

EARLY-AGE STRENGTH DEVELOPMENT OF SILICA-GEL BONDED REFRACTORY CASTABLES: EFFECT OF HYBRID BONDING

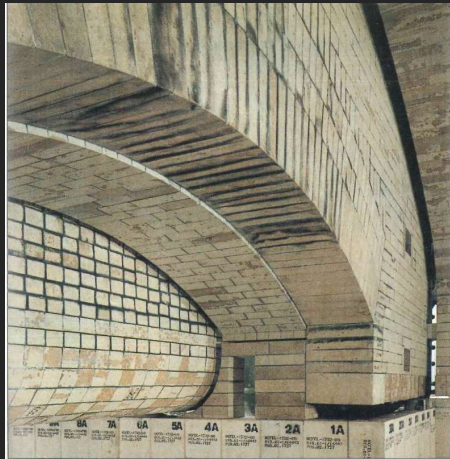
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3D printing for refractory castables:
a risky path or a pioneering step?

Context of the study

Traditional shaping
process



Vaulted crown of
glass furnace

Assembly bricks by
bricks



Intensive labour
Time-consuming and
costly process

Innovative shaping
process



► Context of the study

Current step

Cement–bonded printable refractory ink



Objective

Cement **free**–bonded printable refractory ink

Colloidal silica (CS)
vs
Micro-silica (MS)

Need

Understanding of the early-age strength development

- ✓ Improved drying performance
- ✓ Lower environment impact

- ✓ Stiffness for buildability
- ✓ No mechanical strength for pumpability and extrusion



Approach of the study

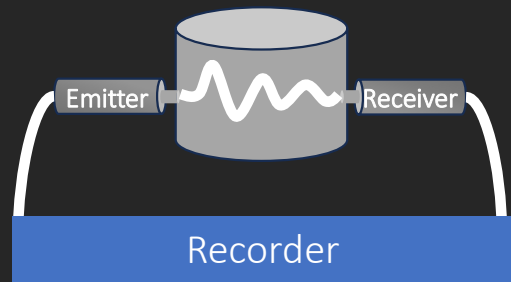
Comparative study of the evolution
over the time of the stiffness and
strength development

Raw material	REF-CAC	MS-OCAC	MS-0,25CAC	MS-0,5CAC	CS-OCAC	CS-0,5CAC
Tabular & reactive alumina	95	97	96,75	96,5	97	96,5
CAC (SECAR 71)	5,00	0,00	0,25	0,50	0,00	0,50
	—	3,00	3,00	3,00	—	—
	—	—	—	—	3,00	3,00

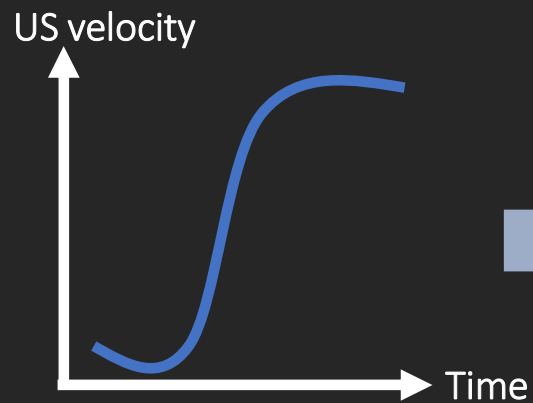
Methodology

Determination of the stiffness and strength development over time

Stiffness development
(US velocity technique)

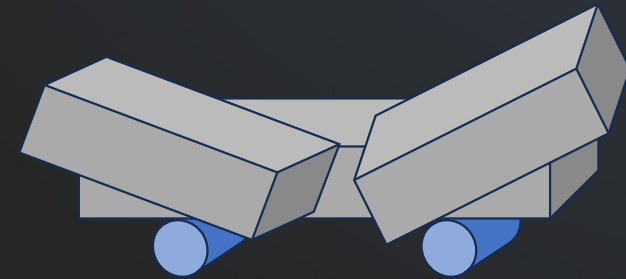


$$\text{US Velocity} \propto \sqrt{E}$$



Stiffness
indicator

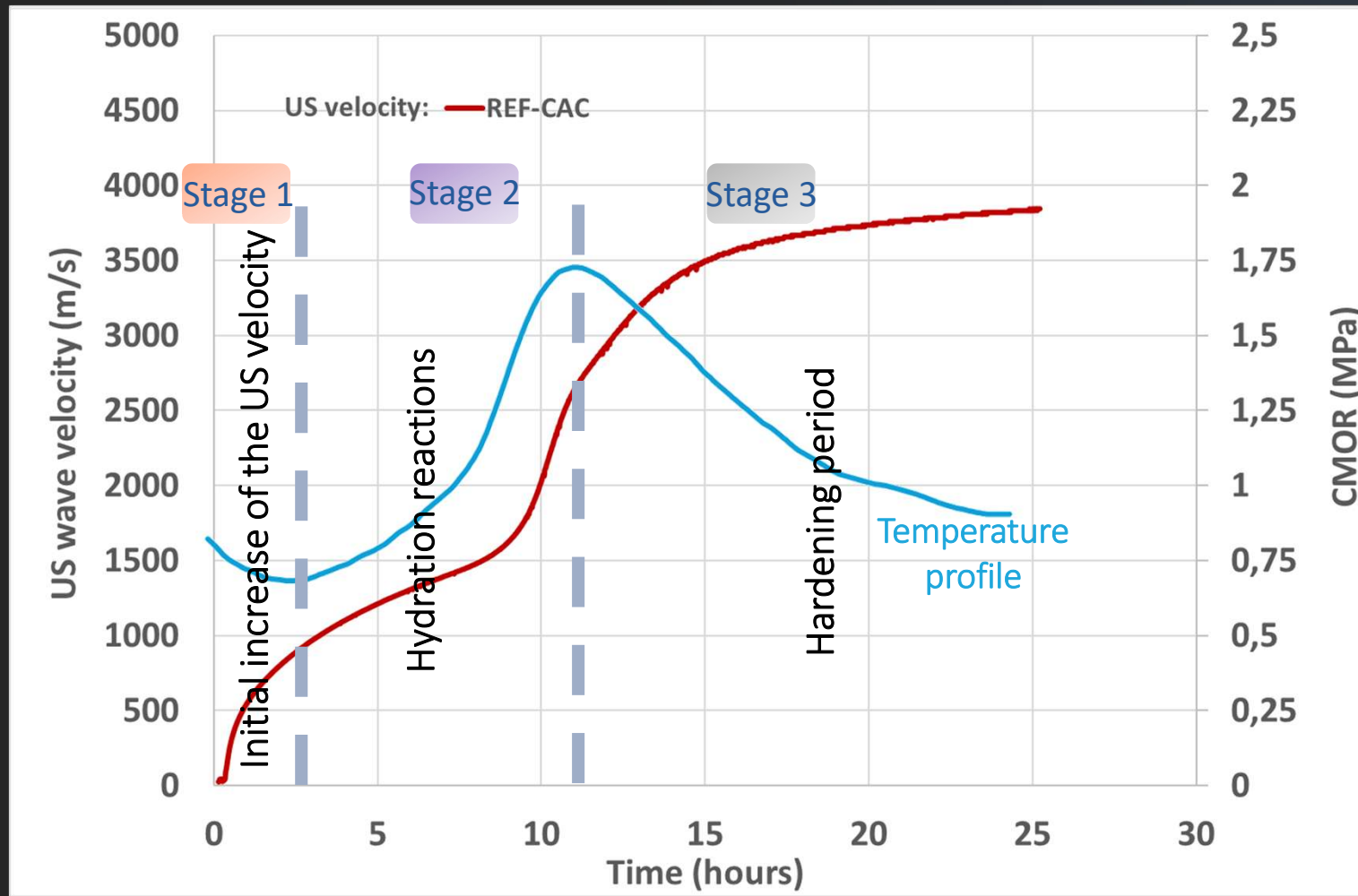
Strength development
(3 points bending test)



CMOR

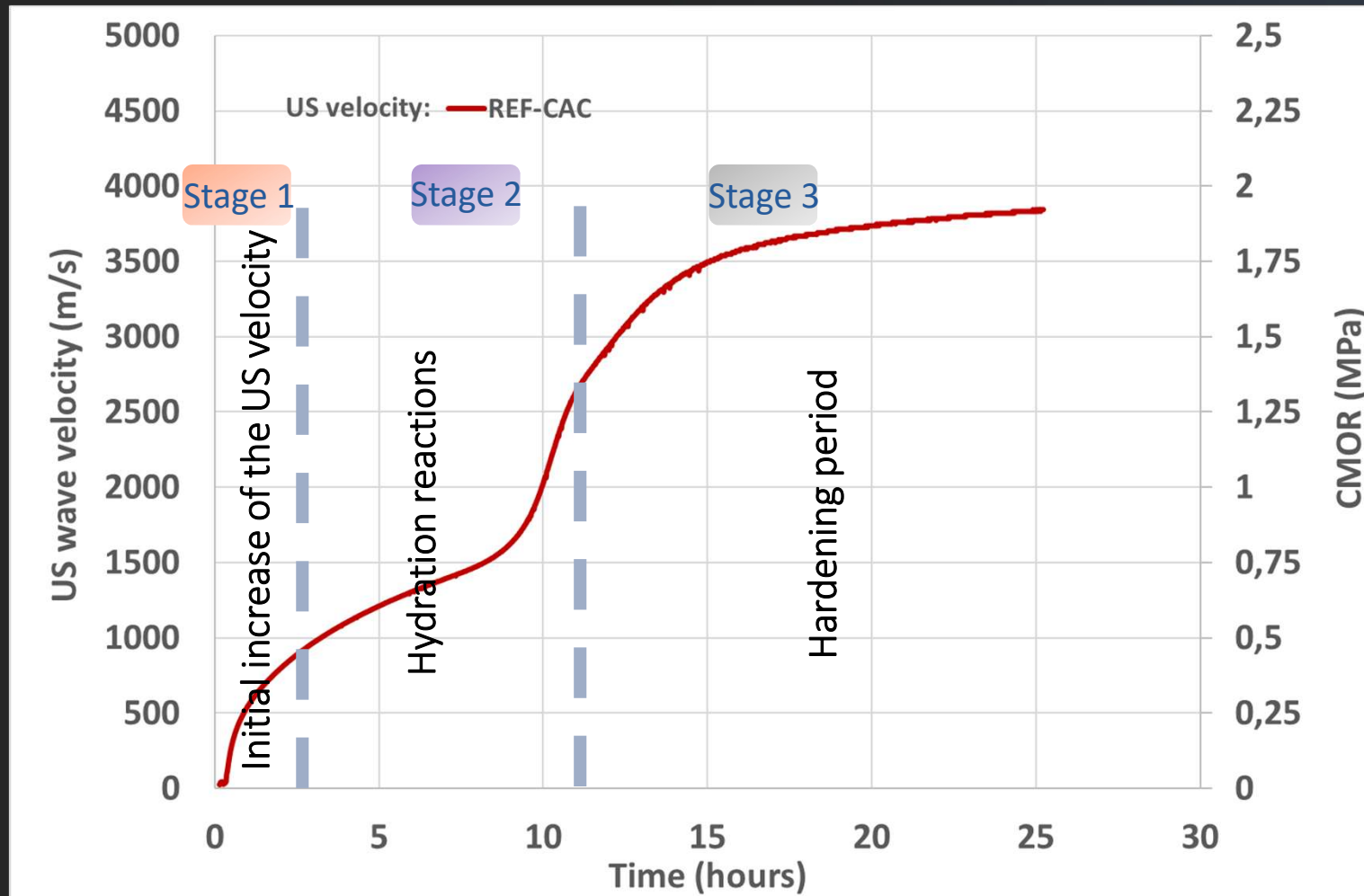
1, 2, 4, 9, 18 and 24 hours
after water addition

Results – REF-CAC



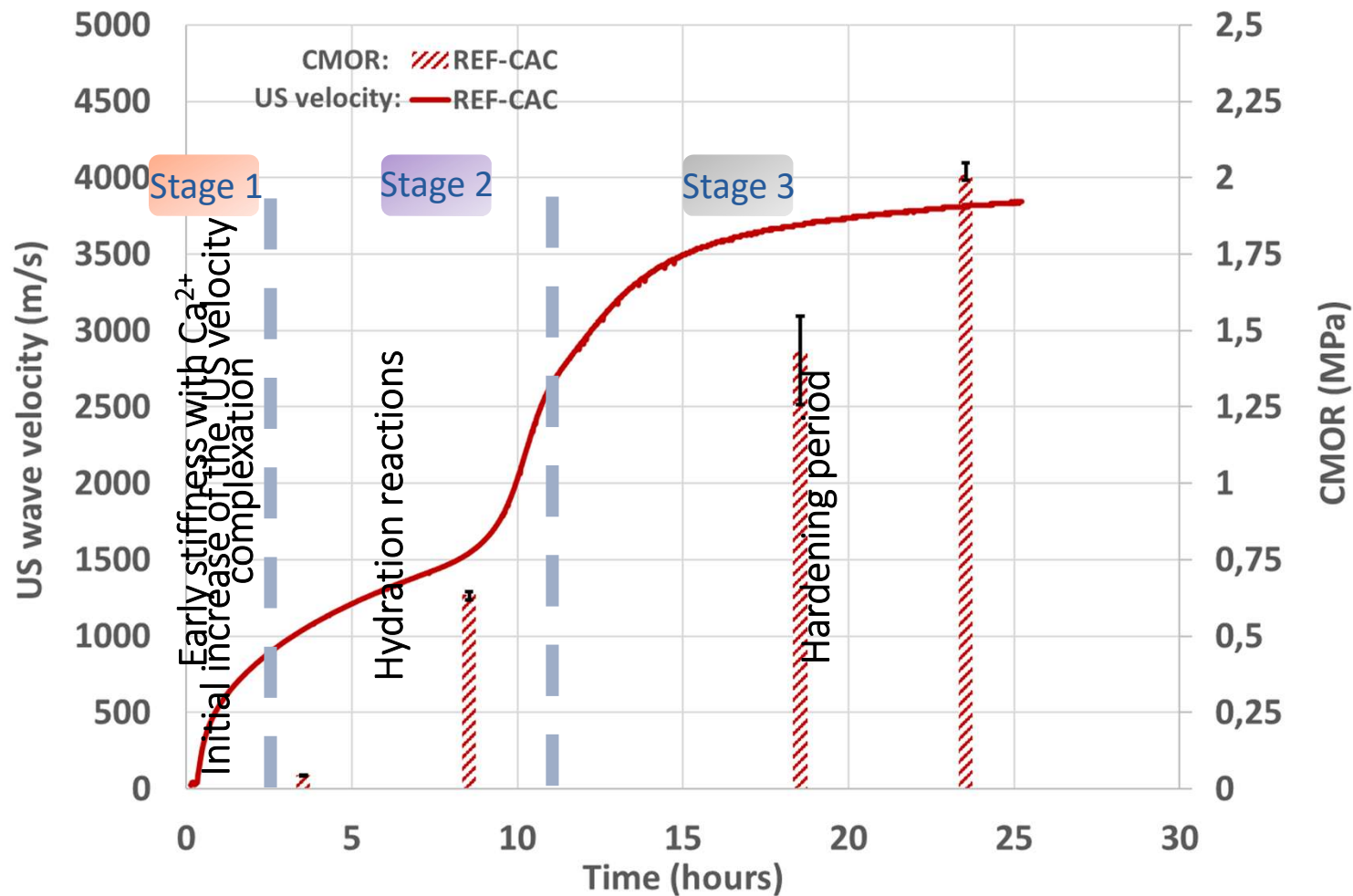


Results – REF-CAC





Results – REF-CAC



Stage 1

No mechanical strength but an early stiffness due an increase of viscosity to Ca^{2+} complexation with PCE*

Stage 2

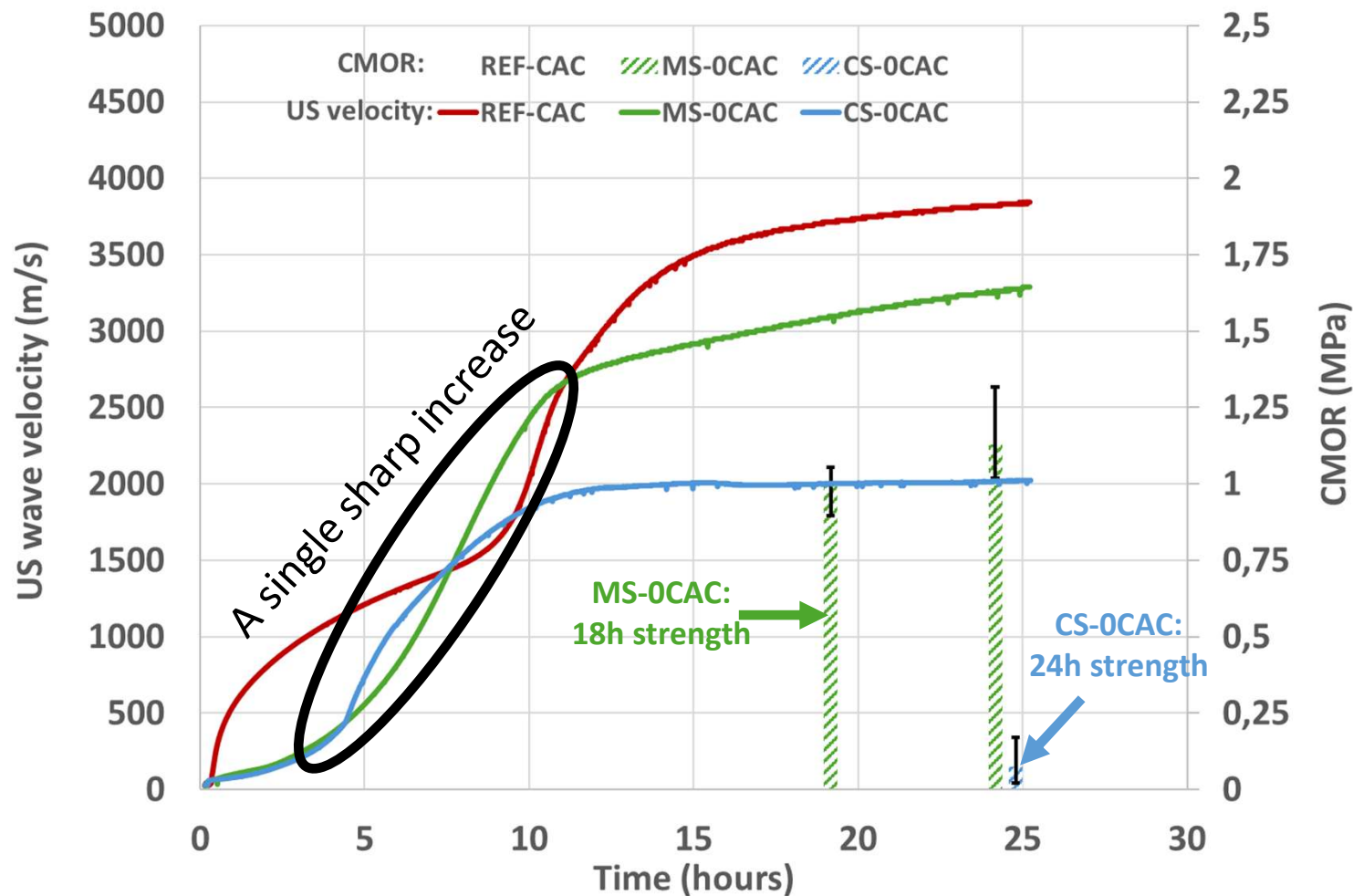
Start of the mechanical strength development

Stage 3

On going of the mechanical strength development

*J. Kasper, O. Krause, C. Dannert: Formation of green strength in hydraulically bonded refractory castables at room temperature, Open Ceramics 18, p. 1-10, 2024

Results – MS-OCAC & CS-OCAC

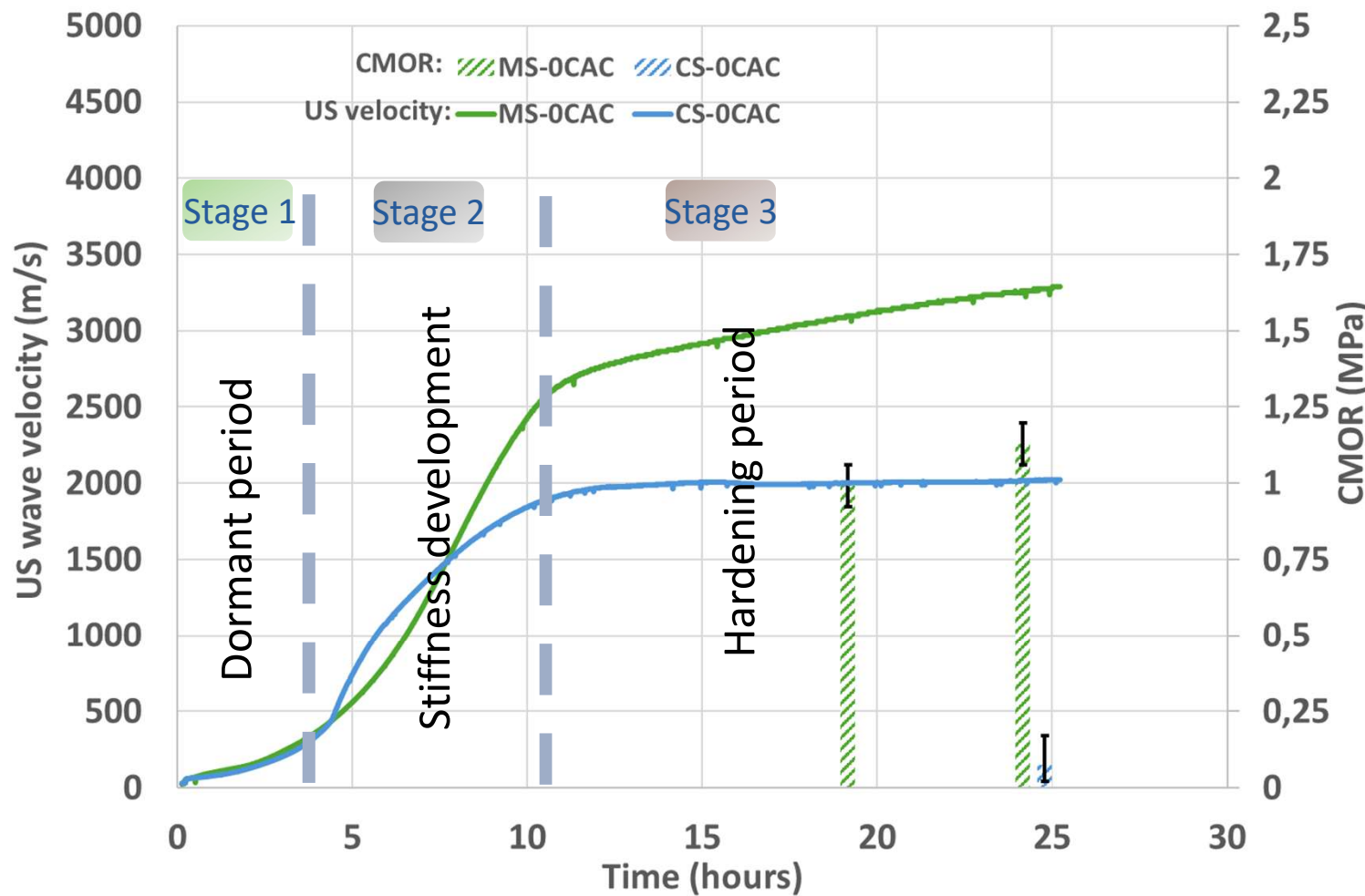


Stiffness of MS-OCAC and CS-OCAC no linked with a real strength development

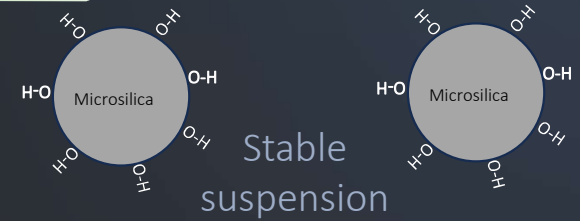
For MS-OCAC strength detected at 18 hours

For CS-OCAC strength detected at 24 hours

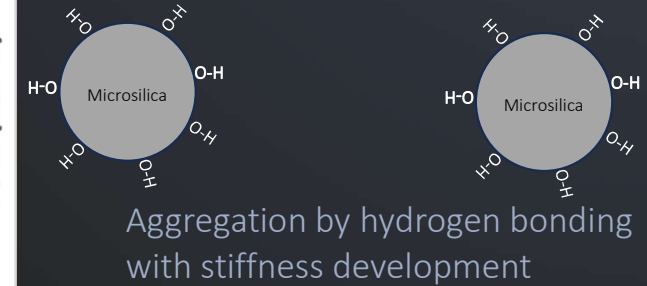
Results – MS-0CAC & CS-0CAC



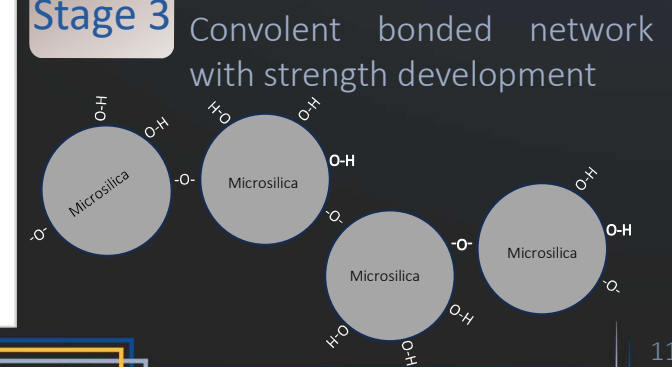
Stage 1



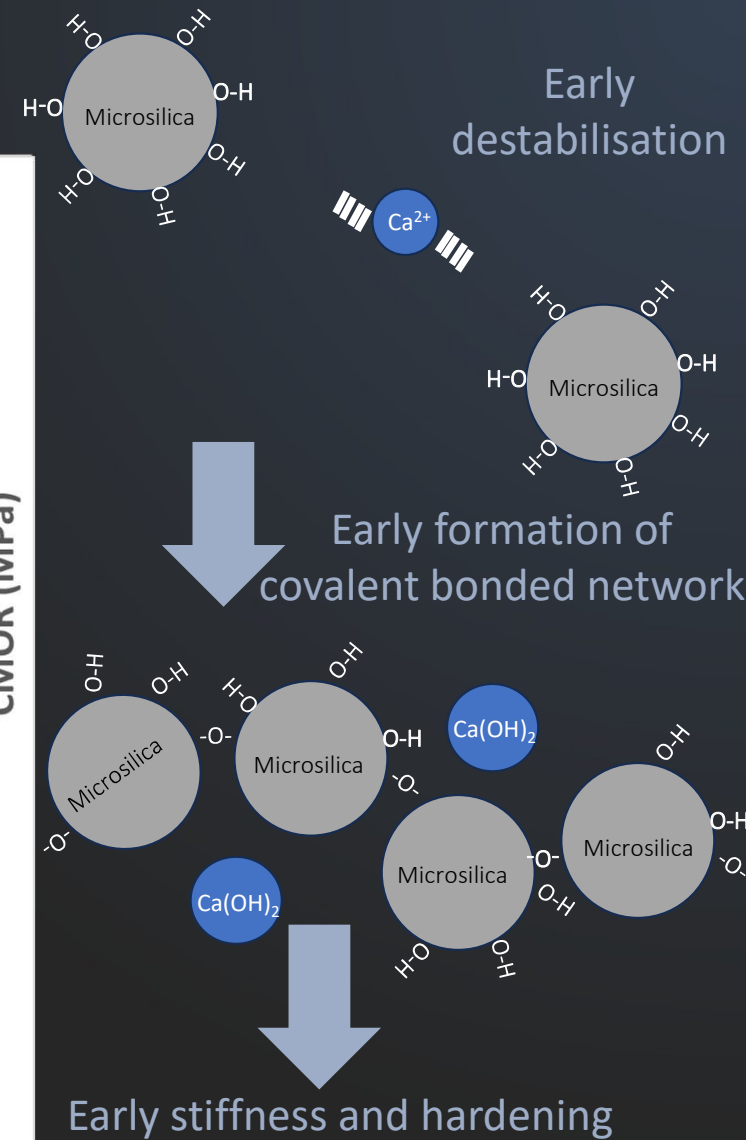
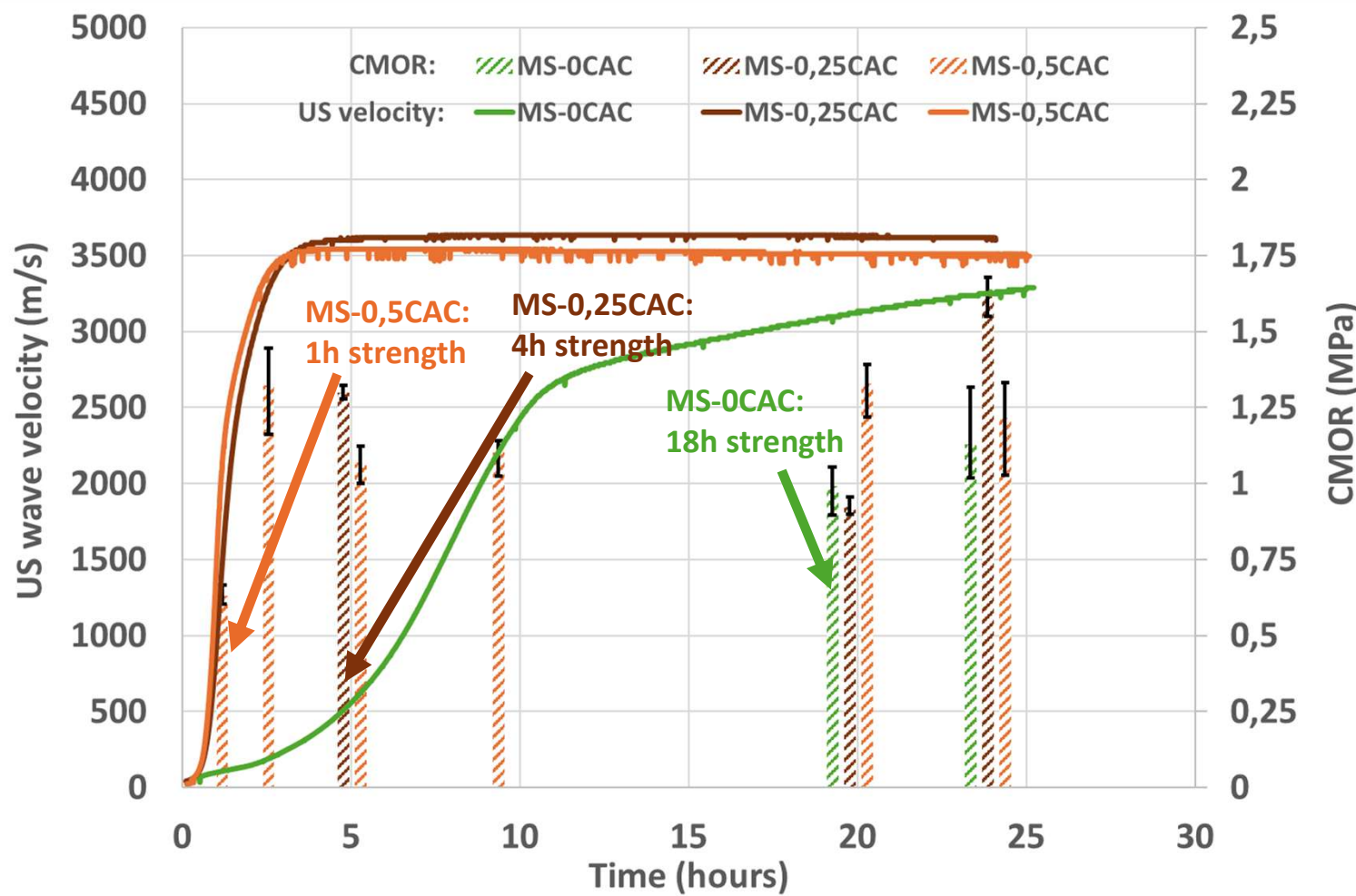
Stage 2



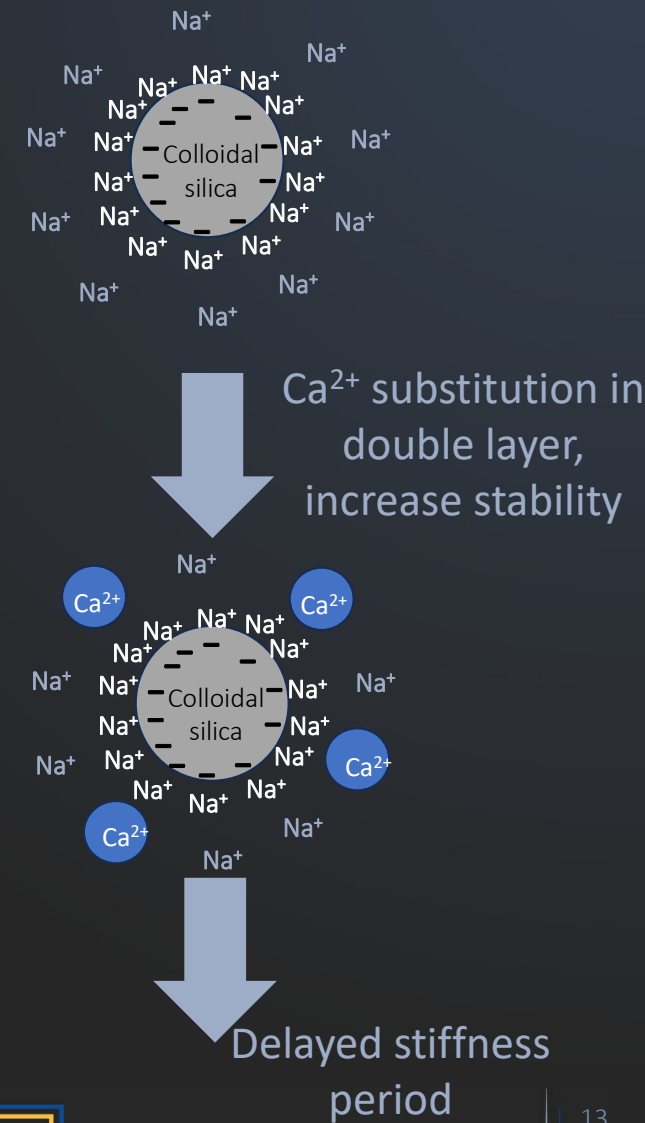
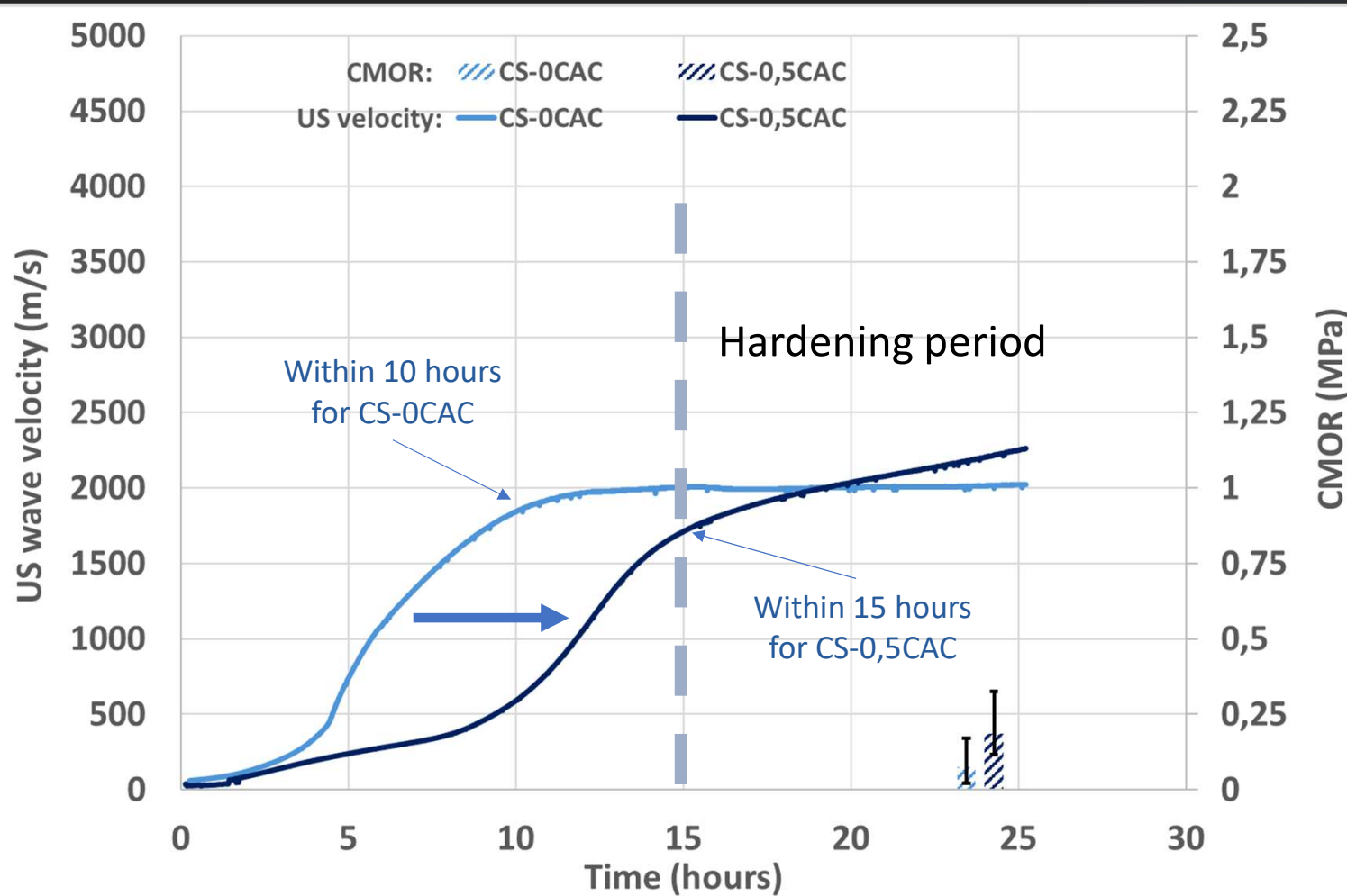
Stage 3



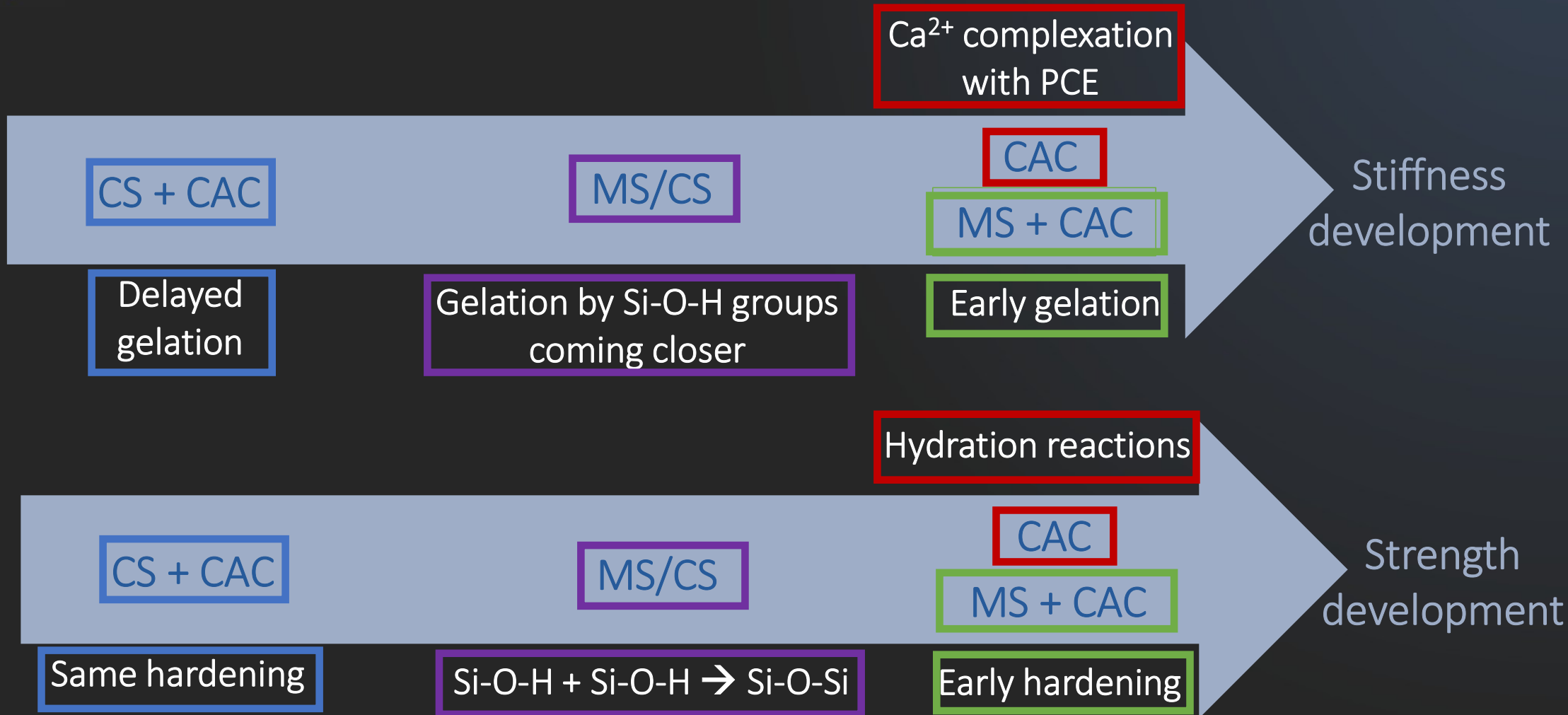
Results – MS-0,25CAC & MS-0,5CAC



Results – CS-0,5CAC



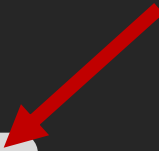
Summary



Perspectives

For 3D printing process during the deposit layer what is matter?

We need a stiffness
period at early age



Buildability

Pumpability

Extrudability

Tailoring setting behaviour of cement free system by hybrid bonding for engineering sustainable printable refractory ink



One step at a time...