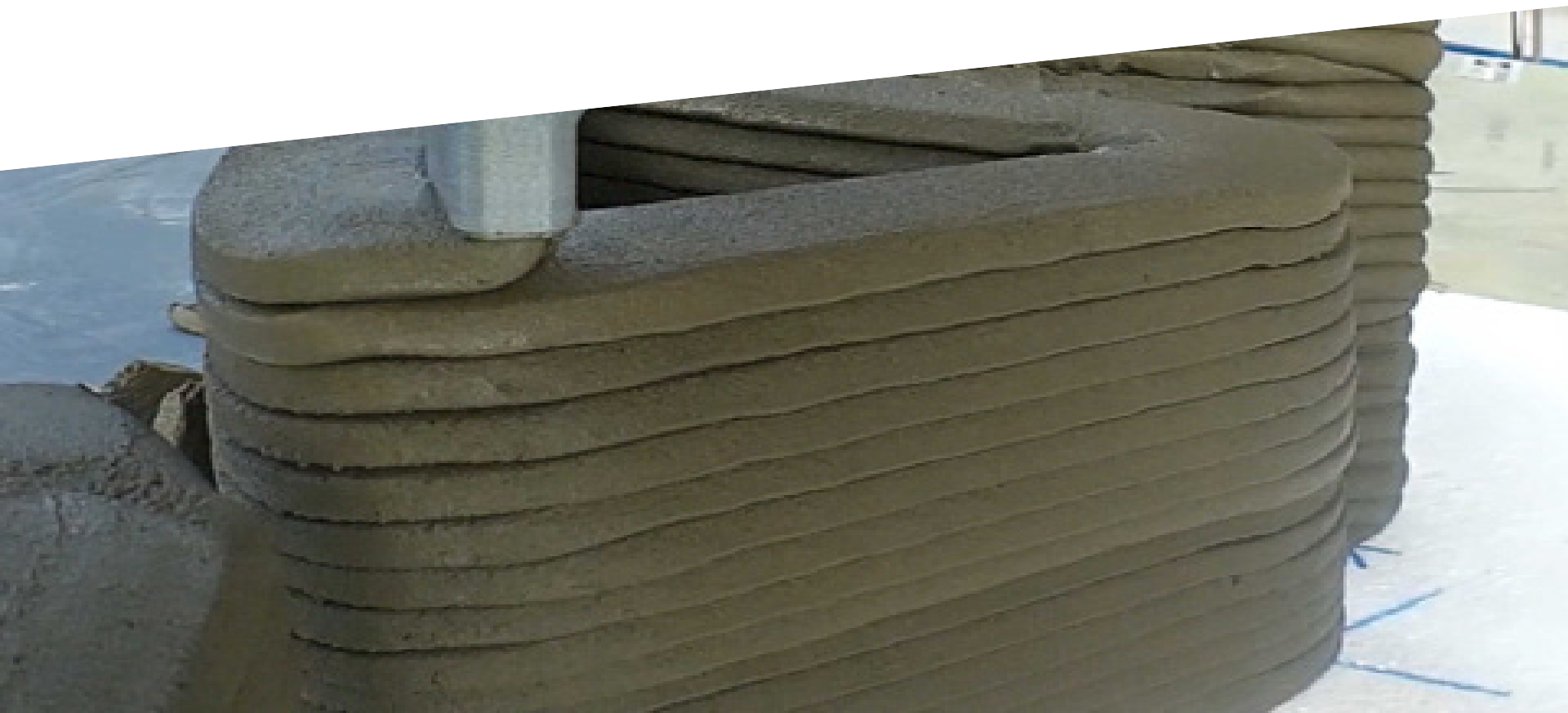




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# 3D Concrete Printing - Technological issues in concrete mix design and extrusion

Technical visit to the National Institute of Standards and Technology (NIST)  
July 12th, 2017



# 3D Concrete Printing

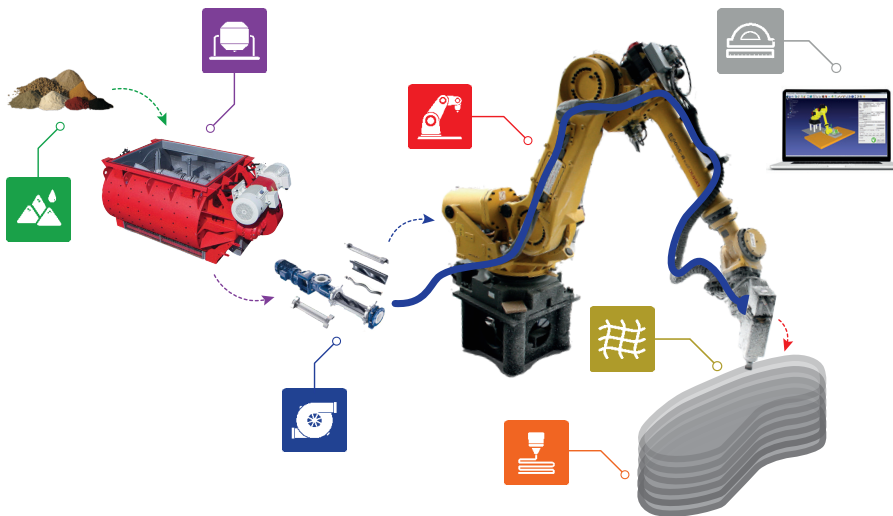


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**3D Concrete Printing** refers to the process used to synthesize a 3D model in successive layers of material to create an object, e.g. a concrete wall

Robot-based 3D Printing Process:



**MATERIALS**



**CONCRETE MIXER**



**CONCRETE PUMP**



**ROBOT CONTROL**



**CONCRETE EXTRUSION**



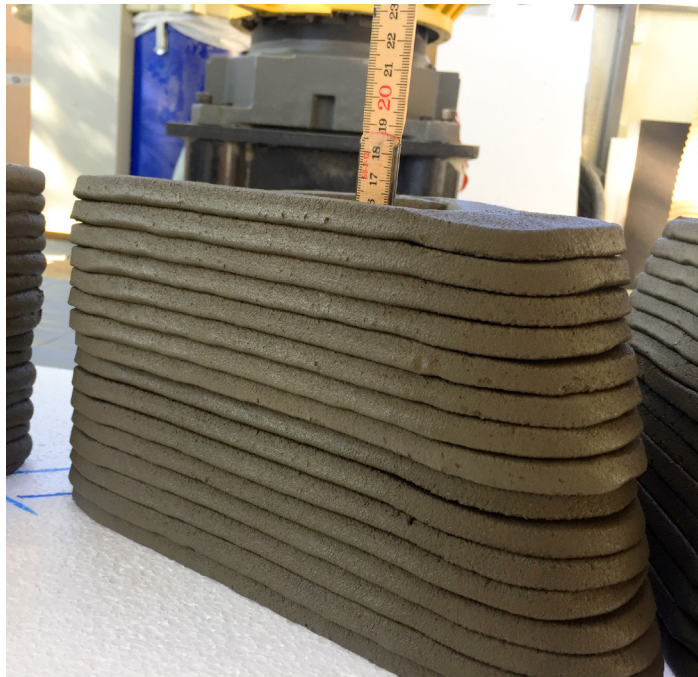
**REINFORCEMENT**



**DESIGN**

## Fresh concrete is the filament:

- Similar materials to that of concrete
- Max. particle size (1 to 4mm)
- Concrete admixtures

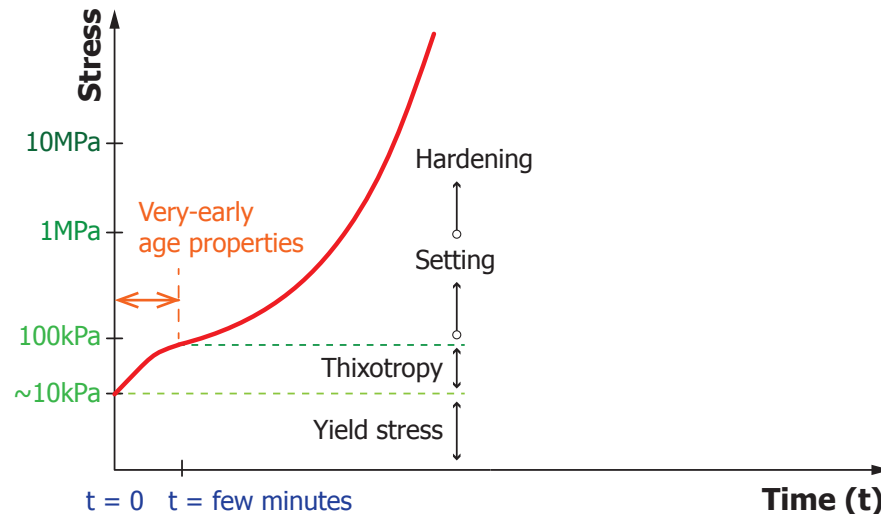


## Material challenges:

- Pumpability vs. Buildability
- Concrete rheology (fresh state)



## Concrete properties and mix design

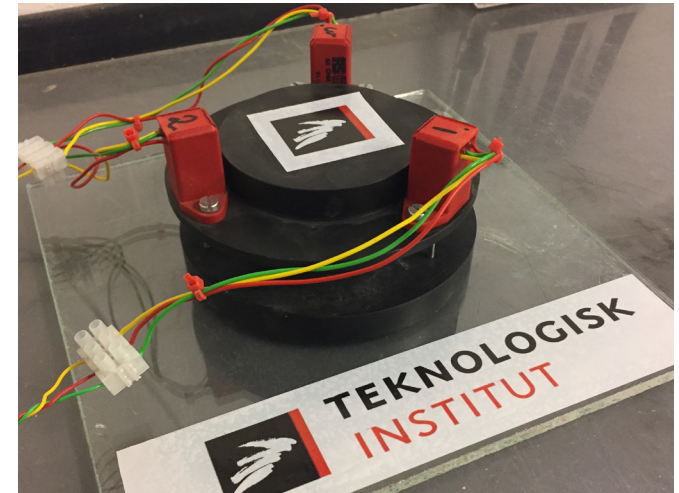


- Cement hydration and cement types
- Concrete admixtures (retarders and accelerators)
- Strength development and drying shrinkage

### Current challenges being addressed:

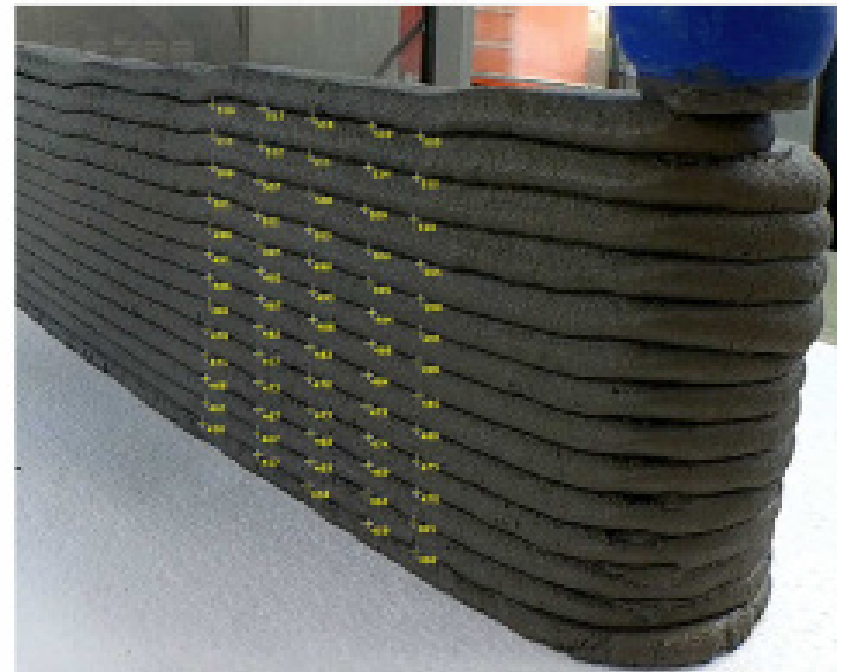
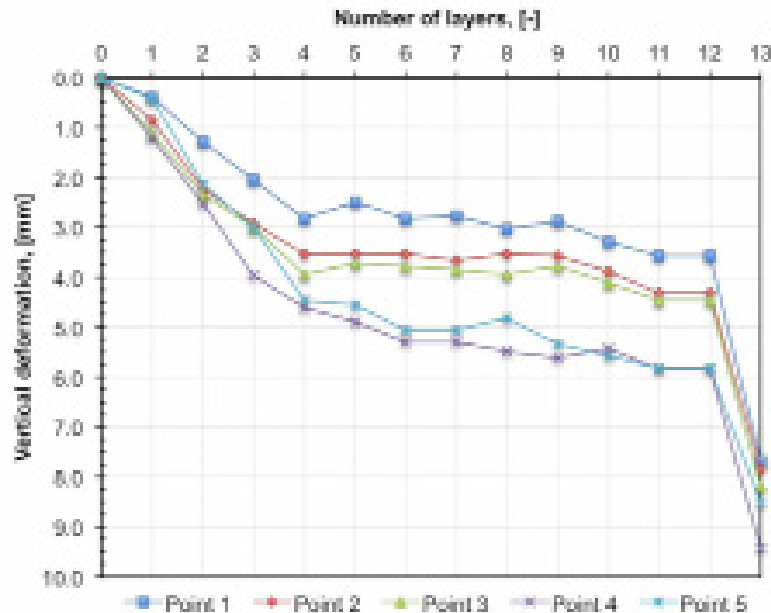
- mix design that enables to balance concrete pumpability and buildability
- expected product performance is affected by the process, thus online monitoring is a necessary

DTI's Test device (layer deformation)



## Buildability of fresh concrete (test without accelerators)

Printing parameters - layer height: 10mm, layer width: 40mm, variable print speed





# CONCRETE MIXER



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## Batch process:

- **Concrete composition is constant**
- *Fresh-state properties* can be adjusted by adding admixtures while printing



Mixing plant at DTI's Concrete Centre

## Continuous mixing:

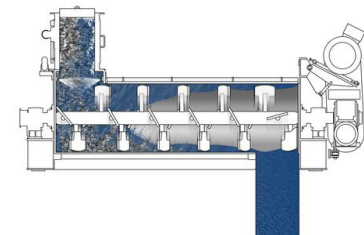
- **Concrete composition is adjustable**
- *Fresh and hardened-state properties* can be adjusted while printing



Source: MTec



Source: MTec



Source: BMH Systems

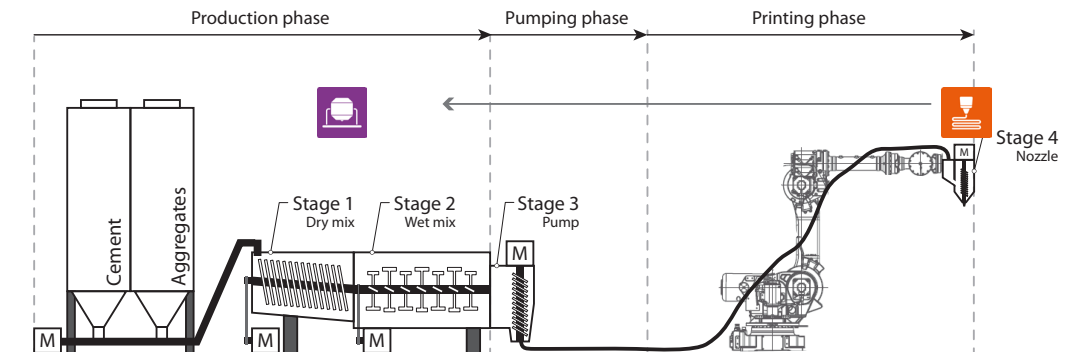
# CONCRETE MIXER



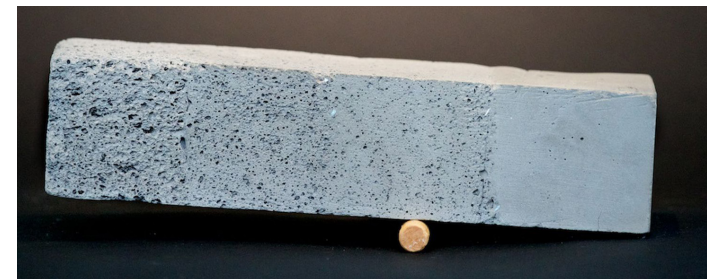
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## Feedback system in a continuous mixing production process:

- Increase robustness of the production process
- Enable the production of functionally-graded concrete elements



Functionally-graded concrete sample



Source: MIT

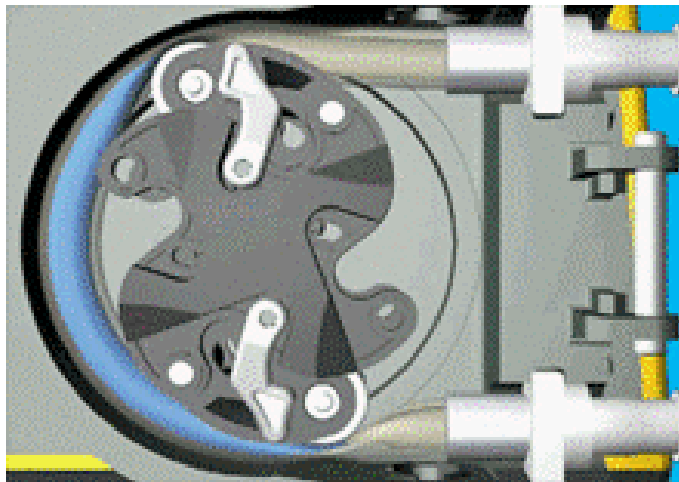
# CONCRETE PUMP



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## Peristaltic concrete pump:

- Pulsating extrusion
- Poor controllability
- Large equipment for initial tests



## Progressive cavity pump:

- Controlled extrusion (rotor-stator)
- Suitable for high-viscosity materials



Source: PCM



# CONCRETE PUMP



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## Progressive cavity pump

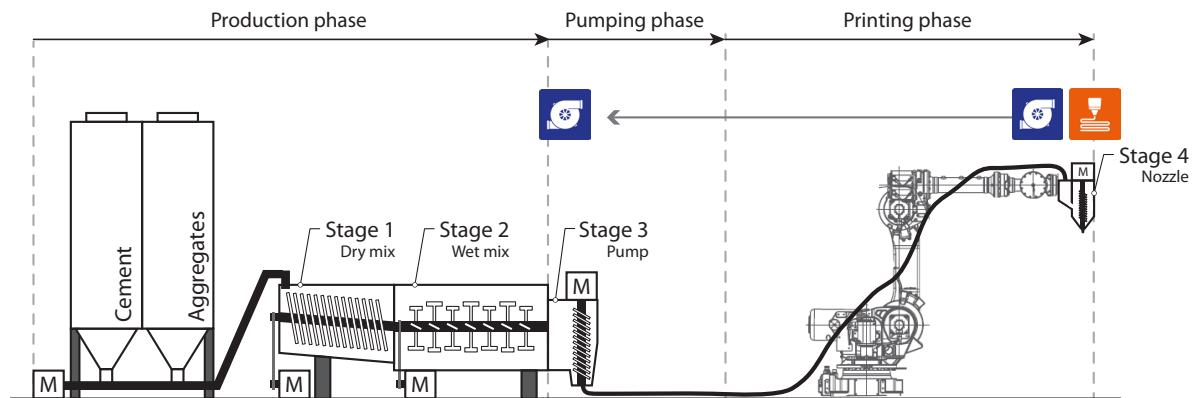
3D Printed prototype



DTI's progressive cavity pump



**Current challenge:** Increase controllability and reliability of the printing process





# CONCRETE EXTRUSION



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## Passive robot nozzle:

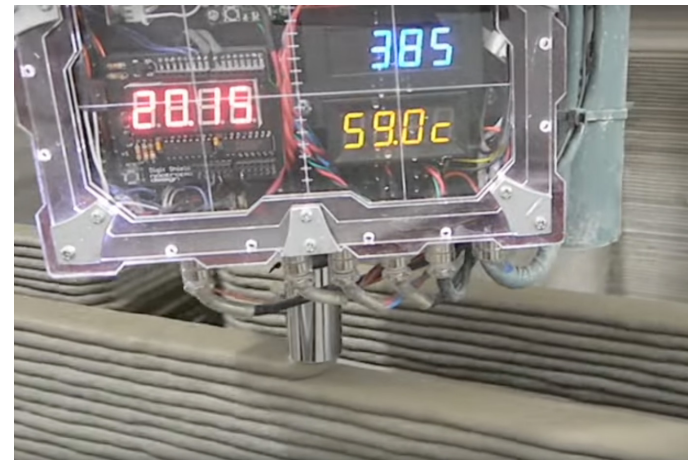
The extrusion is controlled by a pump and the robot nozzle works as a dispenser that defines the shape of the printed layers.



## Active robot nozzle:

The extrusion is controlled at the nozzle by a pump, enabling great precision and addition of admixtures during extrusion.

Source: Total Kustom

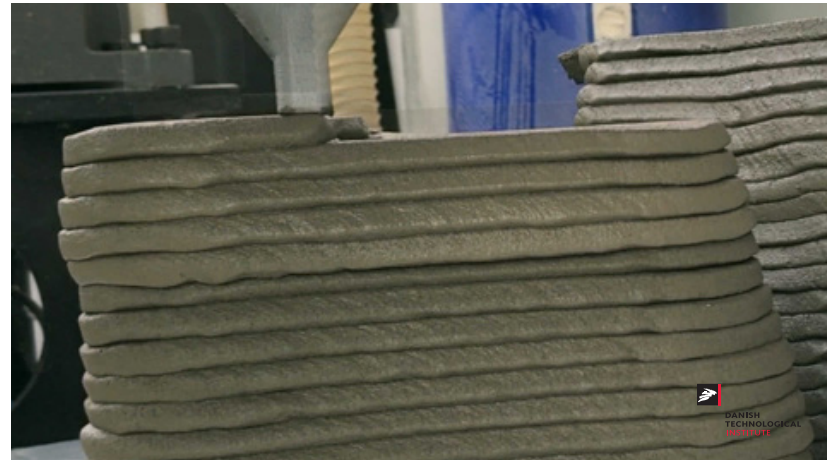


# CONCRETE EXTRUSION



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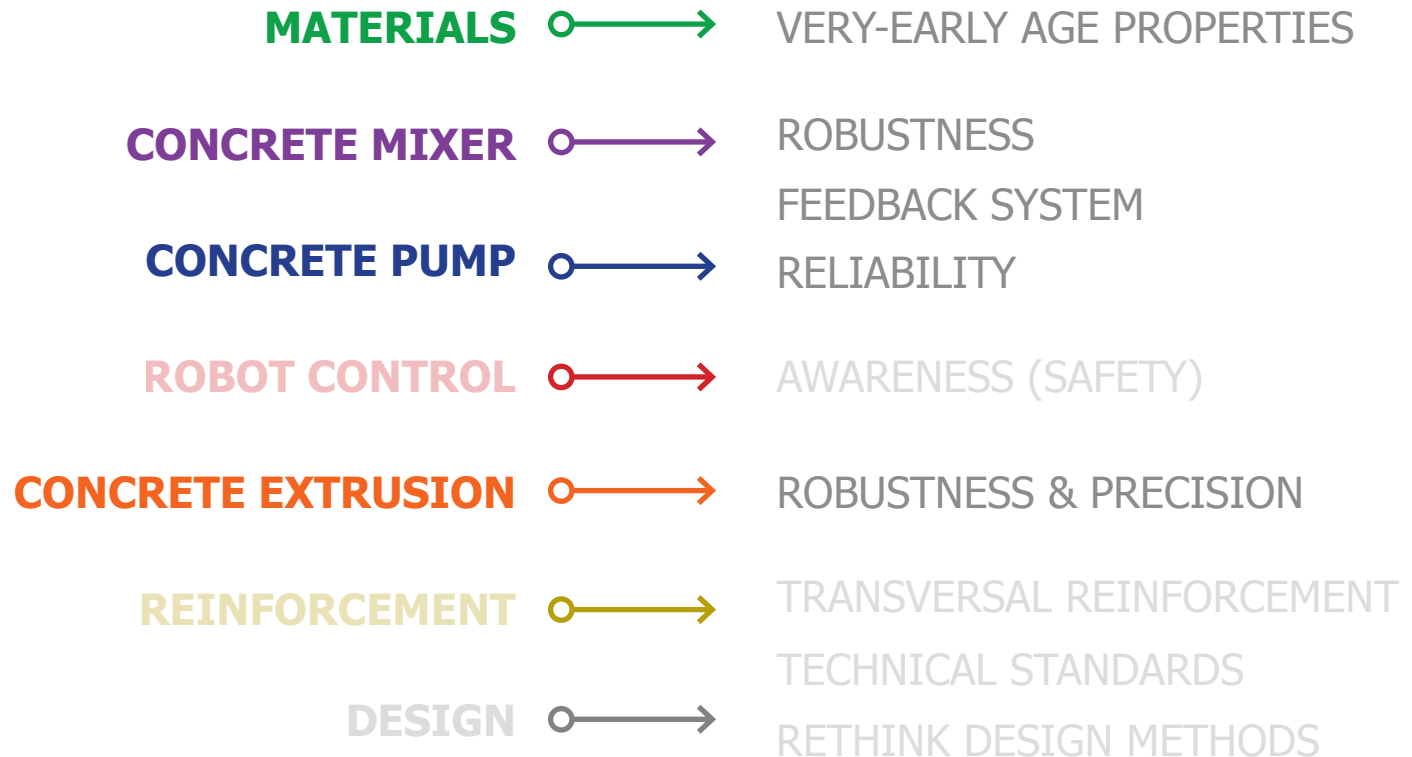
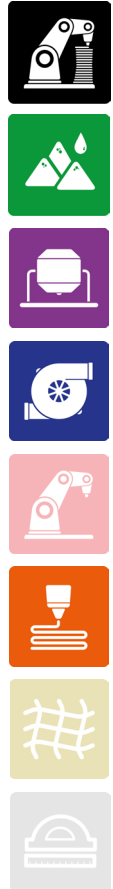
## Nozzle experiments (3D Printed Nozzles)




# 3D Concrete Printing



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**3D CONCRETE PRINTING** → **INTERDISCIPLINARITY**



Thank you for your attention!

**Reference to this presentation:**

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