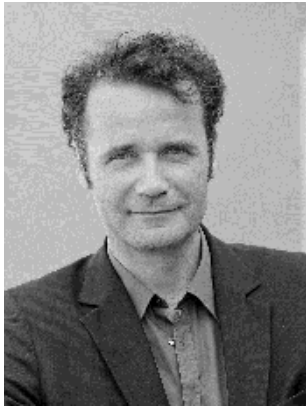


# Selective Paste Intrusion

Targeted adjustment of workability and setting behavior of cement paste

Alexander Straßer | TUM, Chair of Materials Science and Testing | 10<sup>th</sup> March 2021

# Team Additive Manufacturing at the Chair of Materials Science and Testing



Prof. Dr.-Ing.  
C. Gehlen



Dr.-Ing. Thomas  
Kränkel



Carla Matthäus,  
M.Sc.

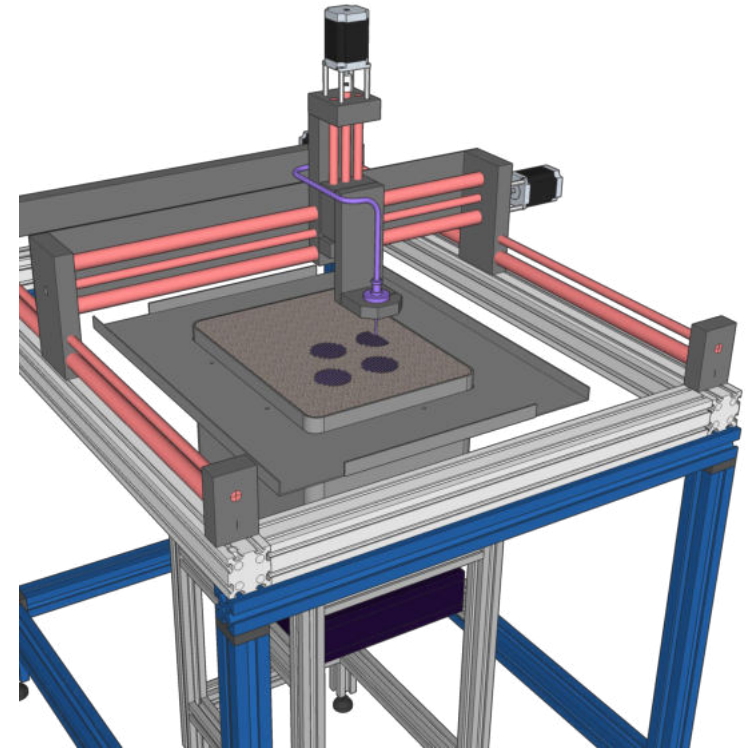
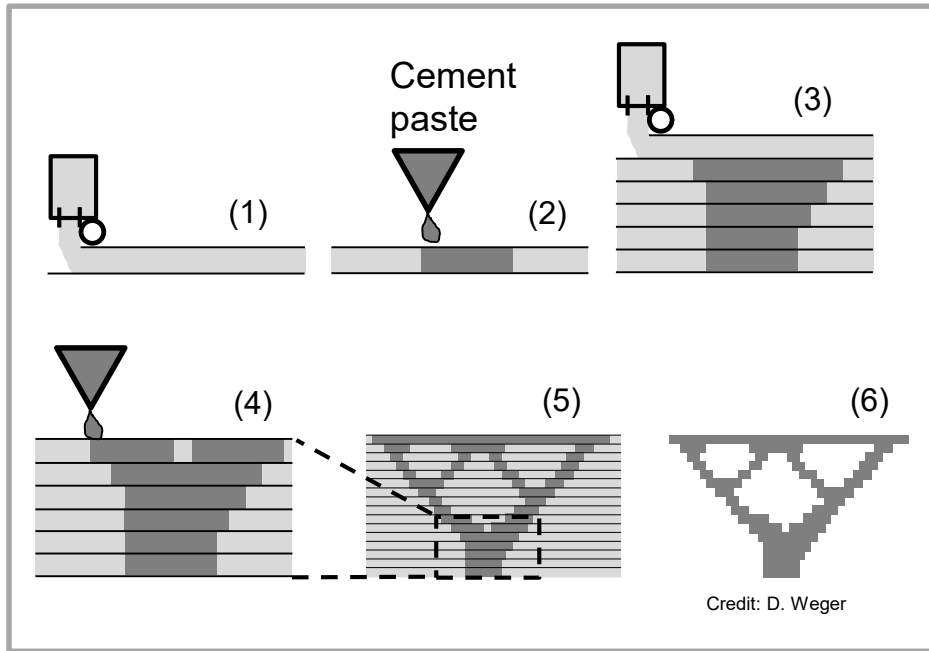


Maximilian Hechtel,  
M.Sc.



Alexander Straßer,  
M.Sc.

# Concept Selective Paste Intrusion



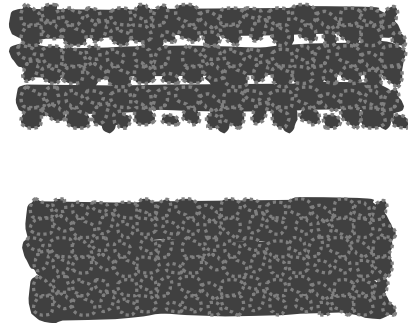
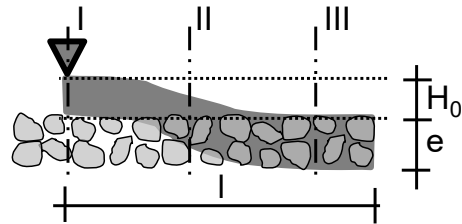
Credit: D. Talke



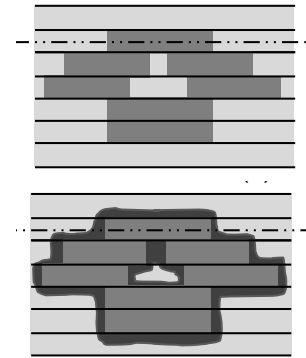
# Selective Paste Intrusion provides freedom in form



# Workability and intrusion depth of the cement paste



Optimum between layer bond and shape accuracy has to be found



# Requirements on the rheological behavior of cement paste

## Requirements

### SHORT SUMMARY

- Cement paste is applied on a layer of aggregates
  - Cement paste has to percolate by itself to bond the aggregates
  - Too high flowability (workability) harms the contour accuracy
- Need of **workability** and an **adjusted intrusion depth** of the cement paste during the print-process for an optimal print-quality

# Challenge and optimization

## **long-lasting workability and fast setting**

BY ADDITIVES

- Better and consistent print-quality during the print-process
- Faster excavation after the print-process (higher economic efficiency)

→ Conflict between high workability and fast setting





# Adjustment of the rheological behavior of the cement paste

## Additives

LONG WORKABILITY AND SHORT SETTING

 Superplasticizer (SP) → ensure workability

 Consistency retaining admixture (CR) → Improvement of workability

 Accelerator → fast setting

- Sodium Aluminate (SA)
- Calcium Nitrate (CN)
- CSH-crystal-seeds (CS)

# Measurement of workability

## mini-slump flow HAEGERMANN-CONE



Credit: Alexander Straßer

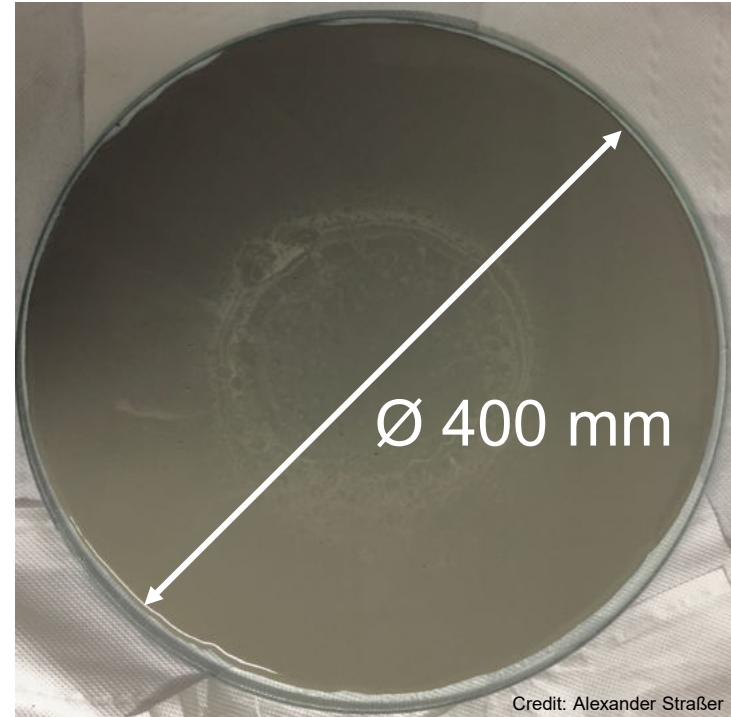
# Measurement of workability

## mini-slump flow

HAEGERMANN-CONE

→ Good compromise between layer bond and contour accuracy:

**400 mm** mini-slump flow



# Measurement of setting

## Needle penetration

VICAT-NEEDL-DEVICE

- Define a reference
- Comparison and validation



Credit: Form + Test

# Referencing cement paste

## Ingredients

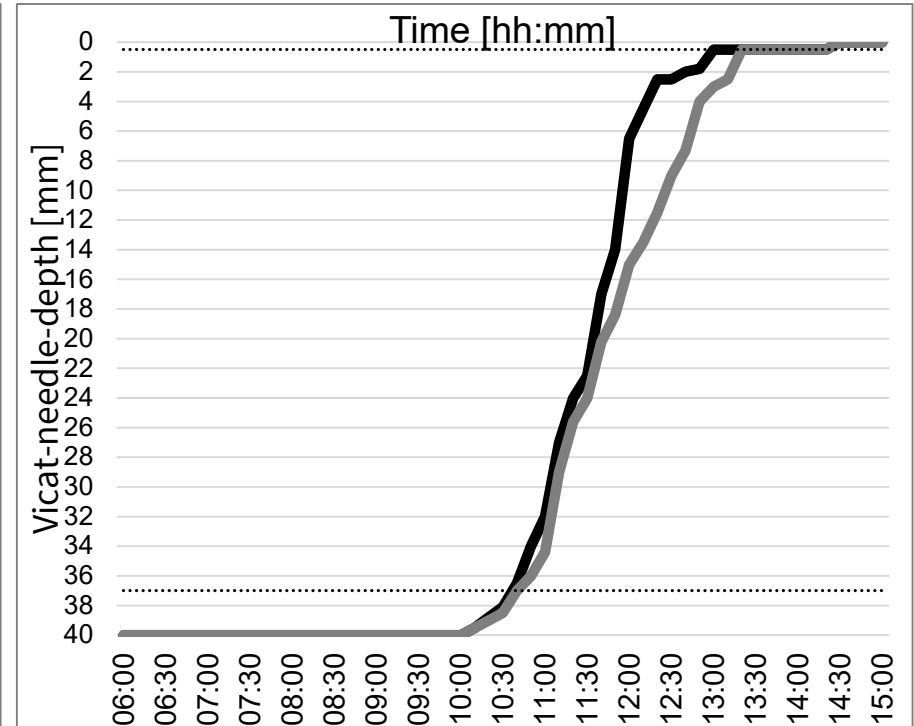
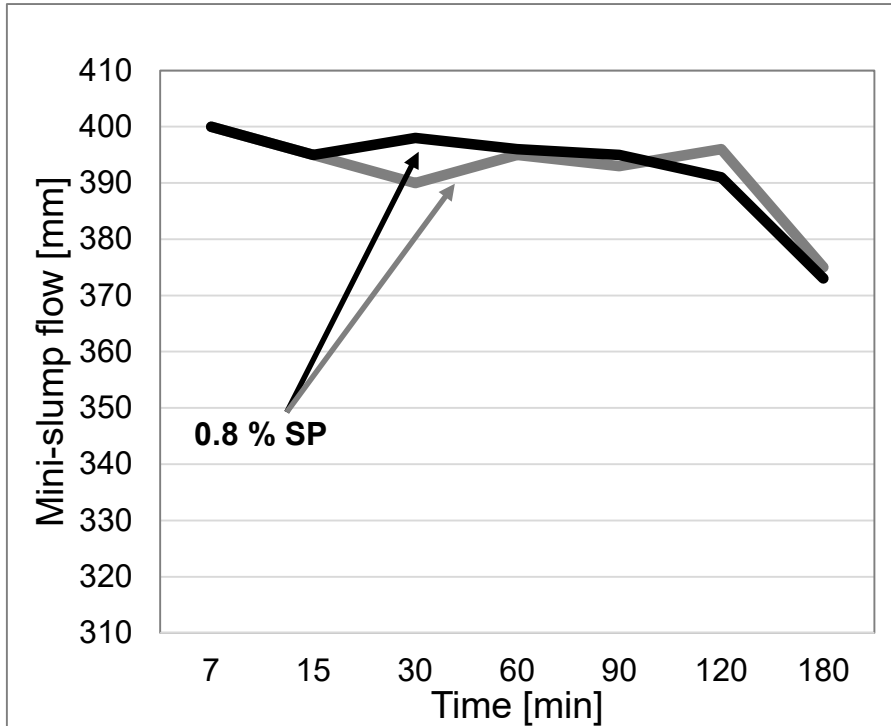
CEMENT, WATER AND PCE-SUPERPLASTICIZER

- OPC (42.5 R)
- w/c - ratio 0.3
- 0.8 % SP (depend on cement weight)



Credit: Alexander Straßer

# Referencing cement paste: results

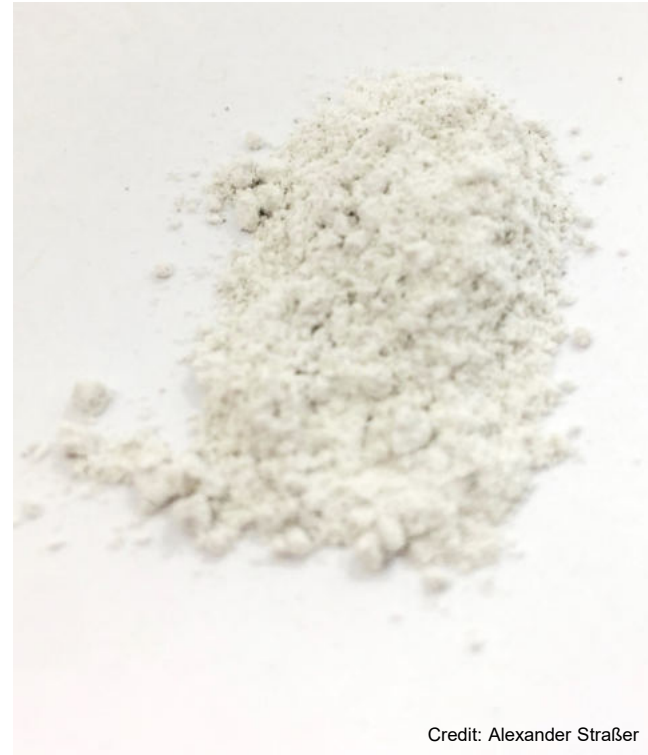


# Variation 1

## Optimization of setting

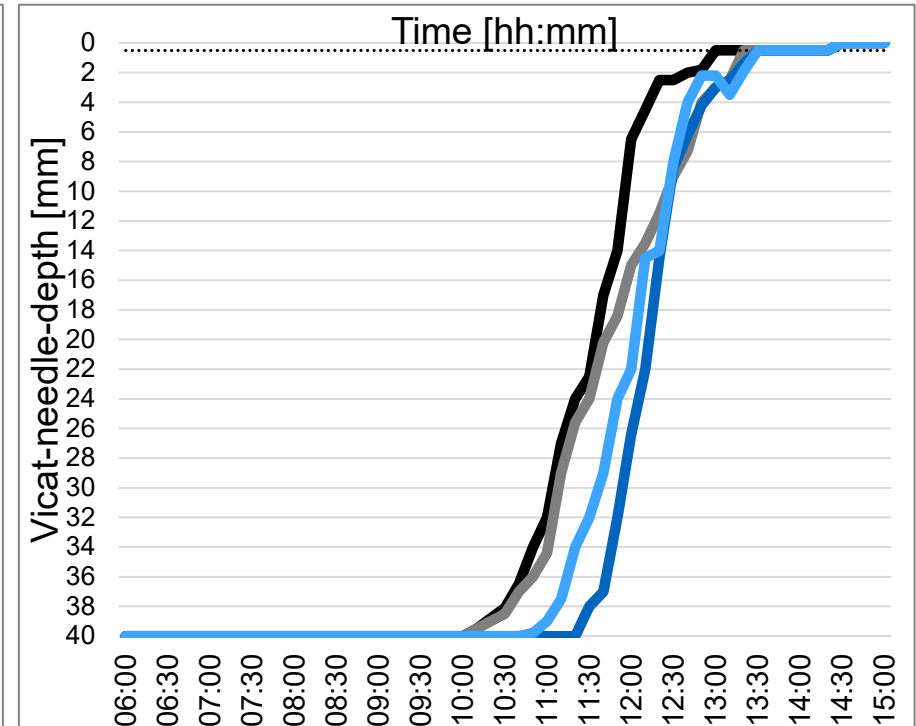
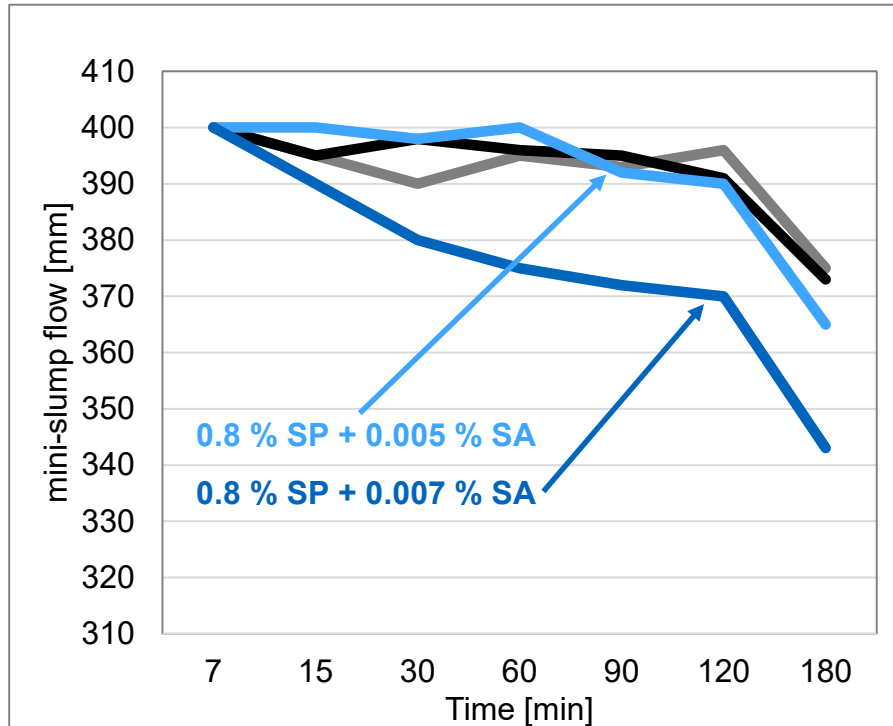
SODIUM ALLUMINATE

- Referencing cement paste as base
- Addition of SA
- Variation of SA-dosage



Credit: Alexander Straßer

# Variation 1: results





## Variation 2

### Optimization of setting

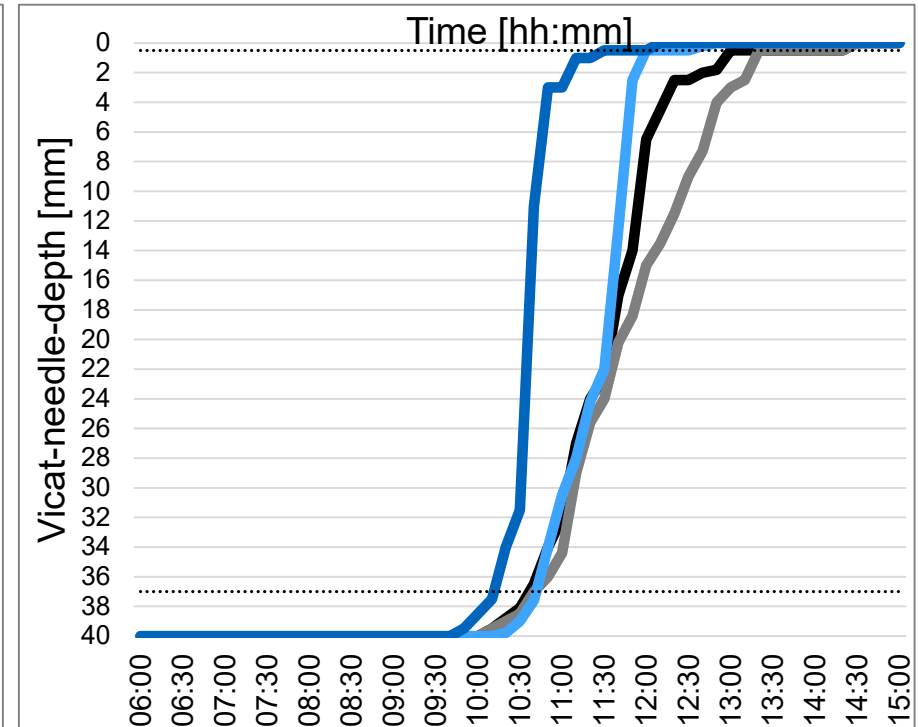
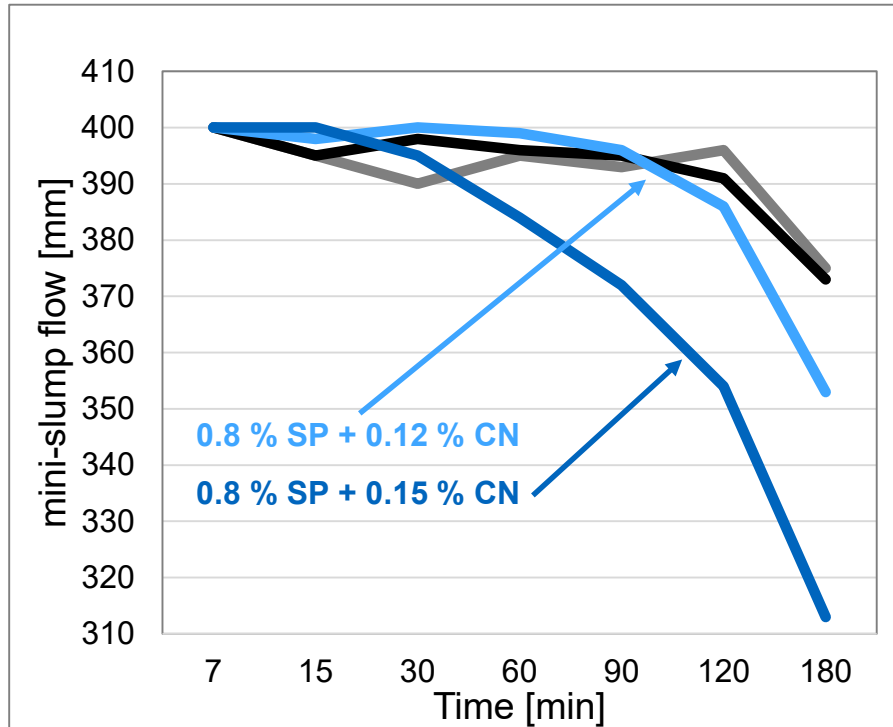
CALCIUM NITRATE

- Referencing cement paste as base
- Addition of CN
- Variation of CN-dosage



Credit: Alexander Straßer

## Variation 2: results

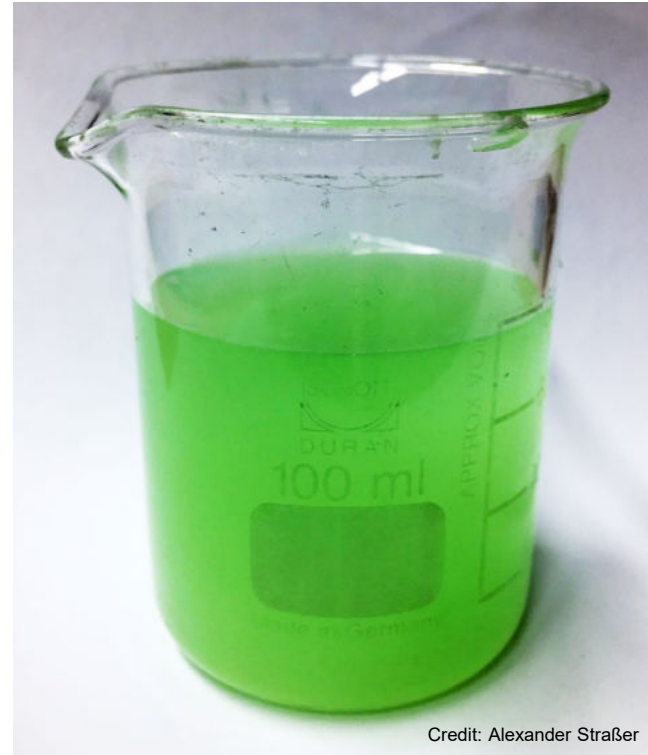


## Variation 3

### Optimization of workability

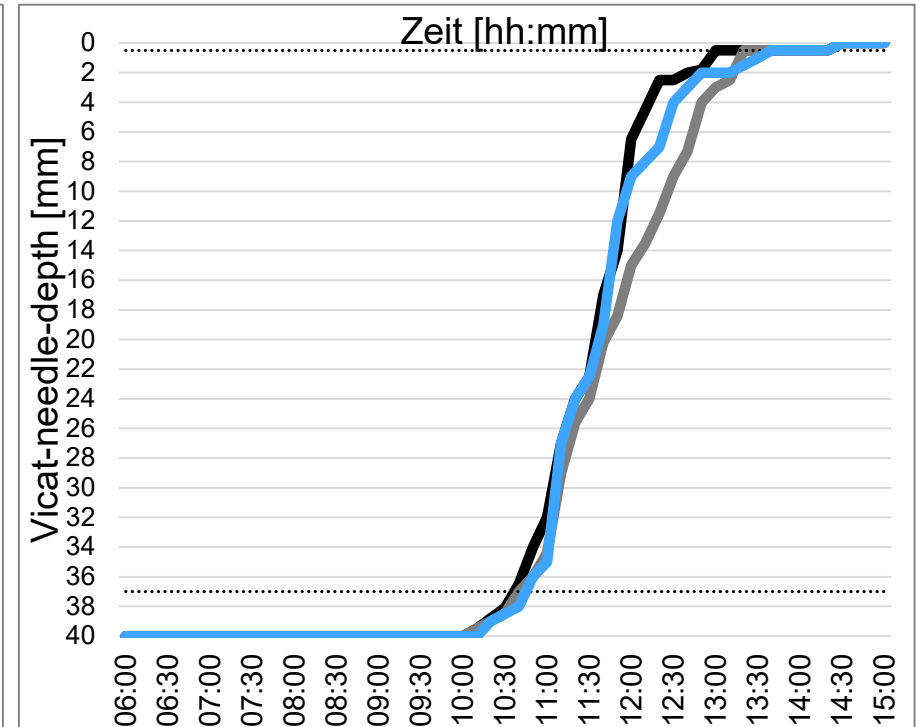
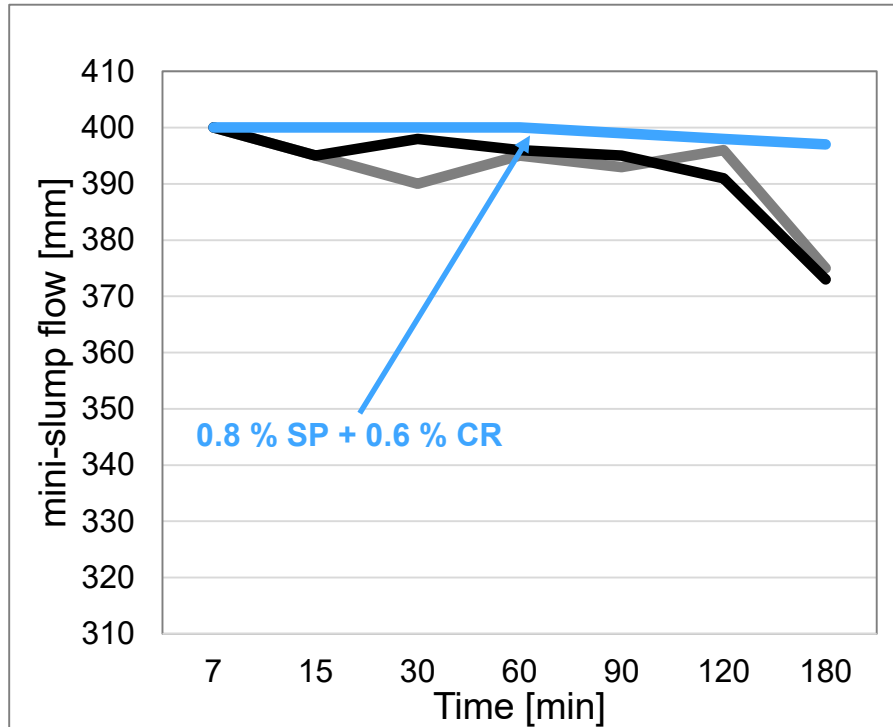
CONSISTENCY RETAINING ADMIXTURE (PCE)

- Referencing cement paste as base
- Addition of CR
- Variation of CR-dosage



Credit: Alexander Straßer

# Variation 3: results



## Variation 4

### Optimization of setting

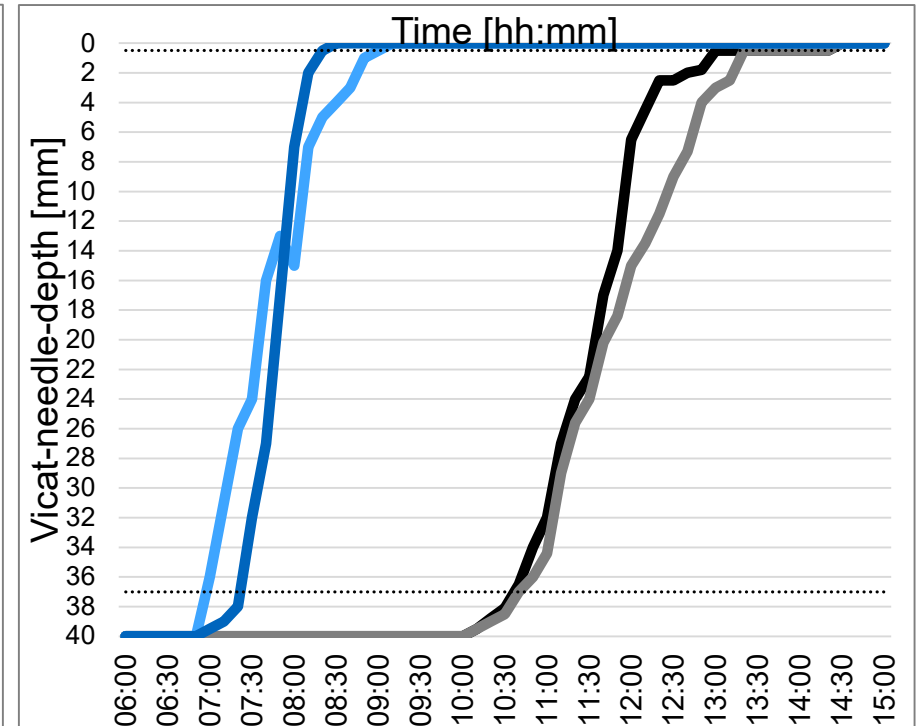
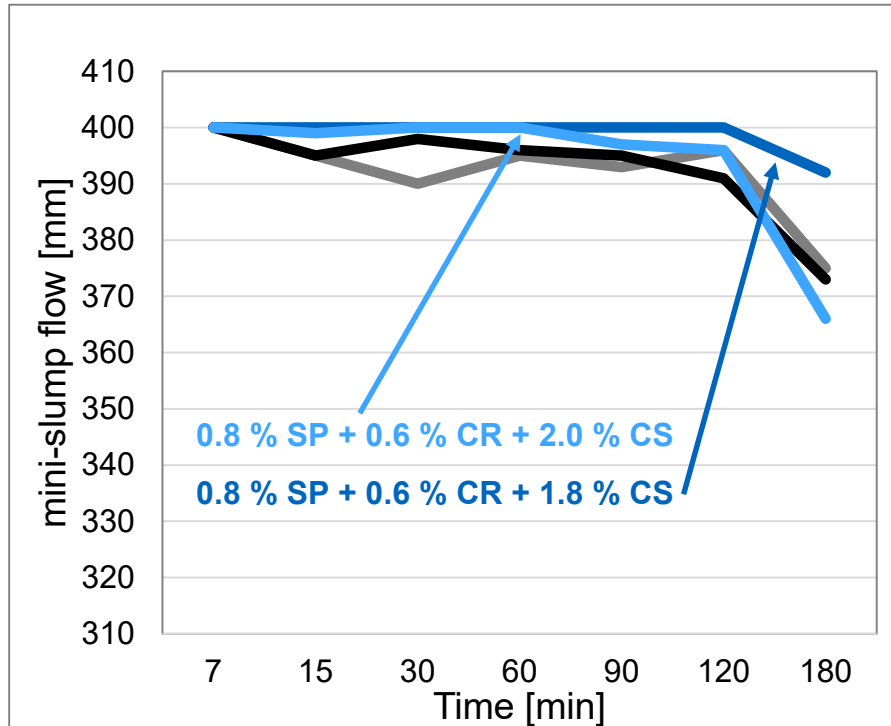
CSH-CRYSTAL-SEEDS

- Optimized cement paste (**Variation 3**) as base
- Addition of CSH-crystal-seeds
- Variation of CSH-dosage



Credit: Alexander Straßer

## Variation 4: results



## Variation 5

### Optimization of setting

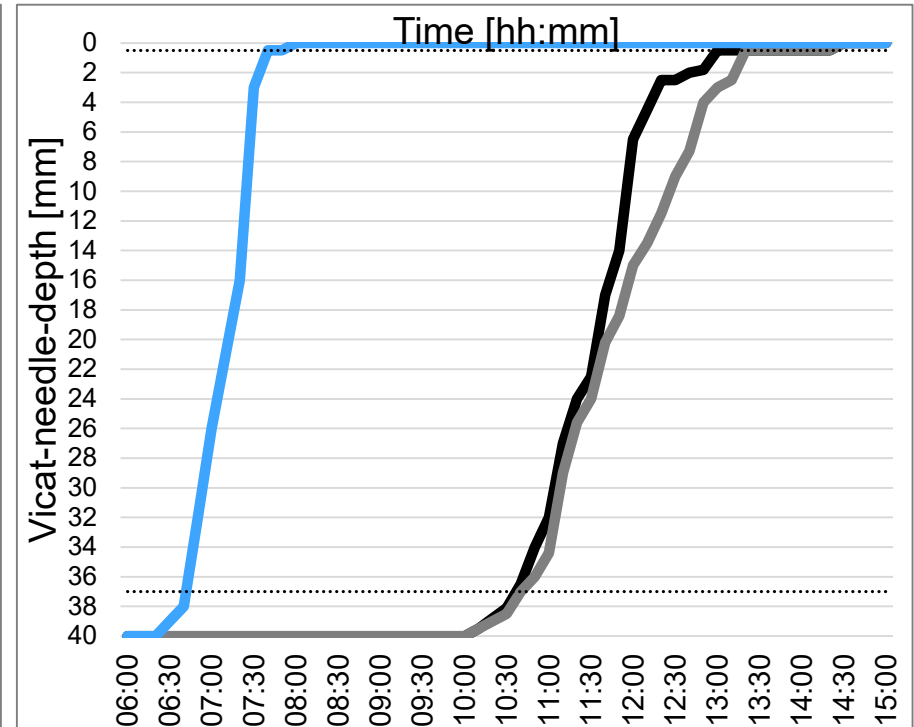
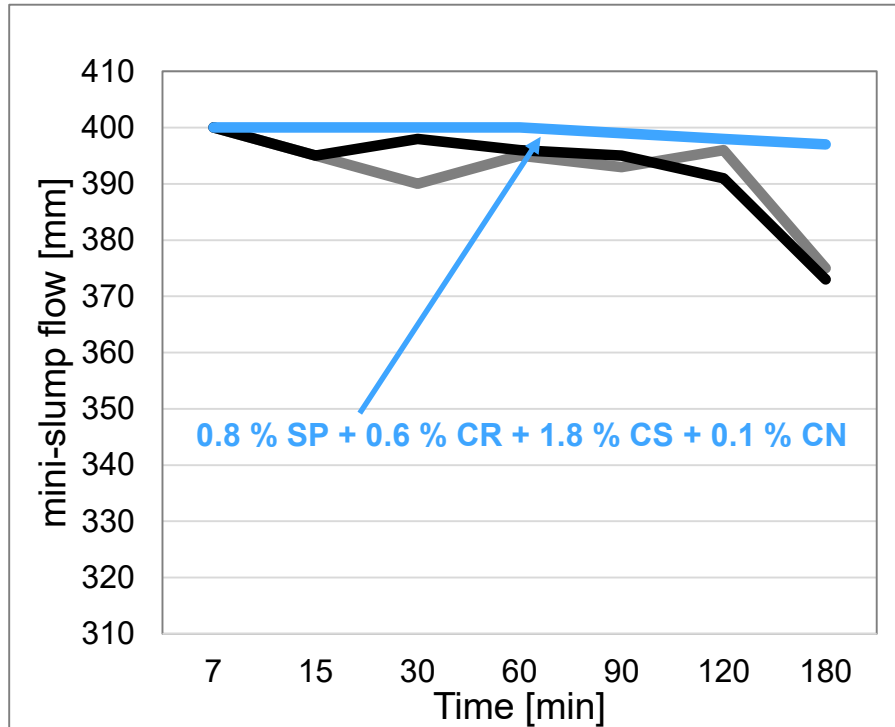
CALCIUM NITRATE...again

- Optimized cement paste (**Variation 4**) as base
- Addition of CN
- Variation of CN-dosage



Credit: Alexander Straßer

# Variation 5: results





# Conclusion

- Superplasticizer is **essential** to ensure workability
- The consistency retaining admixture can be used to **improve the workability** and printing time (up to 180 min)
- With Sodium Aluminate, the **opposite** of the wanted optimization was captured
- CSH-crystal-seed effects to an **earlier initial setting**
- Using Calcium Nitrate leads to a **faster setting time** with a similar initial setting

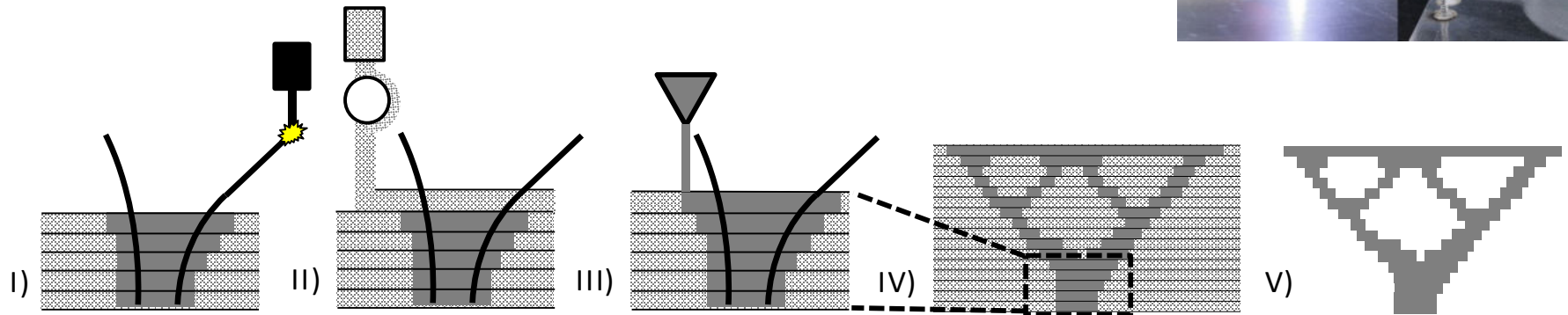
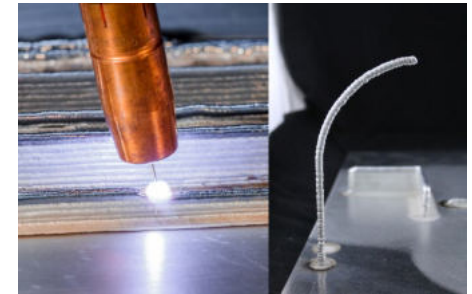
→ By a combination of SP, CR, CS, and CN we...

... measured an earlier final setting (up to 40 % earlier compared to the reference)

... measured constant workability over 180 minutes

# Outlook

## Integration of reinforcement by WAAM



Credit: D. Weger

*Research project in TRR 277: Particle-Bed 3D Printing by Selective Cement Paste Intrusion (SPI) – Particle Surface Functionalisation, Particle Synthesis and Integration of WAAM Reinforcement by TUM, cbm ; TUM, iw; TUBS, iPAT*

# Selective Paste Intrusion

Alexander Straßer | TUM, cbm | [alexander.strasser@tum.de](mailto:alexander.strasser@tum.de)