Silesian University of Technology

RESEARCH UNIVERSITY
EXCELLENCE INITIATIVE
Ministry of Science and Higher Education

RHEOLOGICAL PROPERTIES OF CSA CEMENT MORTARS

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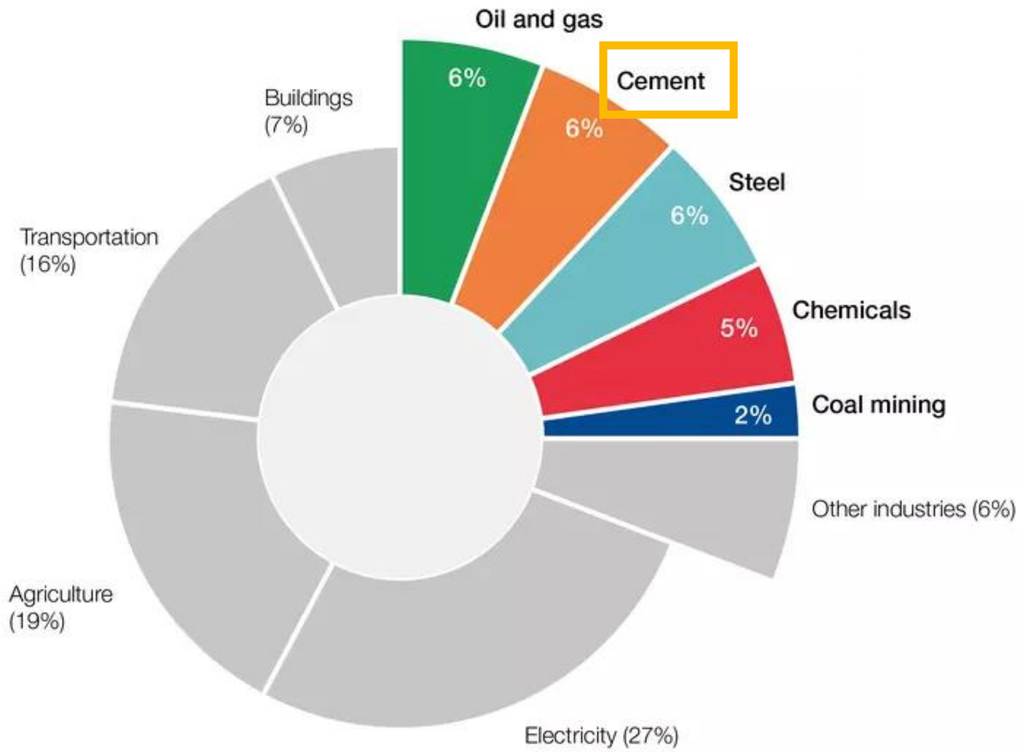
Silesian University of Technology

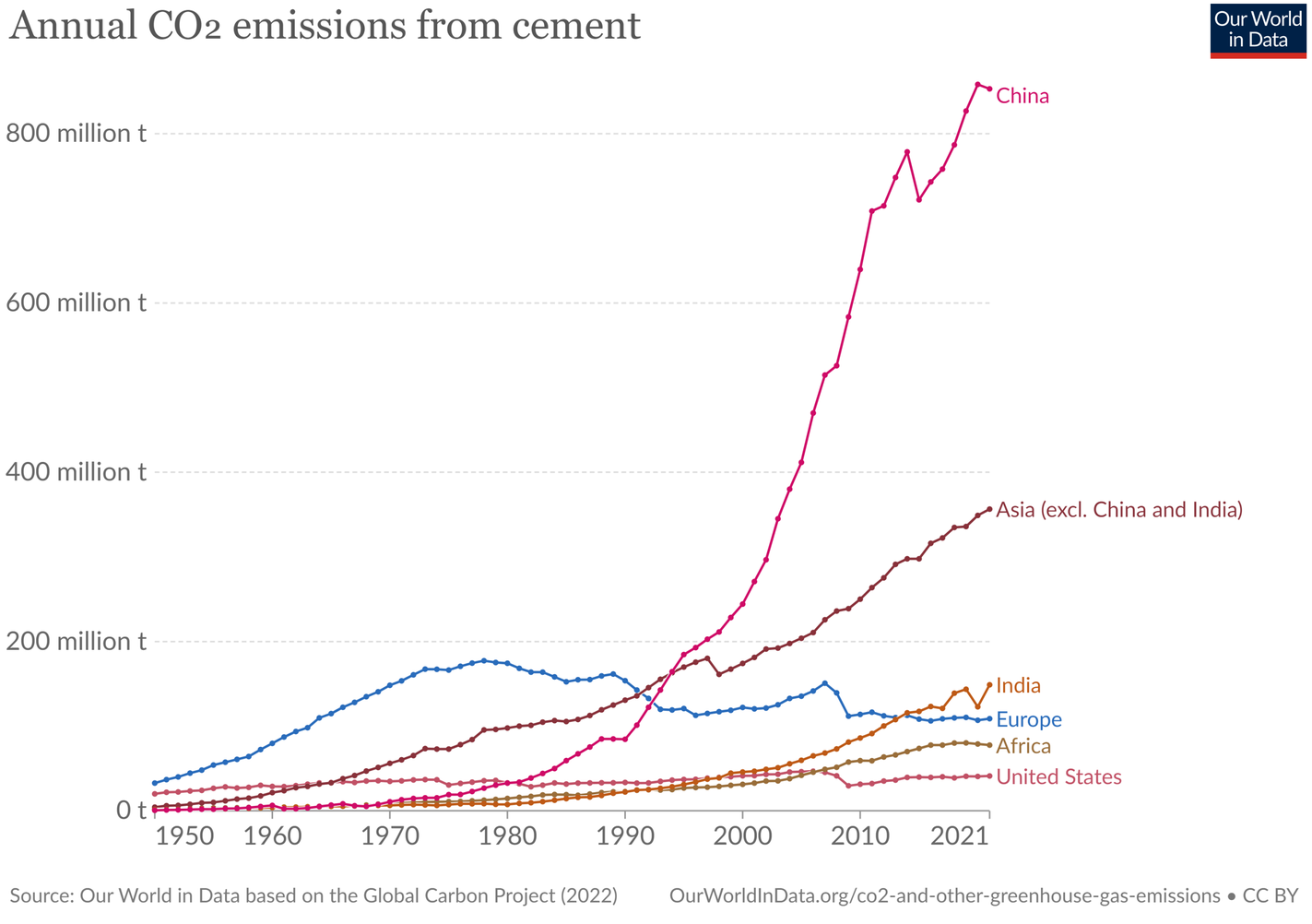
PART 1

CSA CEMENT

CARBON IMPACTS OF CONCRETE



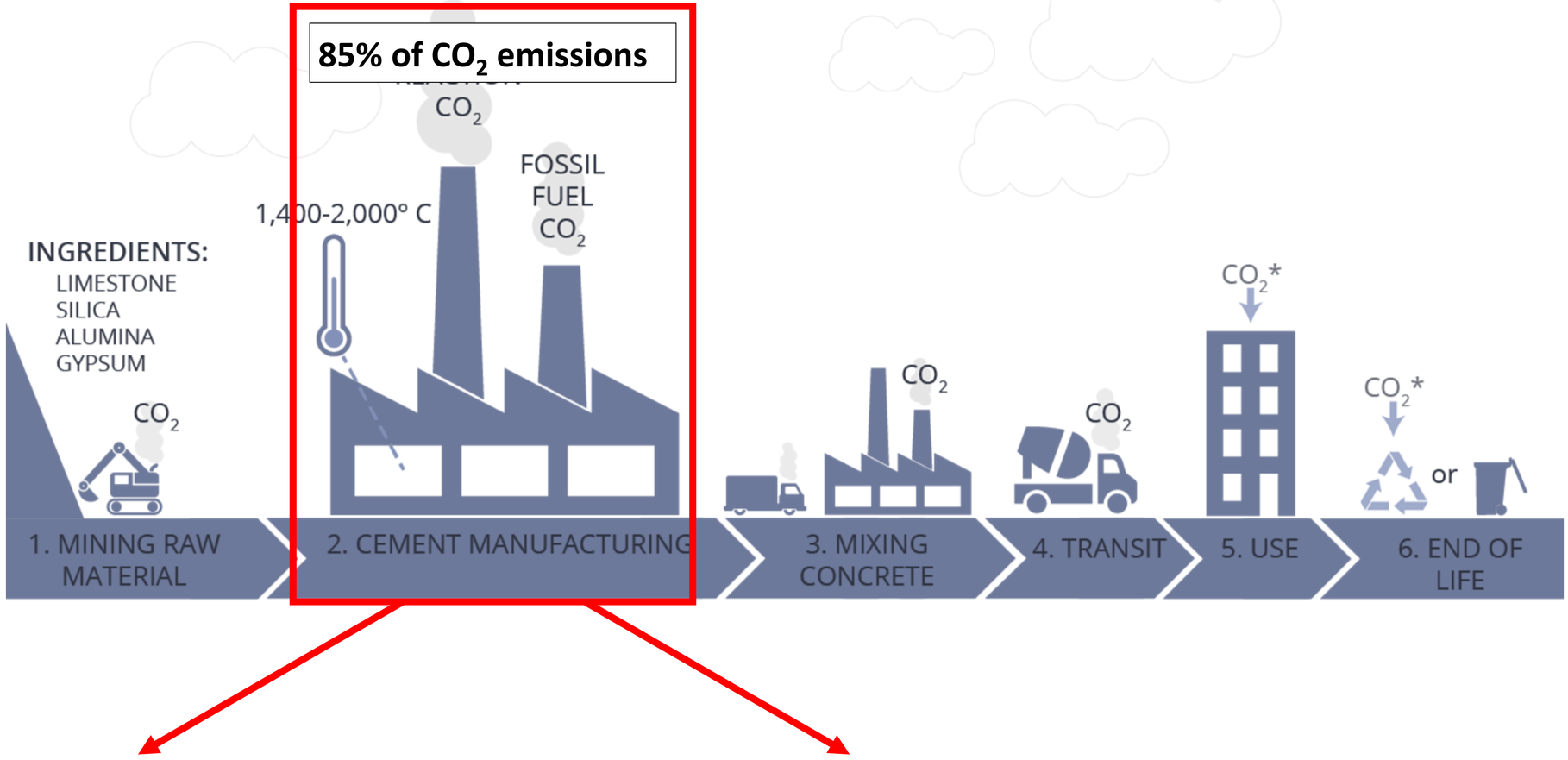
Notes: Oil and gas also includes refining; Steel includes iron; Cement includes concrete.



SIXTH ASSESSMENT REPORT (AR6) Climate Change 2022 Mitigation of Climate Change Summary for Policymakers

CARBON IMPACTS OF CONCRETE

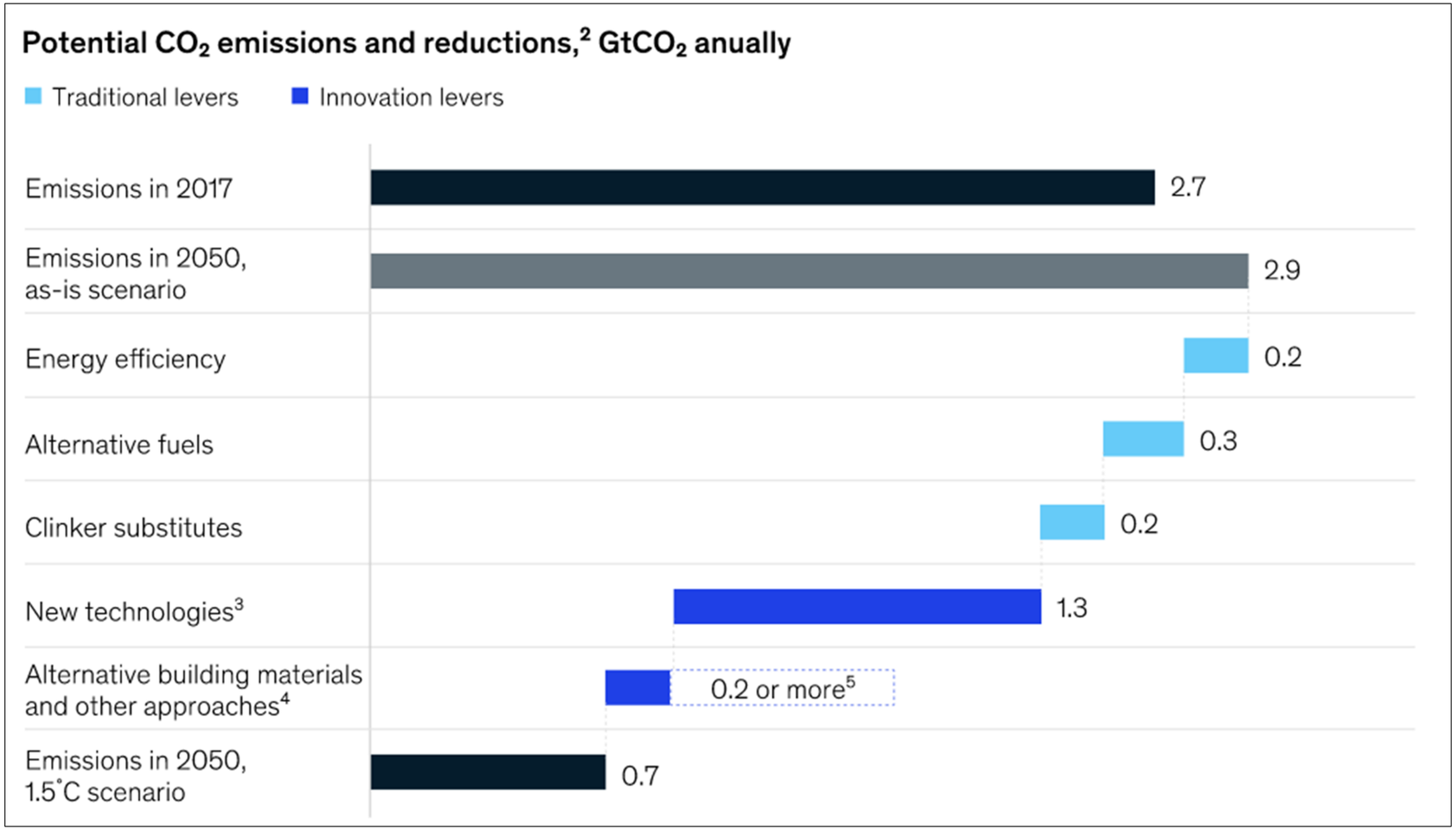
$$CaCO_3 \rightarrow CaO + CO_2$$



CALCINATION PROCESS:
~50% of total carbon impact

FOSSIL FUELS:
~30% of total carbon impact

CARBON IMPACTS OF CONCRETE



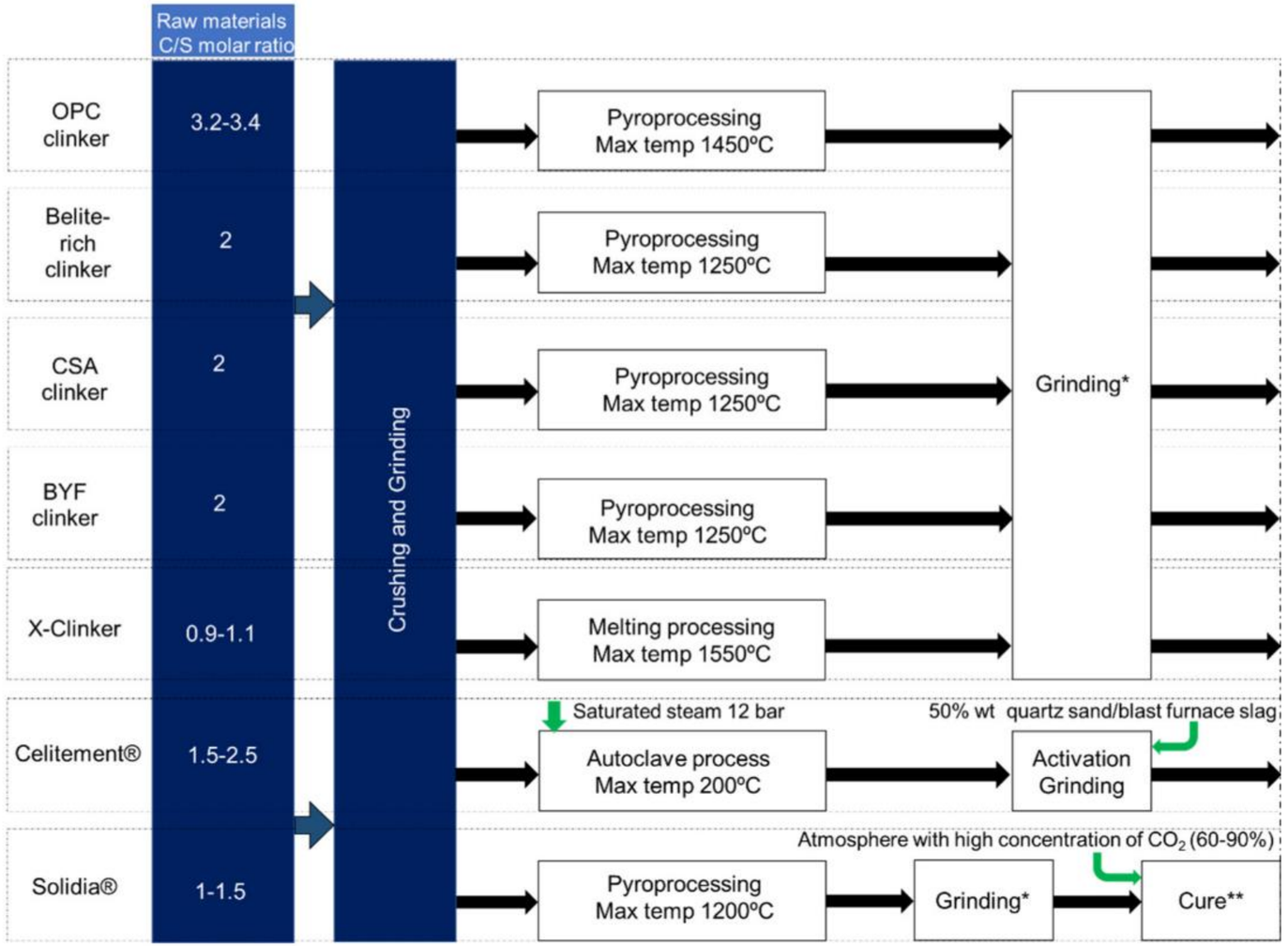
https://www.mckinsey.com/industries/chemicals/our-insights/laying-the-foundation-for-zero-carbon-cement

SOLUTION - ALTERNATIVE CLINKER TECHNOLOGIES

- Alkali-actived binders;
- **Calcium sulfoaluminate (CSA) cement;**
- Reactive belite-rich Portland cement (RBPC);
- Biomineralisation;
- Etc.

PROBLEMS:

1. Lack of knowlegde;
2. Low avalibility;
3. High production costs;
4. Technological challenges during construction.



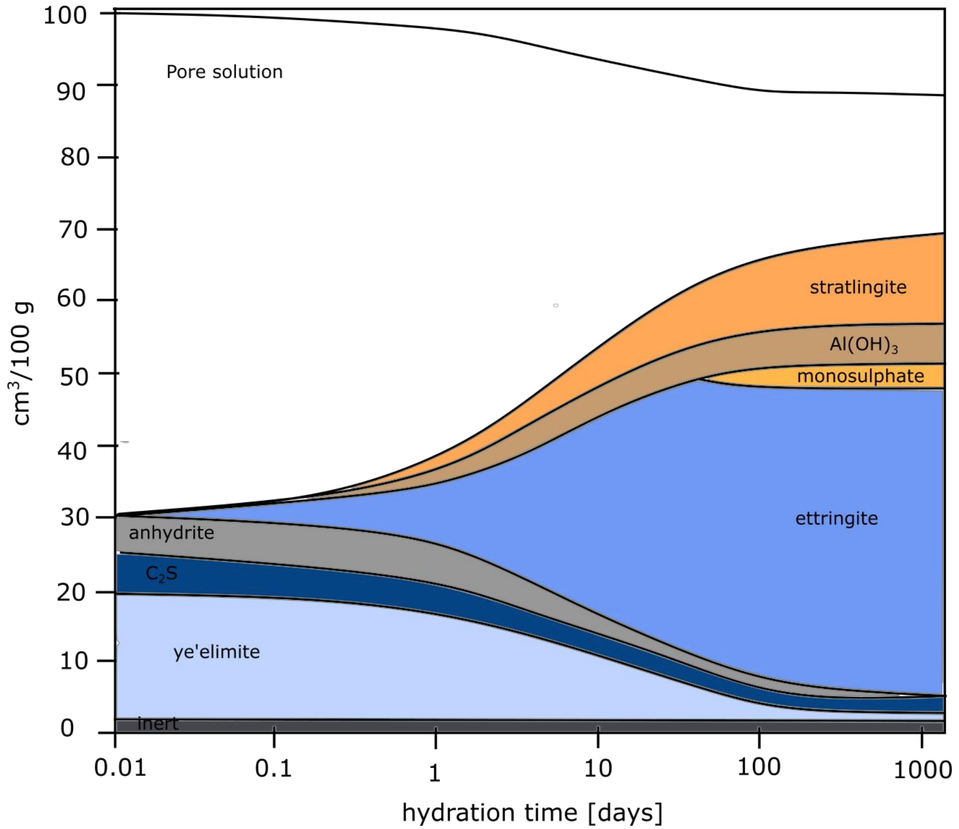
*The grinding stage is considered to be similar in all the cases presented

**Mortar and concrete curing should be performed under controlled conditions

Antunes, M.; Santos, R.L.; Pereira, J.; Rocha, P.; Horta, R.B.; Colaço, R. Alternative Clinker Technologies for Reducing Carbon Emissions in Cement Industry: A Critical Review. Materials 2022, 15, 209. https://doi.org/10.3390/ma15010209

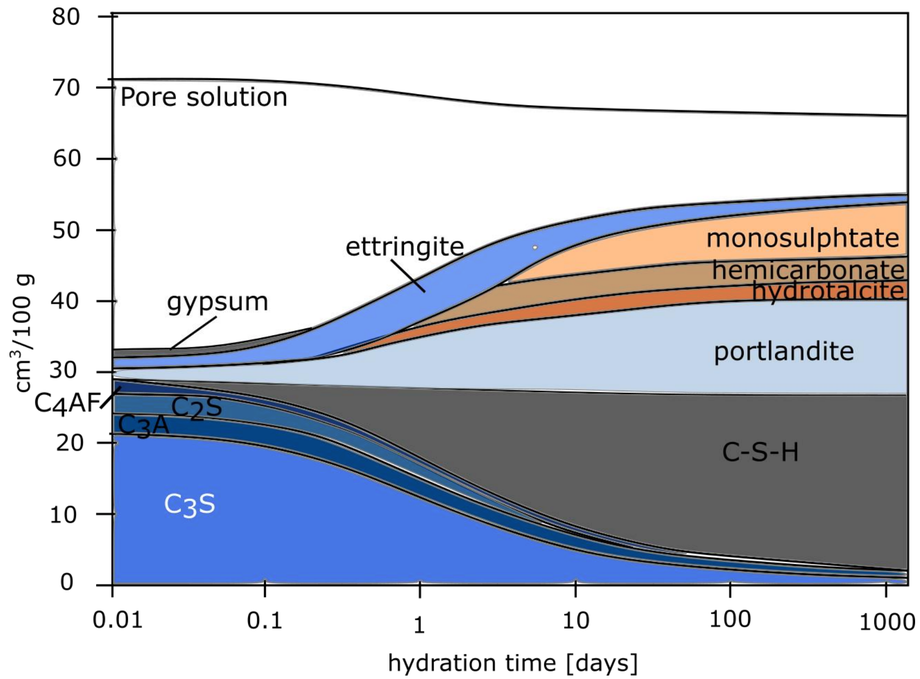
CSA CEMENTS

CSA Cement, also named Calcium Sulphoaluminate Cement is a hydraulic binder based on calcium sulphoaluminate, rather than calcium silicates which are the basis of Portland cement.



CSA CEMENT HYDRATION

Winnefeld, F., Kaufmann, J., Concrete produced with calcium sulfoaluminate cement – a potential system for energy and heat storage, 1st Middle East Conf. Smart Monit. Assess. Rehabil. Civ. Struct. (2011) 1–9.



PORTLAND CEMENT HYDRATION

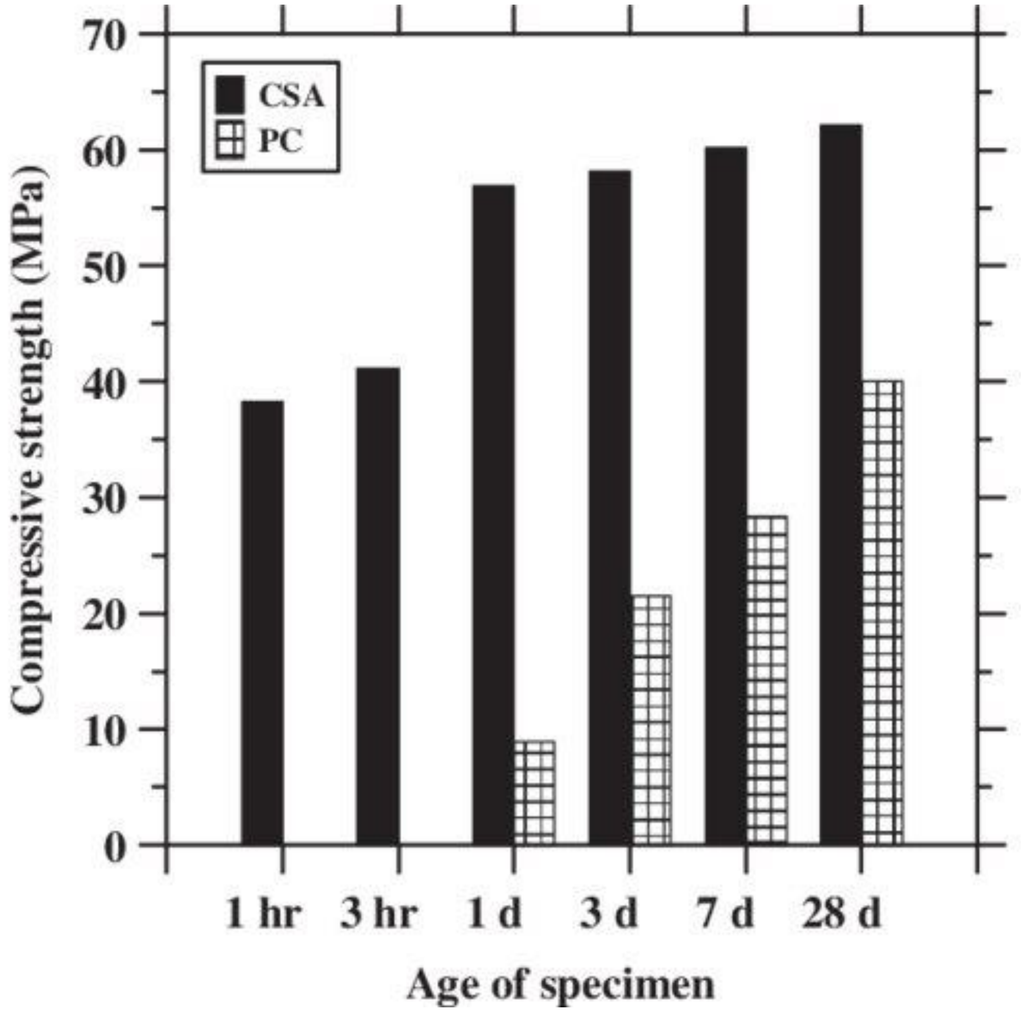
Source: Lothenbach, B., Saout, G. Le, Gallucci, E., Scrivener, K., Influence of limestone on the hydration of {Portland} cements, Cem. Concr. Res. (2008) 848–860.

CSA CEMENTS

CSA Cement, also named Calcium Sulphoaluminate Cement is a hydraulic binder based on calcium sulphoaluminate, rather than calcium silicates which are the basis of Portland cement.

- Rapid setting time,
- High early strength,
- Low shrinkage,

- Lower CO_2 emissions from clinker
- High costs



Seongwon Hong, Kyle de Bruyn, Eric Bescher, Chris Ramseyer & Thomas H.-K. Kang (2018) Porosimetric features of calcium sulfoaluminate and Portland cement pastes: testing protocols and data analysis, Journal of Structural Integrity and Maintenance, 3:1, 52-66, DOI: 10.1080/24705314.2018.1426168

PART 2

RESEARCH METHODS

RESEARCH AREAS

EFFECT OF W/C RATIO

- 3 w/c ratios 0.5; 0.55; 0.6.,

EFFECT OF CSA CLINKER SUBSTITUTION

- 10%, 20%, 30% of CEM I 42.5R (OPC) substitution
- 10%, 20%, 30% of limestone (LL)
- 10%, 20%, 30% of fly ash (FA) substitution.

EFFECT OF SUPERPLASTICIZERS

- 3 types of superplasticizer
  - SP1 - polycarboxylate ether;
  - SP2 – modified acrylic polymers;
  - SP3 – polynaphthalene sulfonate.

CSA cement [g]	Water [g]	Sand [g]	Other
450	225; 247.5; 270	1350	-
405; 360; 315	270	1350	45 g; 90 g; 135g of OPC, LL and FA
450	225	1350	SP1 – 0.8% c.m.; SP2 – 1.1% c.m.; SP3 – 1.1% c.m.

TESTING METHODS - RHEOLOGY

- Schleibinger Viskomat NT,
- Tests were conducted on mortars, prepared on the basis of standard EN 196-1
- Measured were plastic viscosity and yield stress after 5 and 60 min from mixing, and changes in torque,
- During the measurement, sample was kept in temperature of 20^{o}C

TESTING METHODS - RHEOLOGY

Rheological parameters were obtained using simplified Bingham model:

$$M = g + hN$$

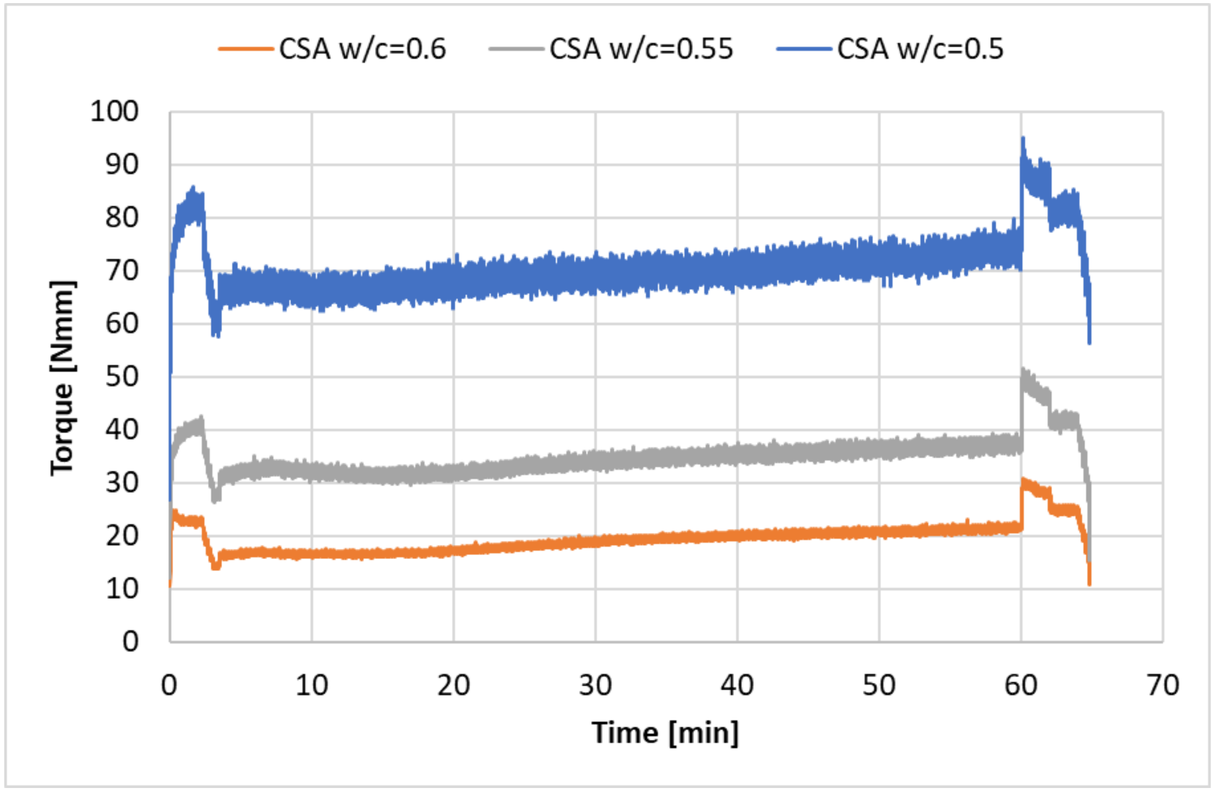
M – torque,
N – rotational speed
g – shear resistance → yield stress τ_0
h – plastic flow resistance → plastic viscosity η_{pl}

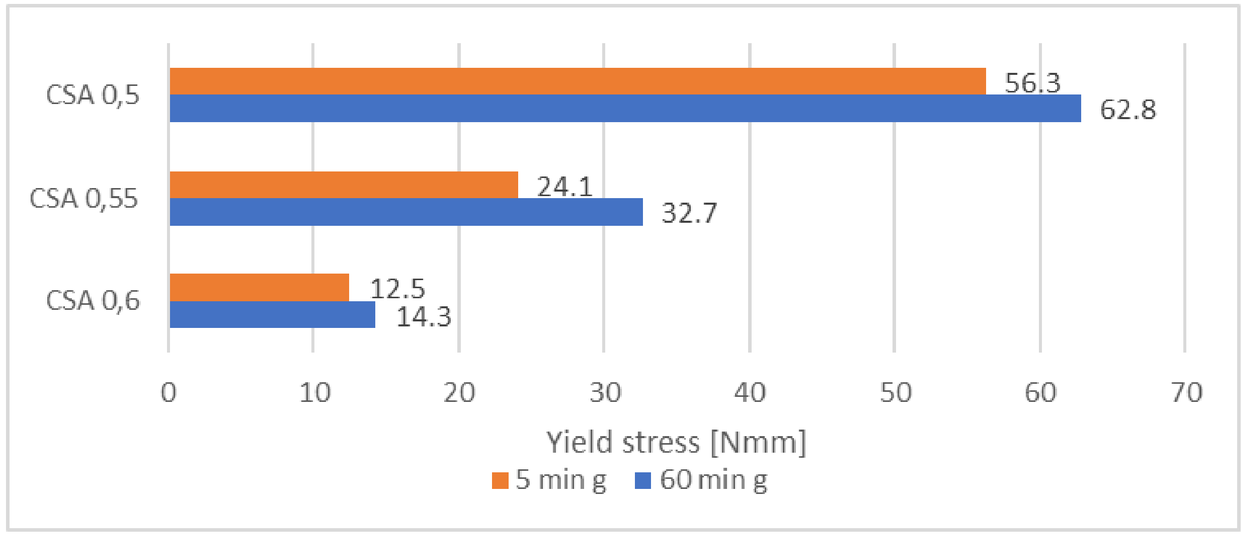
PART 3

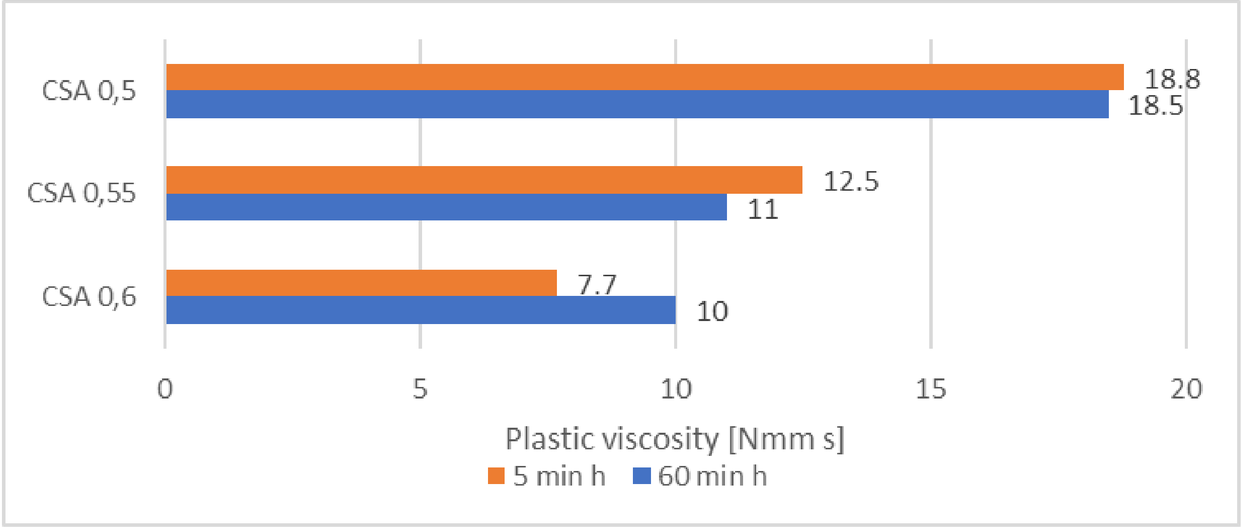
RESULTS

EFFECT OF W/C RATIO

RHEOLOGY OF CSA CEMENT

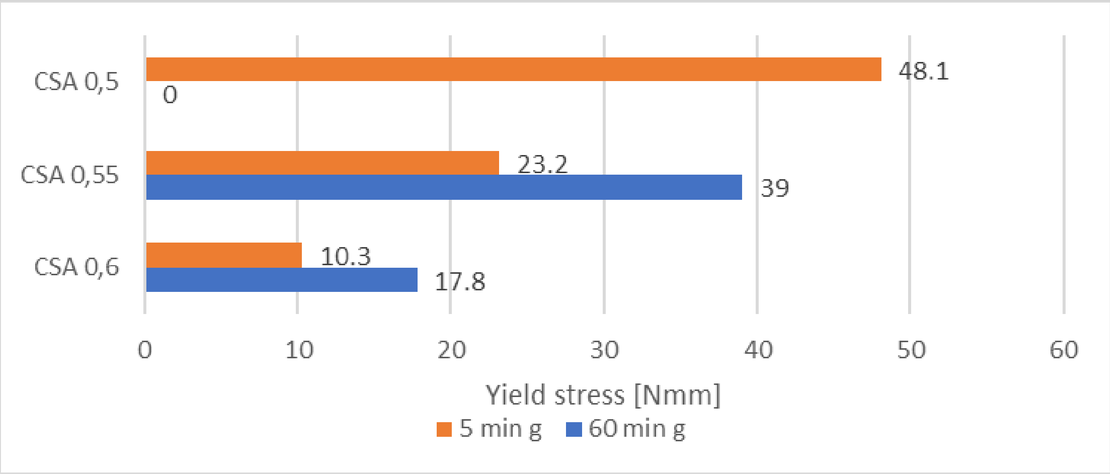


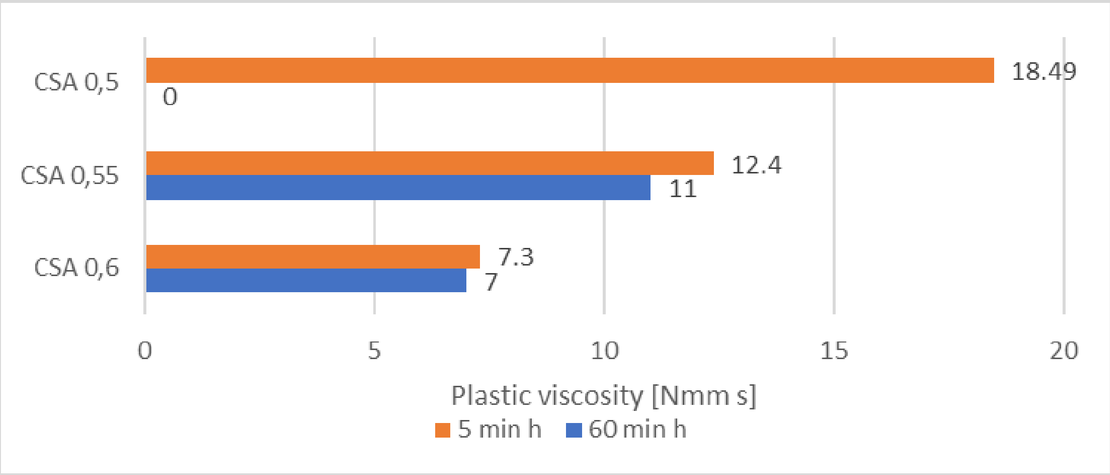




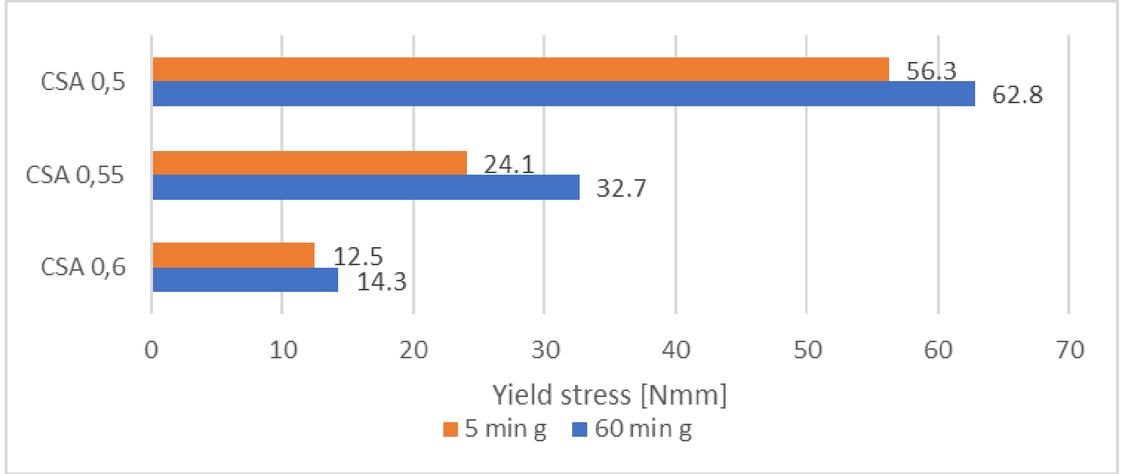
RHEOLOGY OF CSA CEMENT

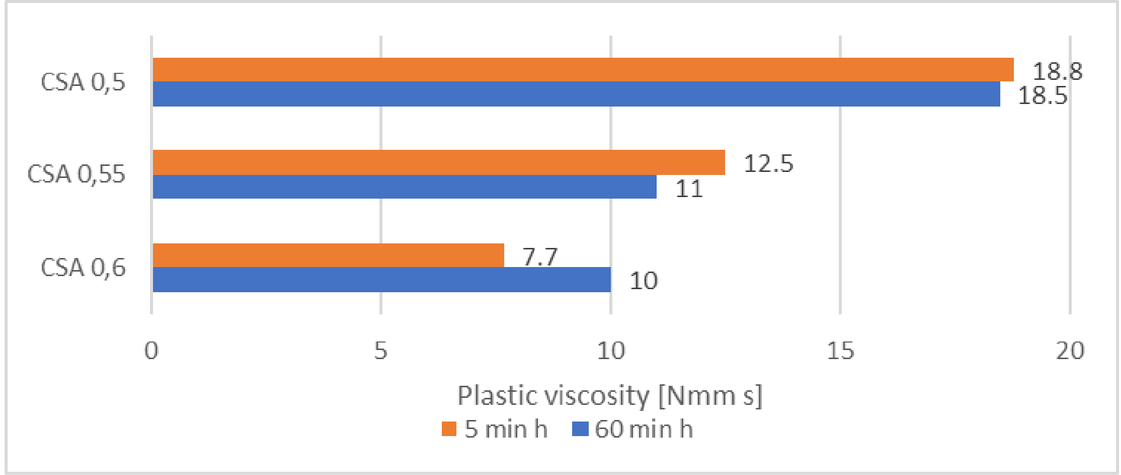
PARAMETERS MEASURED AFTER 60min





PARAMETERS MEASURED 60min AFTER CONSTANT MIXING

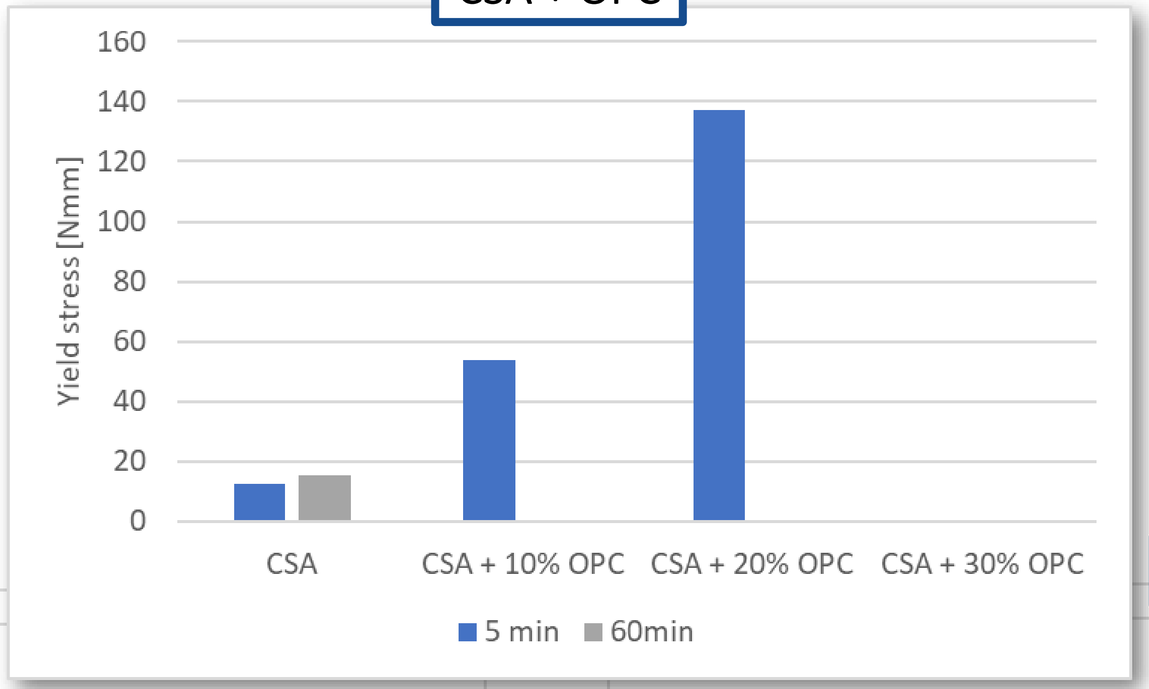




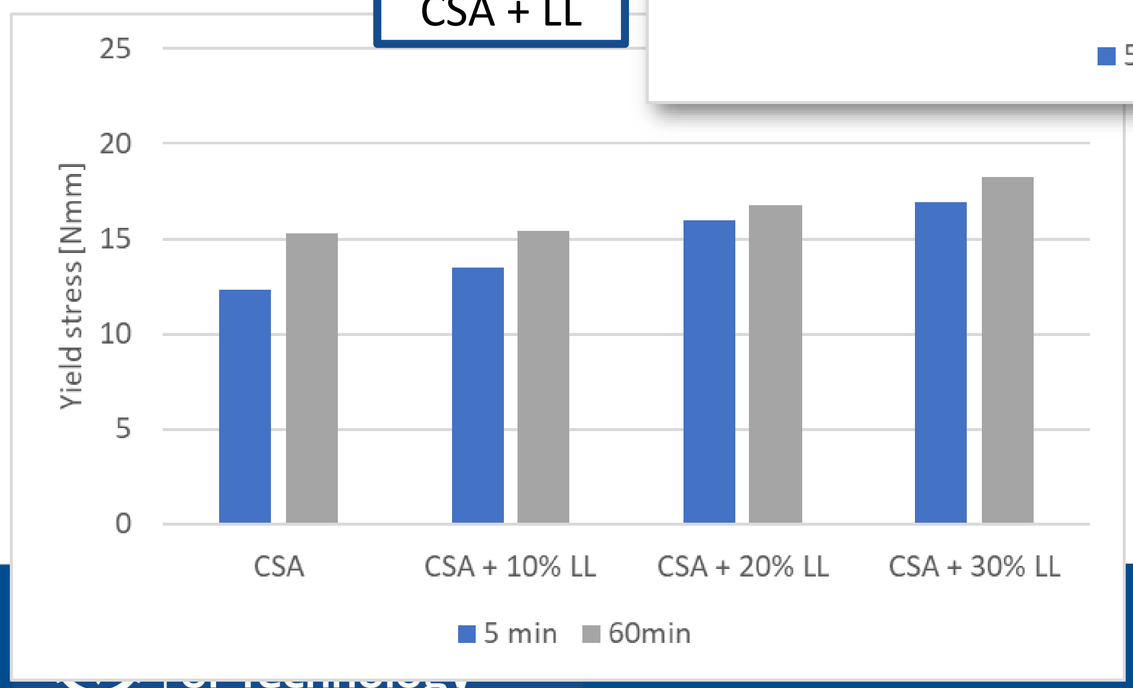
CSA CEMENTS WITH OPC, LL and FA

CSA CEMENTS RHEOLOGY

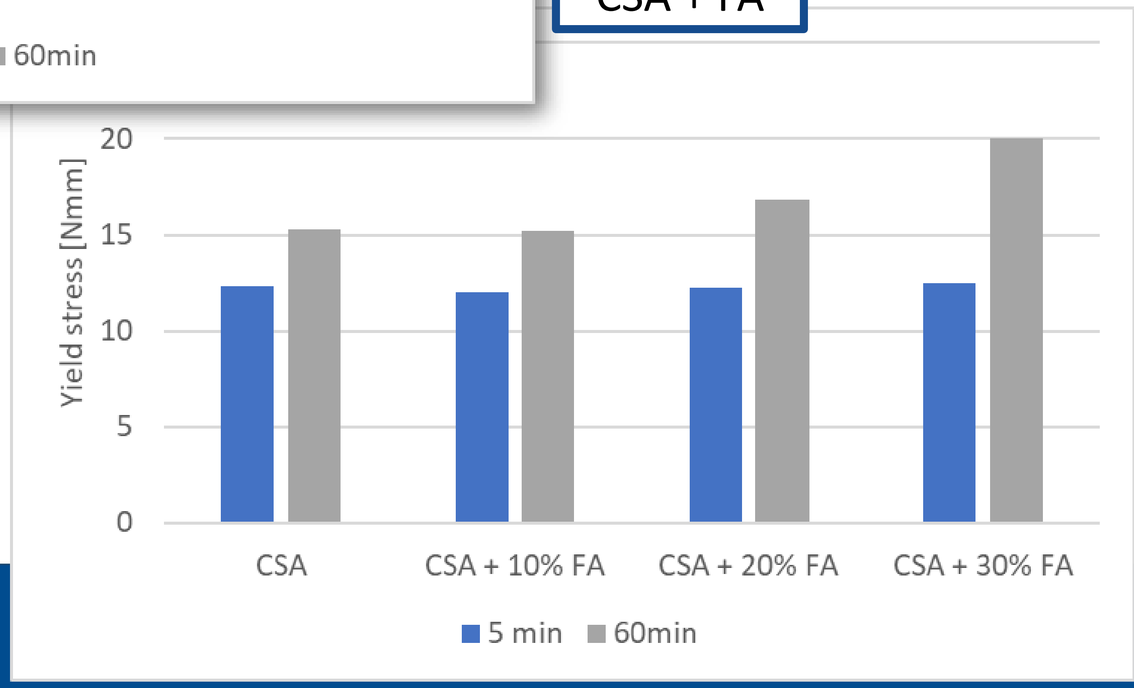
CSA + OPC



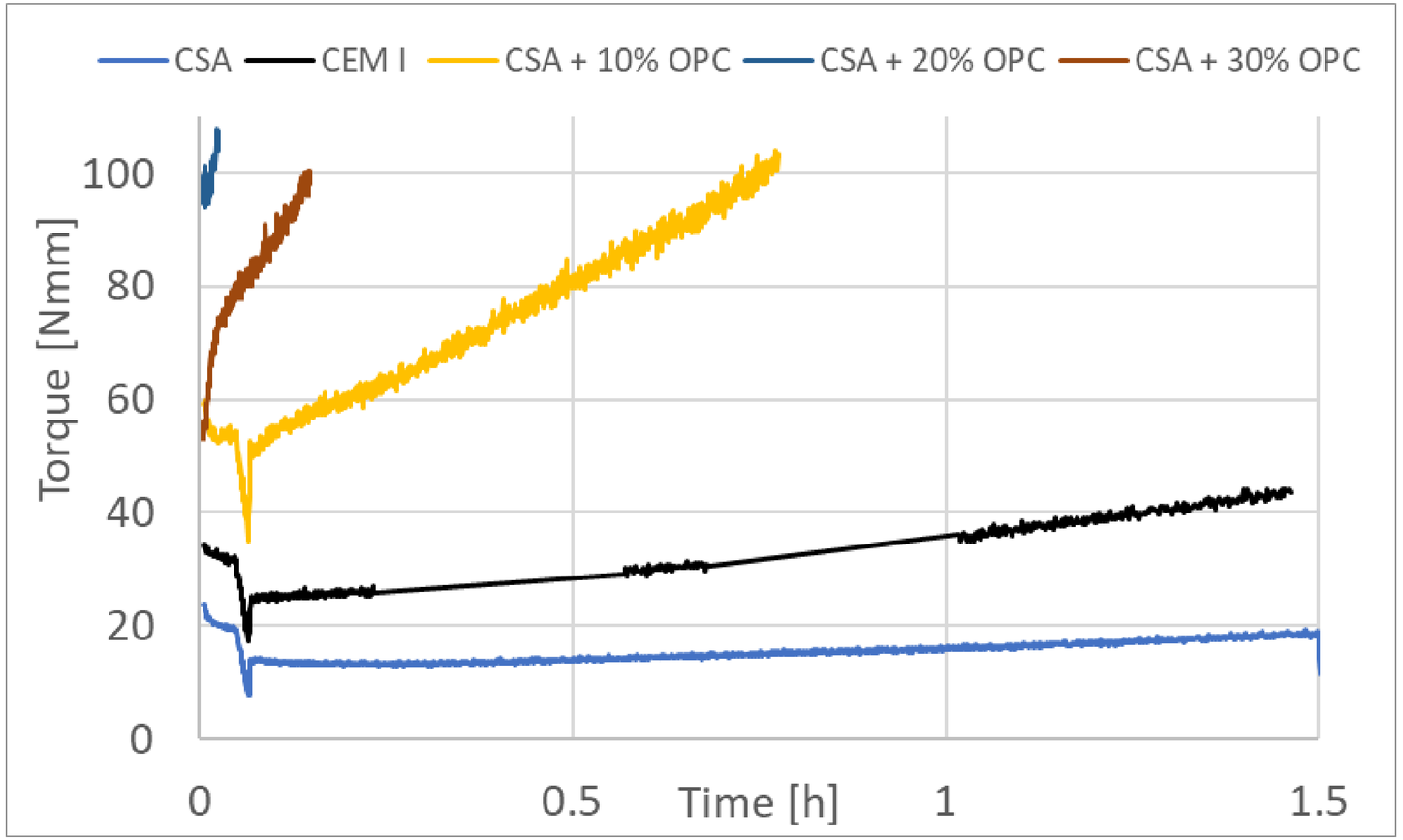
CSA + LL



CSA + FA

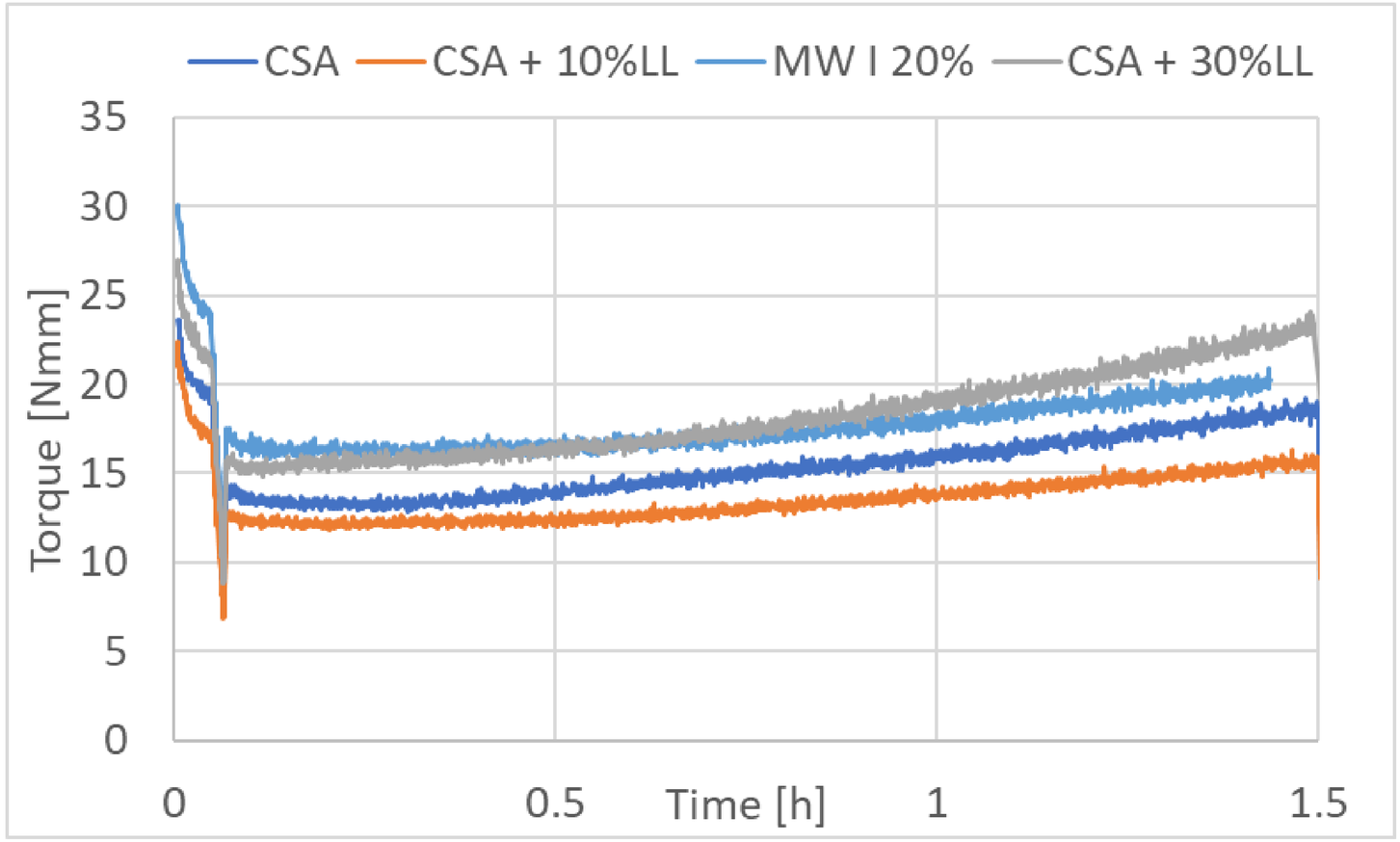


CSA CEMENTS WITH LIMESTONE



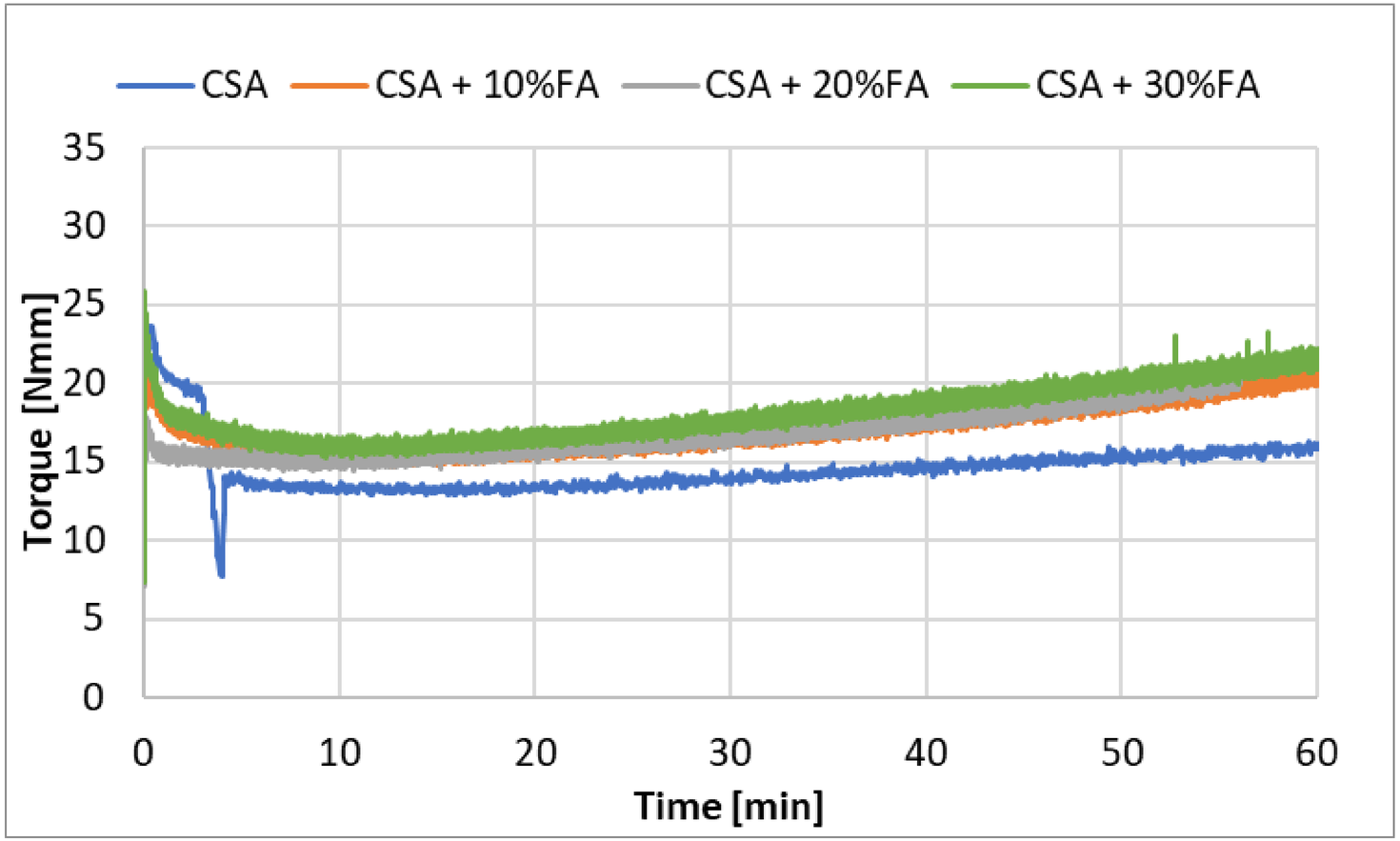
- Mixing CSA with 10-30% of OPC significantly decreases workability

CSA CEMENTS WITH LIMESTONE



- Addition of >20% of limestone decreases the workability of the cement

CSA CEMENTS WITH FLY ASH



- Addition of >20% of fly ash slightly decreases the workability of the cement

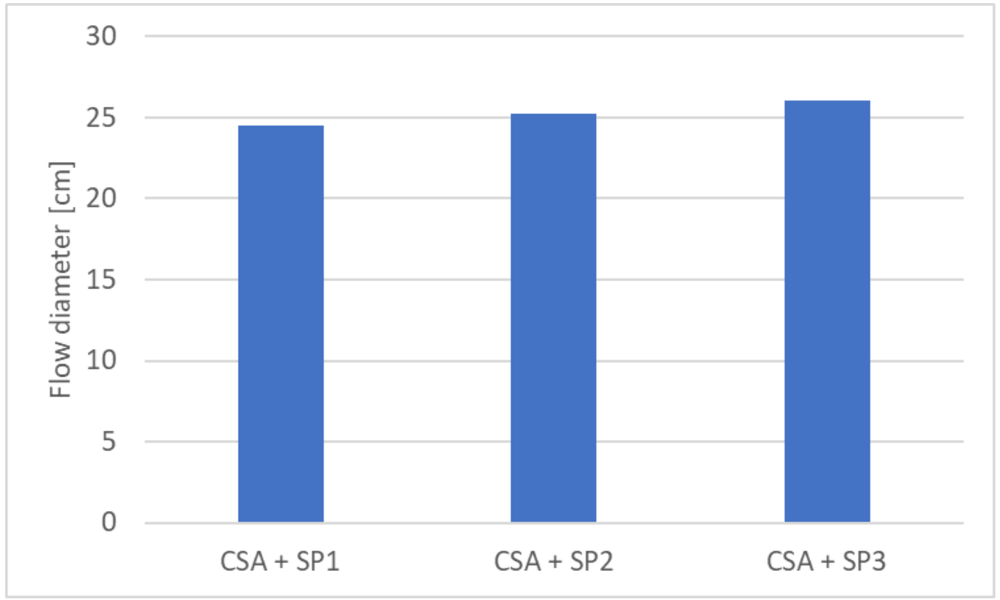
CSA CEMENTS WITH SUPERPLASTICIZERS

RHEOLOGY OF CSA WITH SP

- CSA mortar of w/c ratio 0.5
- SP was added to obtain set consistency measured by flow table

3 types of superplasticizer

- SP1 - polycarboxylate ether – 0.8% c.m.;
- SP2 – modified acrylic polymers – 1.1% c.m.
- SP3 – polynaphthalene sulfonate - 1,1% c.m.



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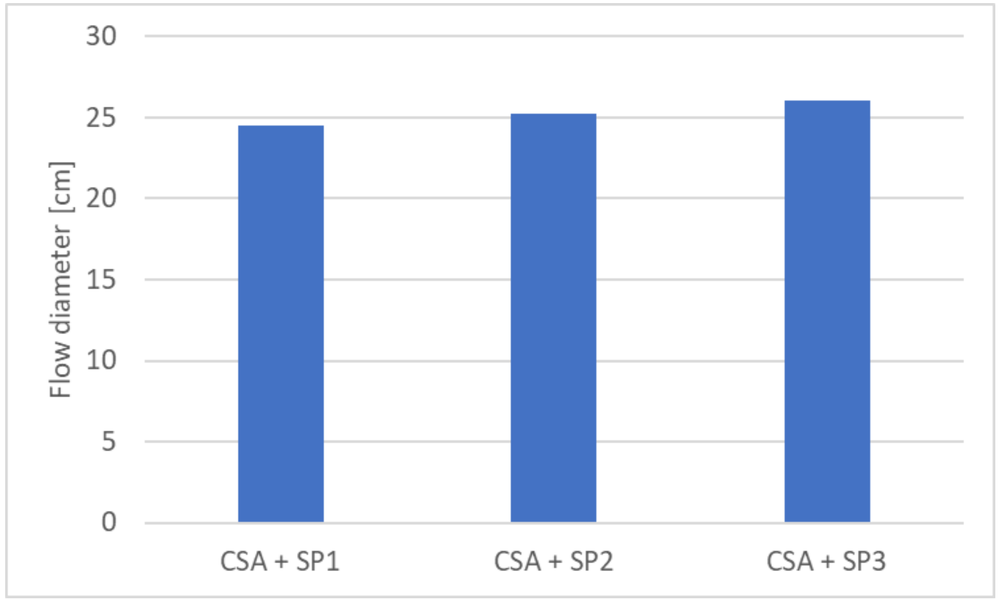

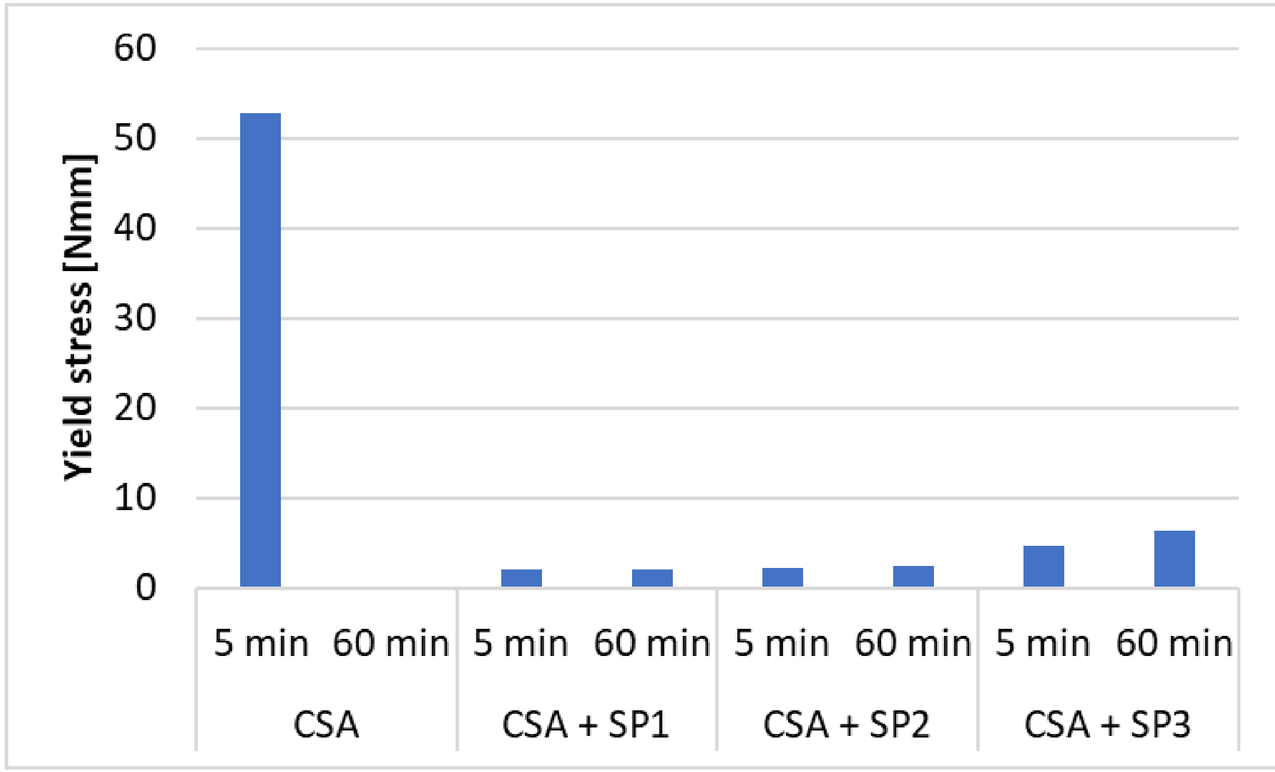

RHEOLOGY OF CSA WITH SP

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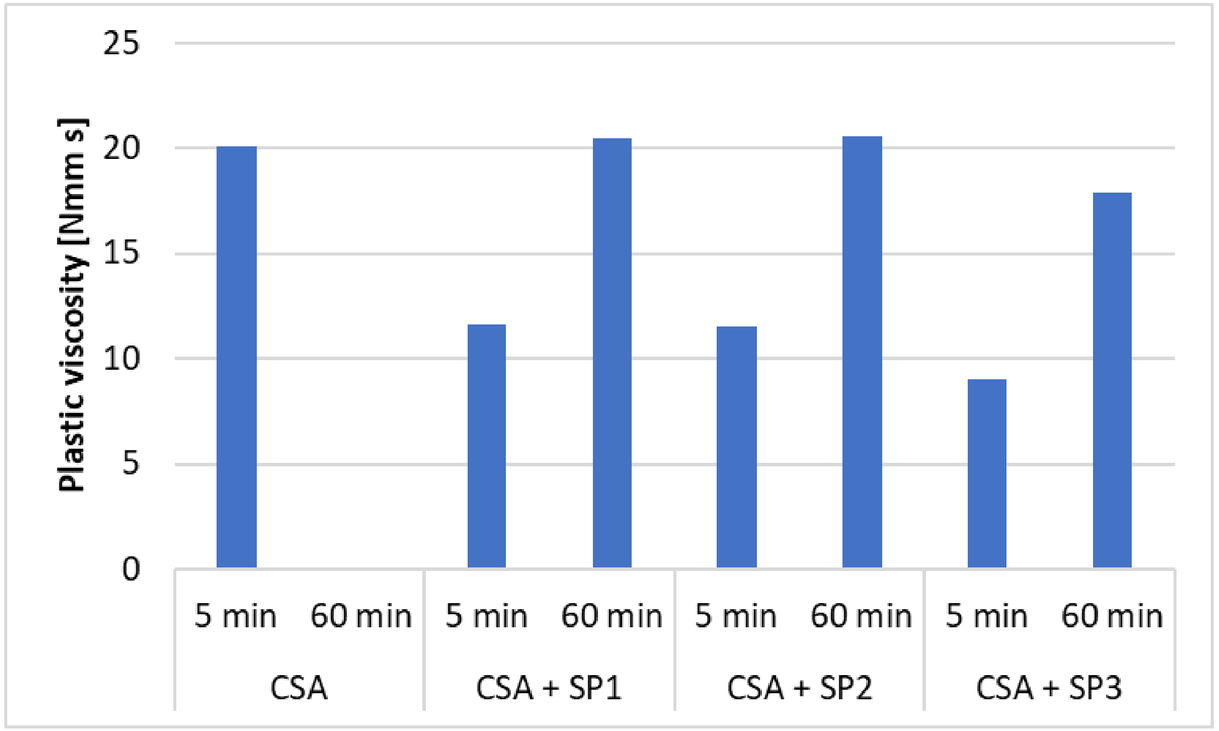
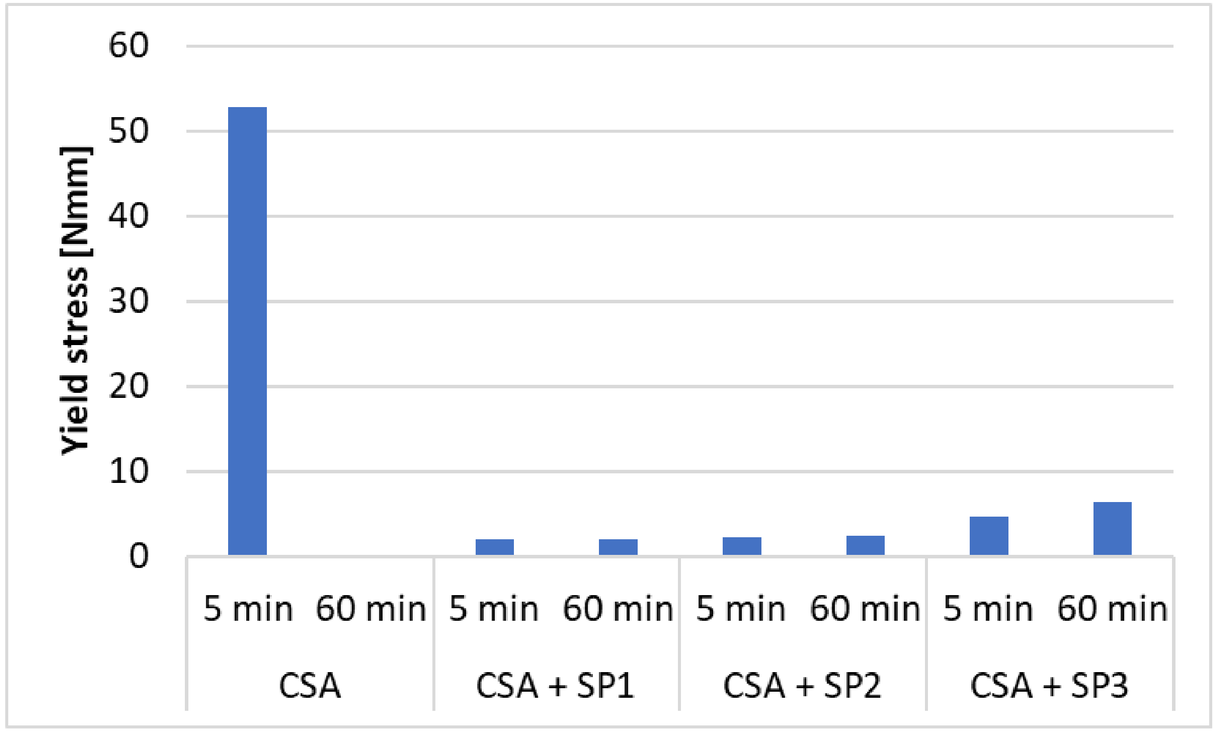
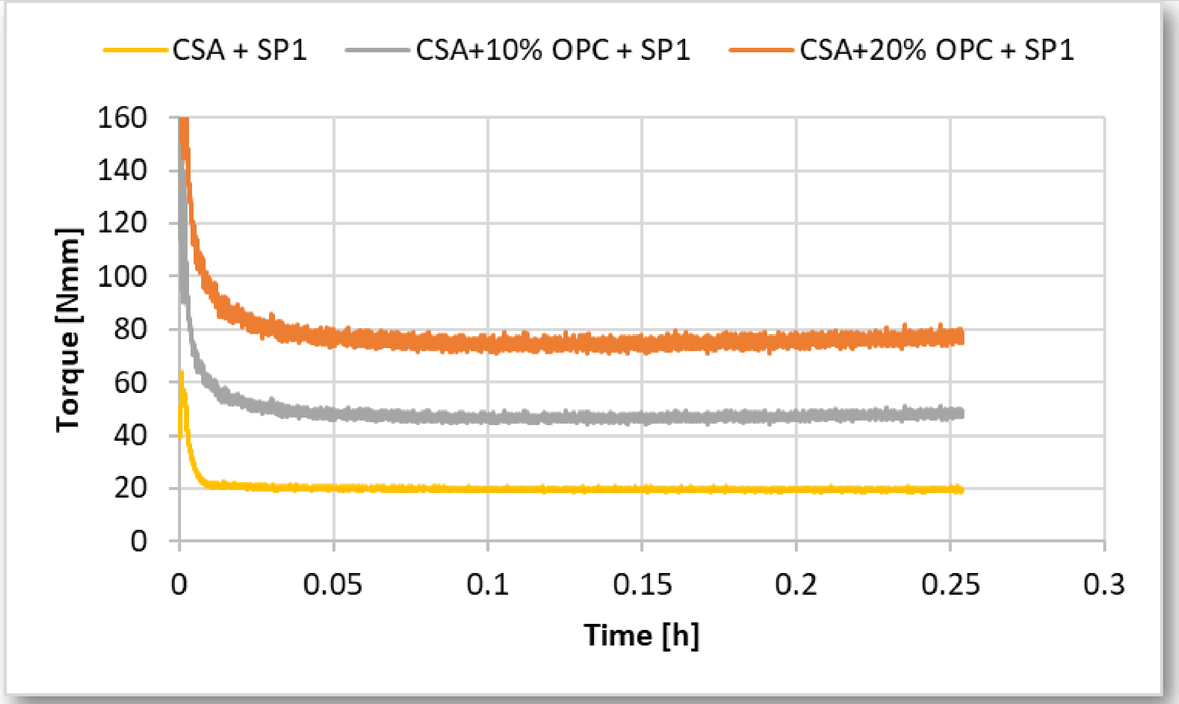
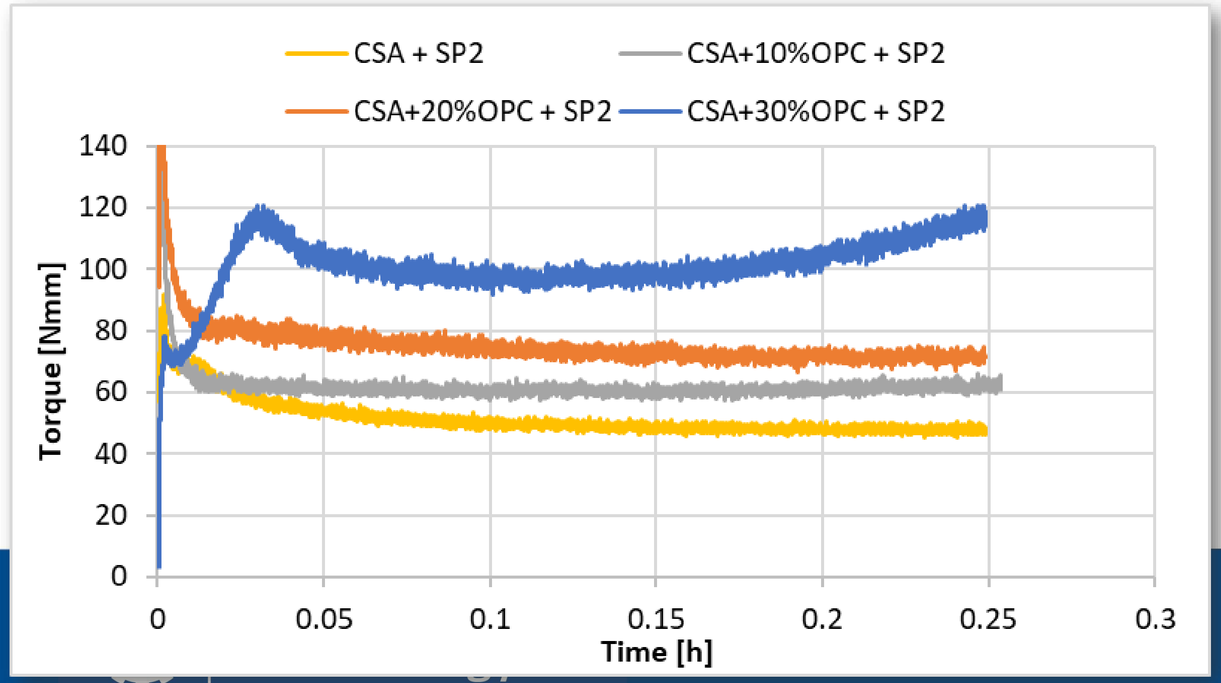


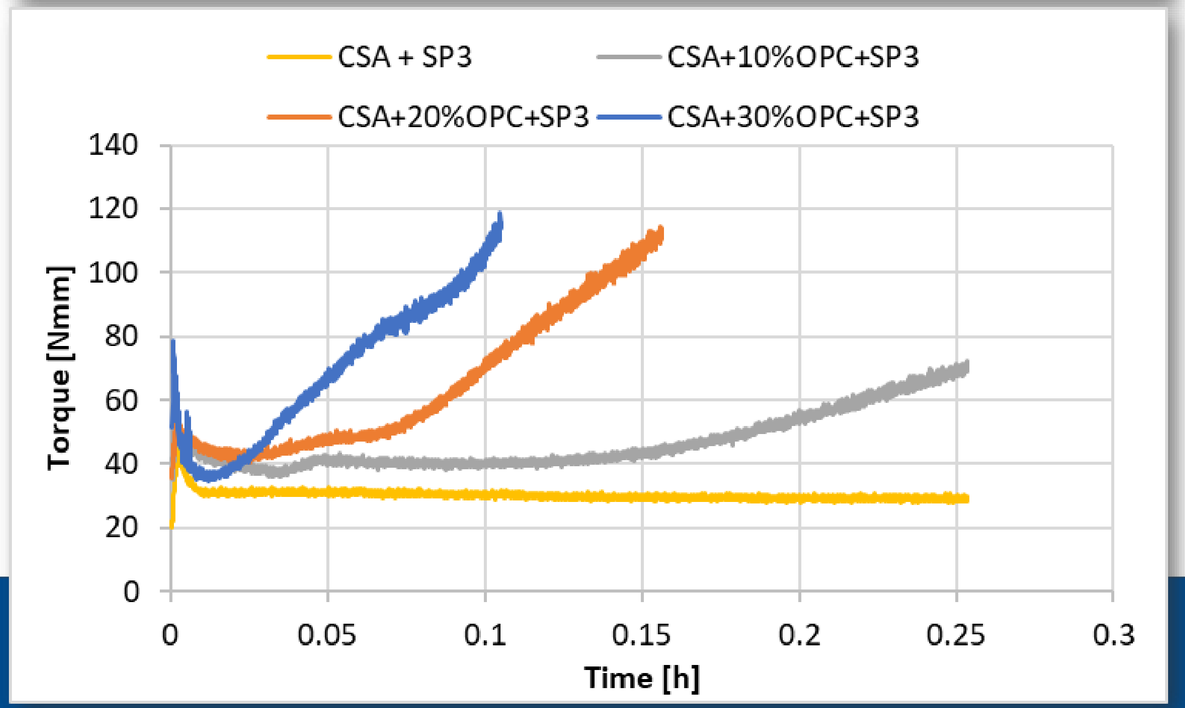


EFFECT OF SP ON CSA+OPC MIXES

Superplasticizers exhibit different effectiveness for the mortars with CSA + OPC mixes.







PART 4

CONCLUSIONS

CONCLUSIONS

- Substitution of 10-30% of CSA cement mass with OPC led to rapid loss of consistency. This effect may occur due to ‘flash setting’ of Portland cement in the presence of CSA cement. Similar effects were not observed in case of limestone or fly ash
- With increased w/c ratio decreased yield stress and plastic viscosity;
- At lower w/c ratios, the stiffening of CSA mortars after 60 min is significant
- Different types of superplasticizer are compatibile with CSA cements
- For CSA + OPC mixes, superplasticizers have different effectiveness.

THANK FOR YOUR ATTENTION

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