Federal Institute for Materials Research and Testing

„Verbesserung der Verarbeitungseigenschaften fließfähiger Betone bei wechselnden Temperaturen"

Improvement of the workability of flowable concrete at varied temperature

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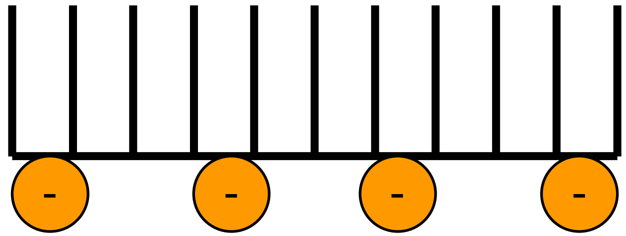
- Production of self-compacting concrete (SCC) world-wide is low and typically limited to precast industry.
- Although SCC can bring many benefits also for the construction site with ready-mix concrete, users fear the poor robustness.
- <u>Temperature effects are considered to be most critical!</u>

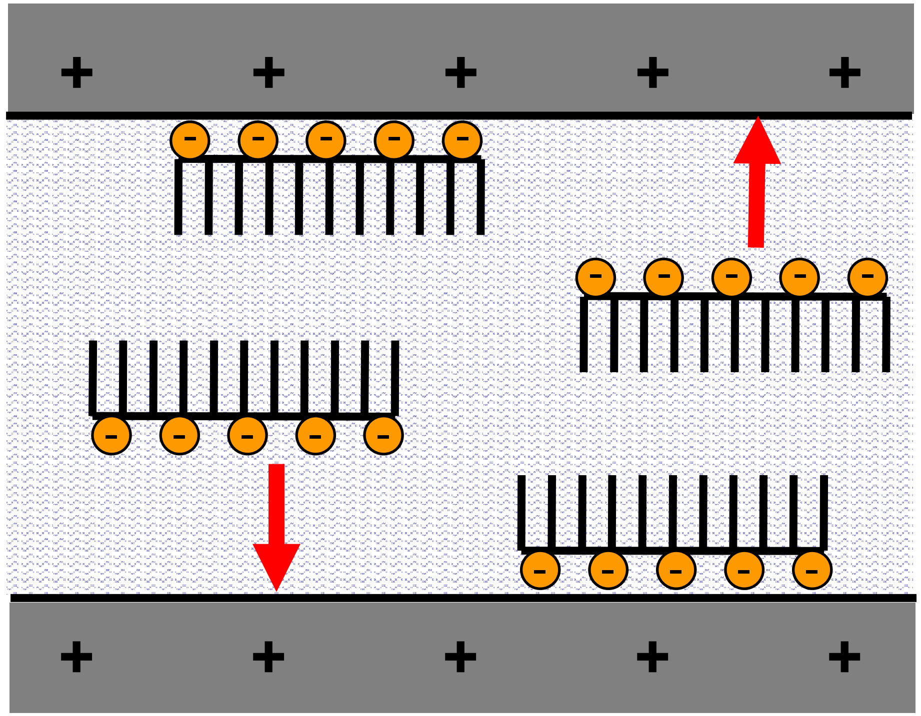
- Experiences from “normal” concrete cannot simply be applied to SCC, since significantly higher volumes of superplasticizer are required.
- Performance changes of SCC due to temperature can be attributed to a modified PCE-cement interaction.

PCE Superplasticizer

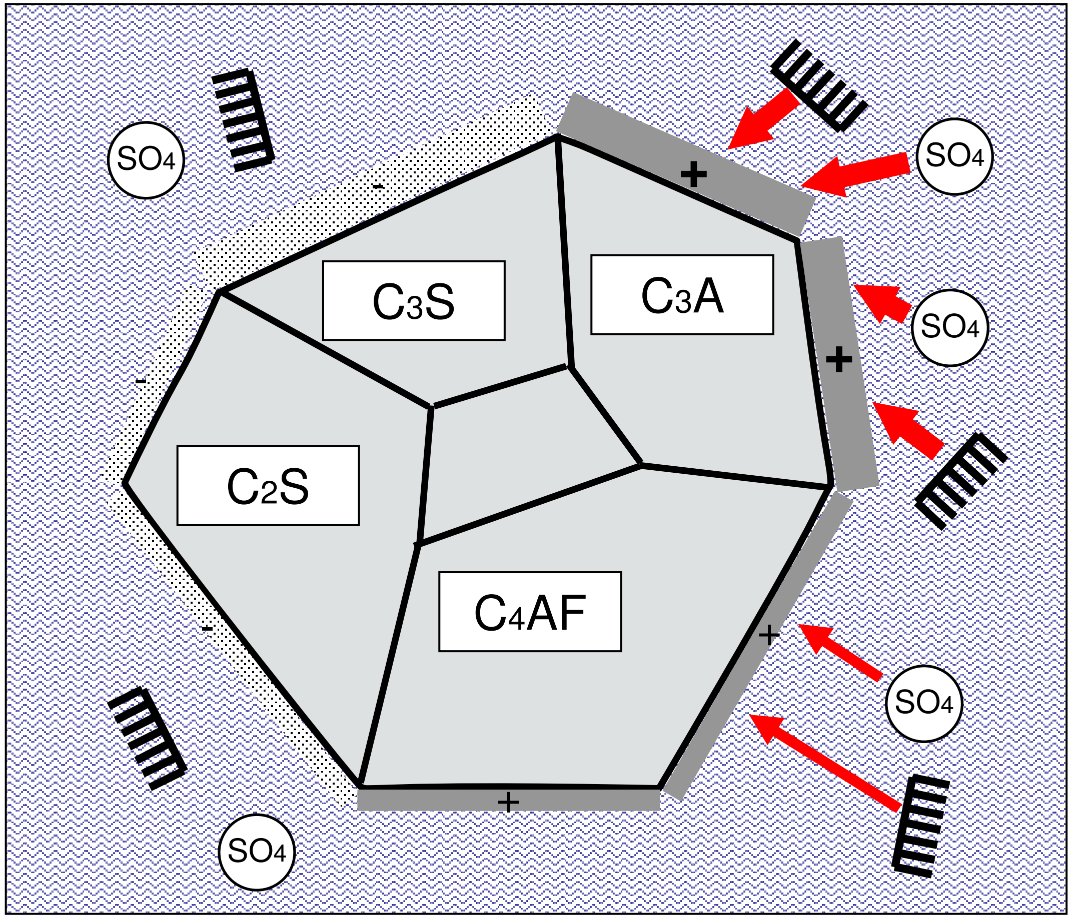
Graft chains for steric hindrance



Negatively charged backbone for adsorption



Cement-PCE-Interaction



- Different clinker phases provide different zeta potential
- PCE adsorbs on surfaces with positive zeta potential
- Competition with sulphate ions
- Sulphate and aluminate generate ettringite, which
    - causes stiffening, but
    - also provides high positive zeta potential
    - and additional adsorption space

Introduction

- Precipitation of ions and hydration speed are strongly depending on the system’s temperature.
- Adsorption and consumption of PCE determines the initial and the time dependent flow performance.
- Temperature can cause <u>both</u> effects, improved and degraded flowability!

Introduction

- Additional influencing factors resulting from the mixture composition exist, e.g.
- Type of filler
- Amount of filler
- Type of stabilising agent
- Amount of stabilising agent

→ The presented research shall highlight some of the effects with relevance for the temperature behaviour.

Experimental setup

Experimental setup

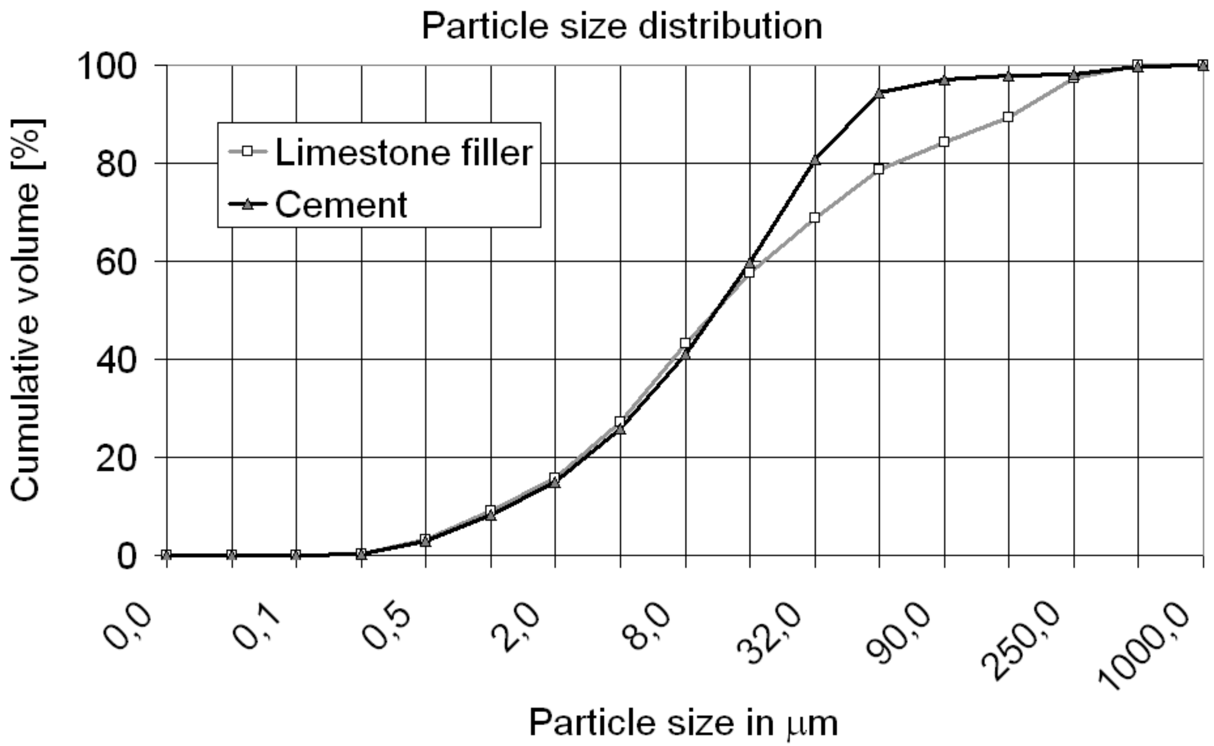
Mixture composition:

- Two characteristically differing mixture compositions
- Powder type
  - Developed according to Okamura method
  - Subsequent reduction of powder to activate stabilising agent
- Combination type
  - Stability based on higher powder content than normal concrete and stabilising agent

	Powder Type SCC	Combination Type SCC
	[kg/m³]	[kg/m³]
Ordinary Portland Cement	310	350
Limestone Filler	250	130
Water	175	175
Aggregates	1599	1679

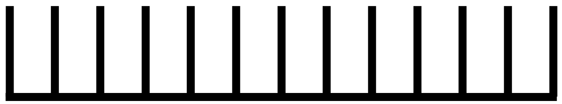
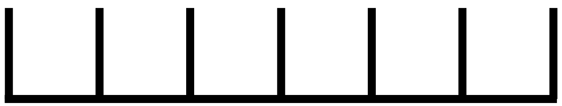
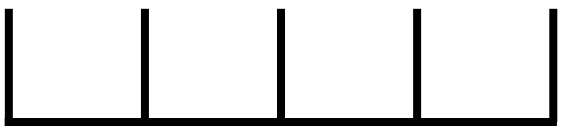
Experimental setup

Limestone filler:



Experimental setup

Aplplied polycarboxylate ether superplasticizer types:

Abbr.	Molecule	Effect
PCE1	Low anionic charge density 	▪ High polymer content required ▪ Good flow retention
PCE2	Medium anionic charge density 	▪ Medium polymer content required ▪ Medium flow retention
PCE3	High anionic charge density 	▪ Low polymer content required ▪ Poor flow retention

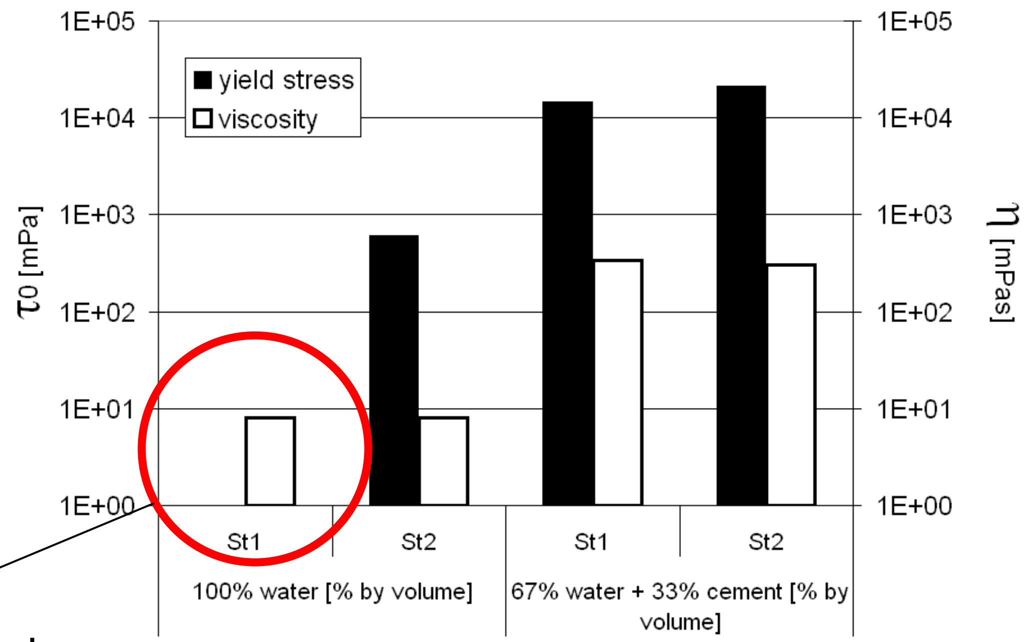
Experimental setup

Stabilising agents:

- Two differently operating stabilising agents
  - St1 (starch ether)

    → Immobilisation of particles
  - St2 (biopolymer)

    → Increase of yield stress and viscosity of fluent phase



St1: No yield stress with water only

Experimental setup:

2 Mixture compositions
3 PCE types
2 Stabilising agents

→ 12 particular SCC/admixture variations

→ Adjustment criterion:

At 20 °C: Slump flow between 650 and 700 mm
30 minutes after mixing

- At varied temperature no further admixture adjustment was conducted.

Experimental setup

Equipment used for demonstrated results:

Paste flow tests with
Hägermann cone

Slump flow tests according to
prEN 12350-8

Experimental setup

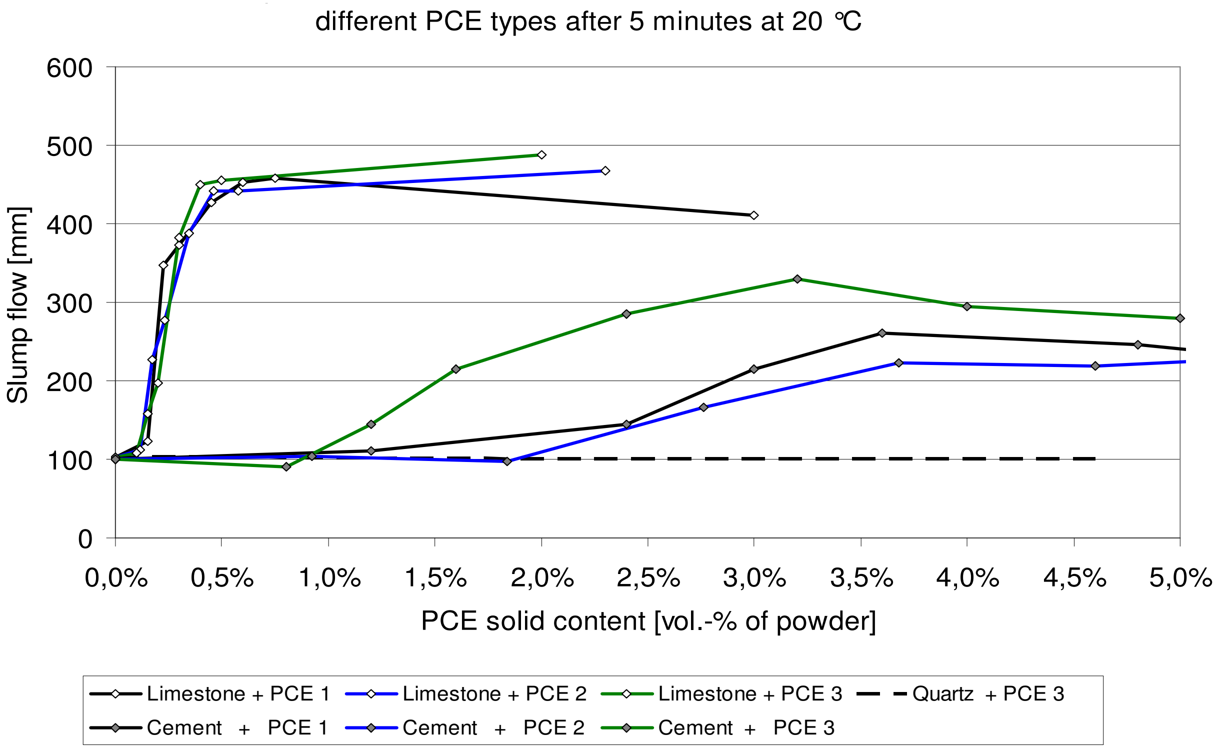
Equipment used for demonstrated results:

Sieve segregation test according to prEN 12350-11

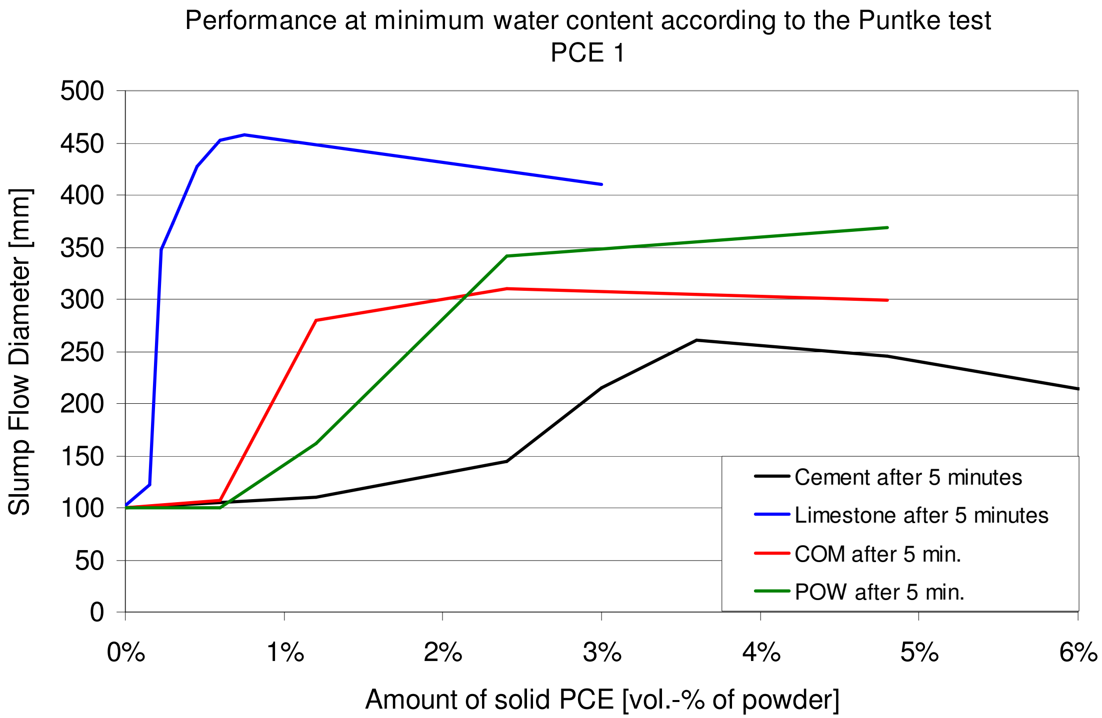
CONTEC Rheometer-4SCC

Influence of filler type

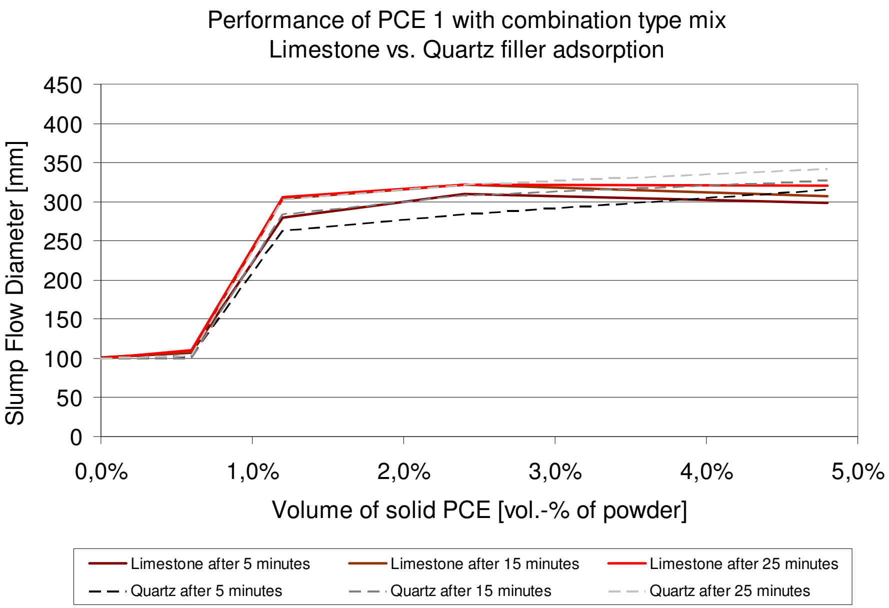
PCE adsorption on limestone filler and cement

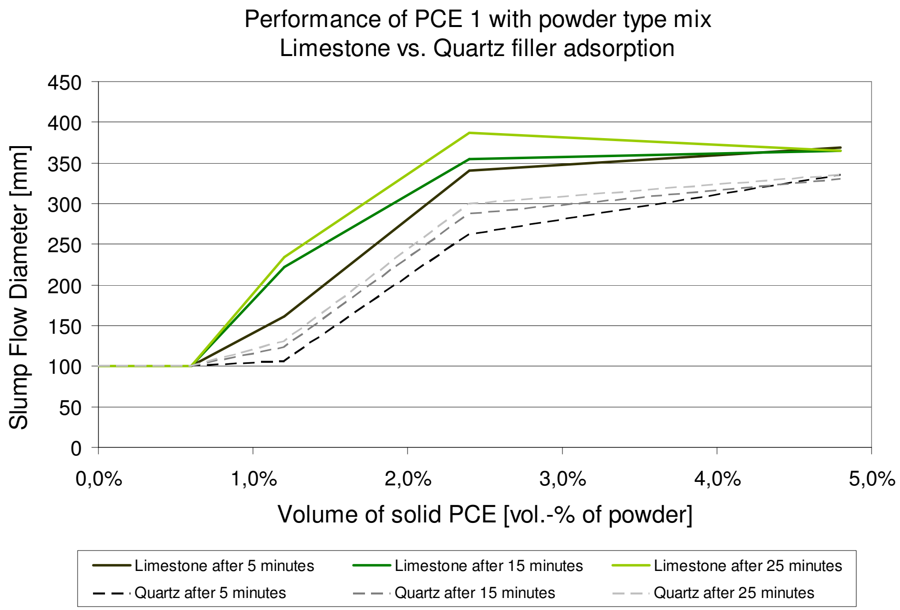


Impact of PCE-limestone adsorption on binder flow

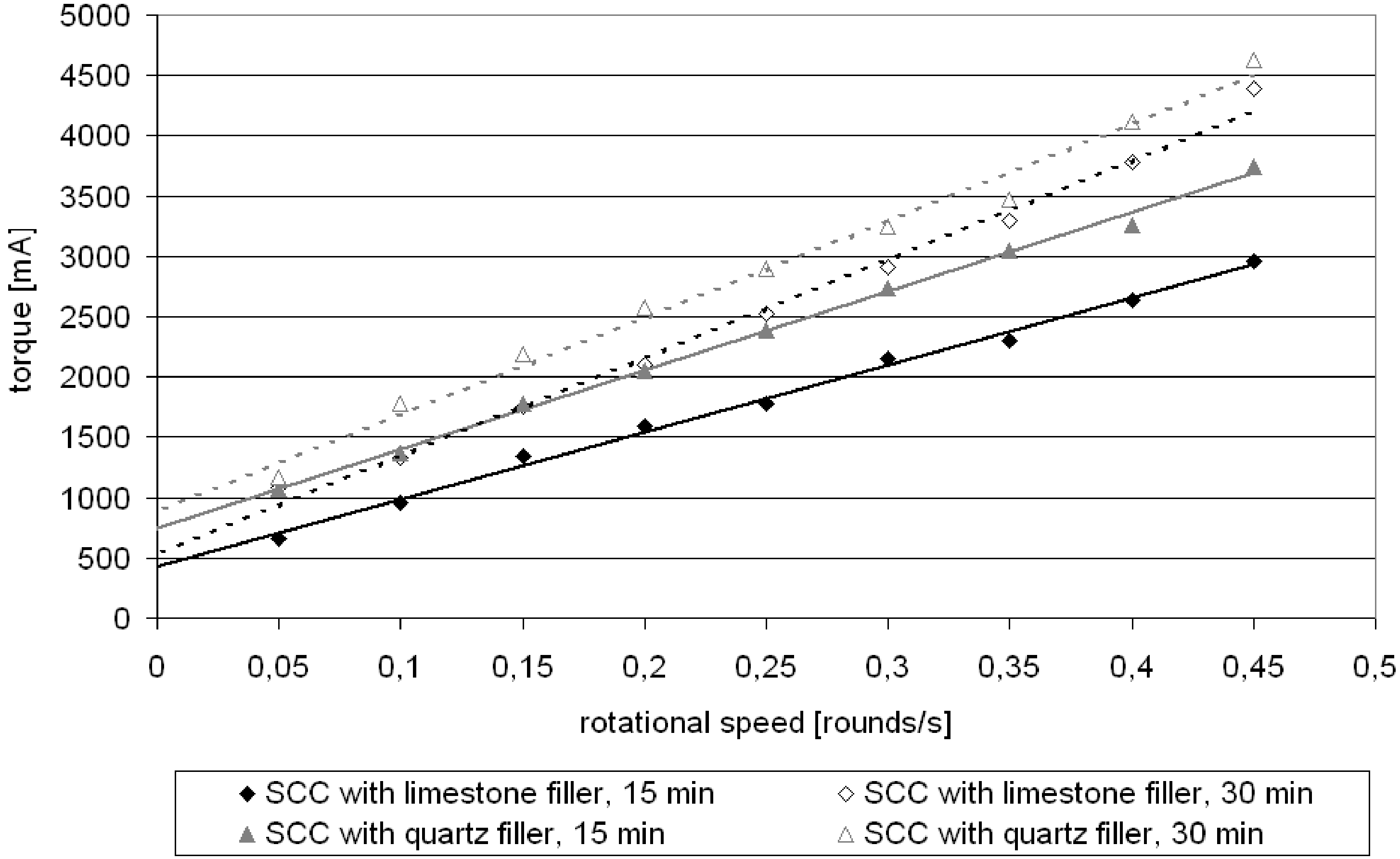


Impact of PCE-limestone adsorption on binder flow





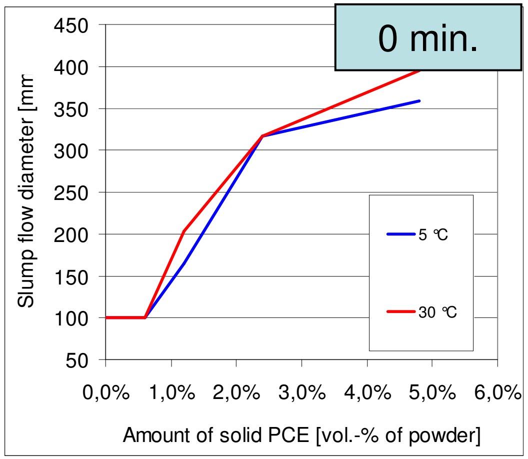
Impact of PCE-limestone adsorption on concrete flow

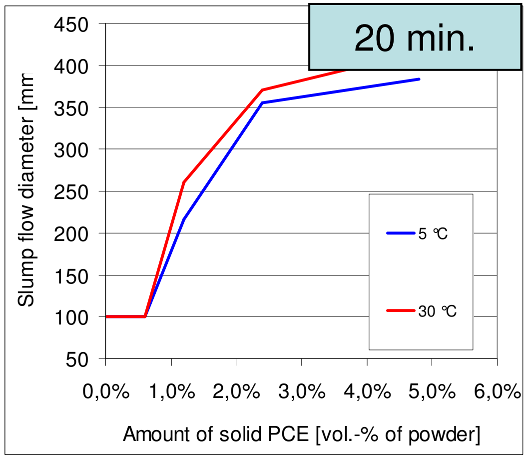


Influence of limestone filler

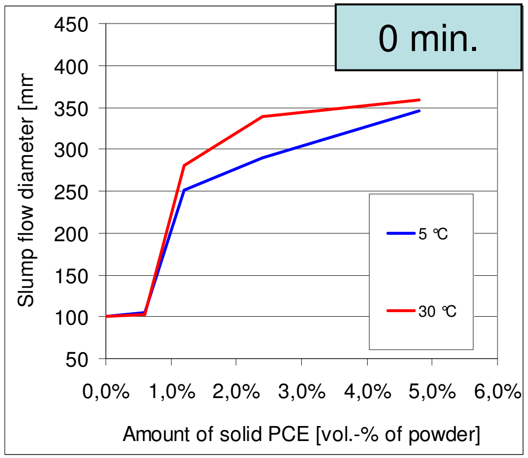
Impact of PCE-limestone adsorption and temperature on binder flow

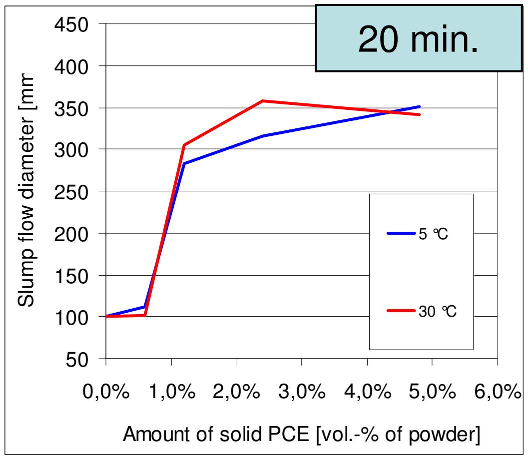
Powder type





Combination type





Influence of limestone filler

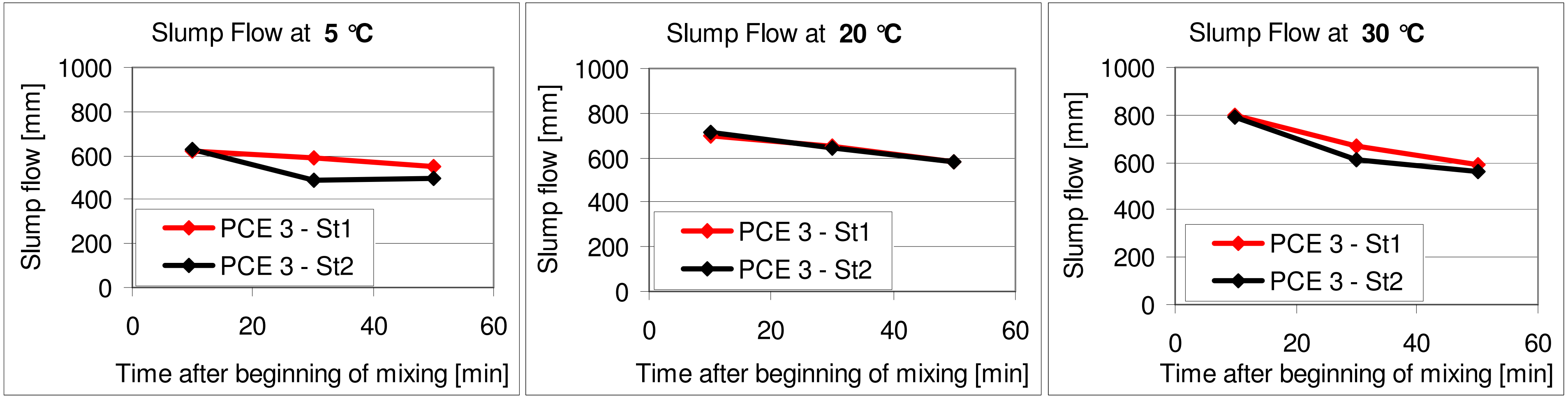
Interim results:

- The PCE-limestone filler interaction can improve flow properties in general.
- Since limestone is less reactive than cement, this interaction can help absorbing negative effects caused by temperature on cement-PCE interaction.

Influence of Stabilising Agent

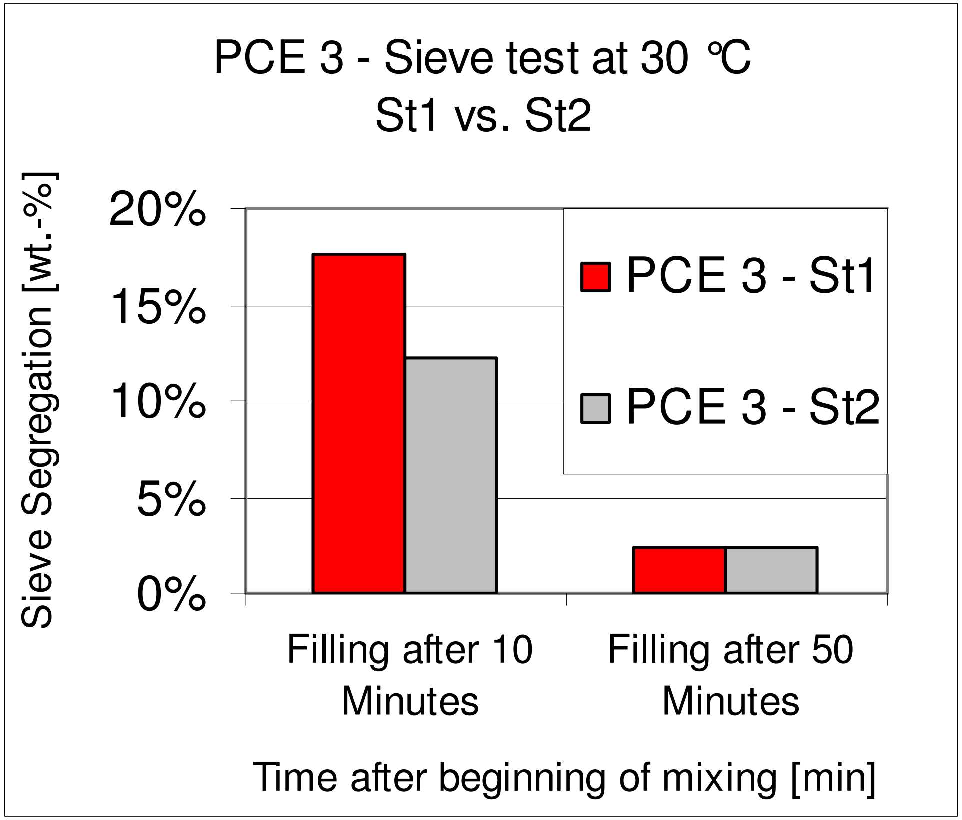
Influence of stabilising agent

Influence of temperature and stabiling agent



Influence of stabilising agent

Influence of VEA at 30 °C



Concrete with St1 at 30 °C after 10 min.

Concrete with St2 at 30 °C after 10 min.

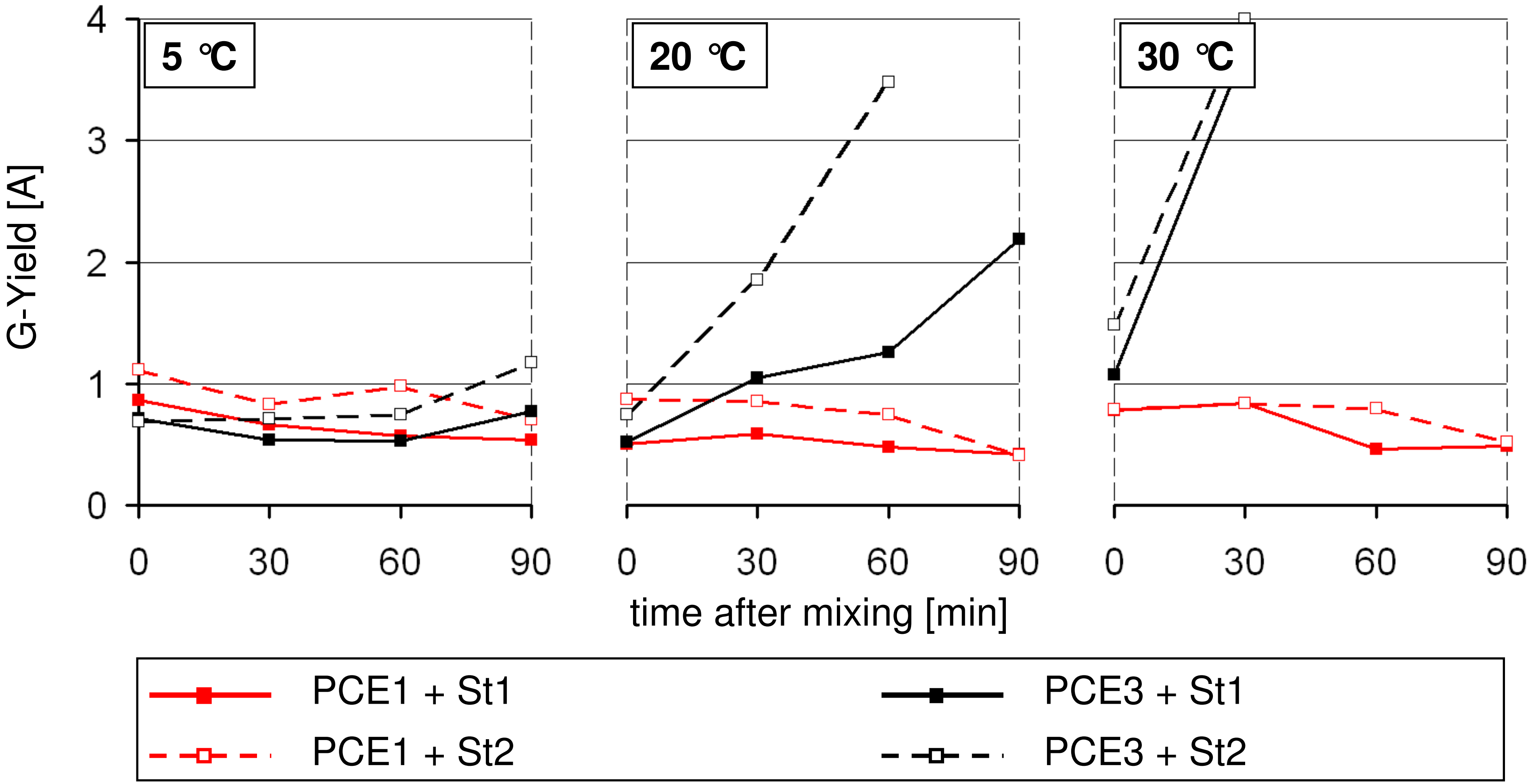
Interim results:

- Effects of stabilising agent type can be prominent when temperatures vary.
- Stabilising agents do not inevitably increase the robustness against temperature effects.
- In the presented results, starch ether seemed to be less affected by varied temperature than the biopolymer, however
  - it also increased the early segregation risk at high temperature.
  - at cold temperatures, when setting is retarded, segregation cannot be excluded.

Influence of PCE type

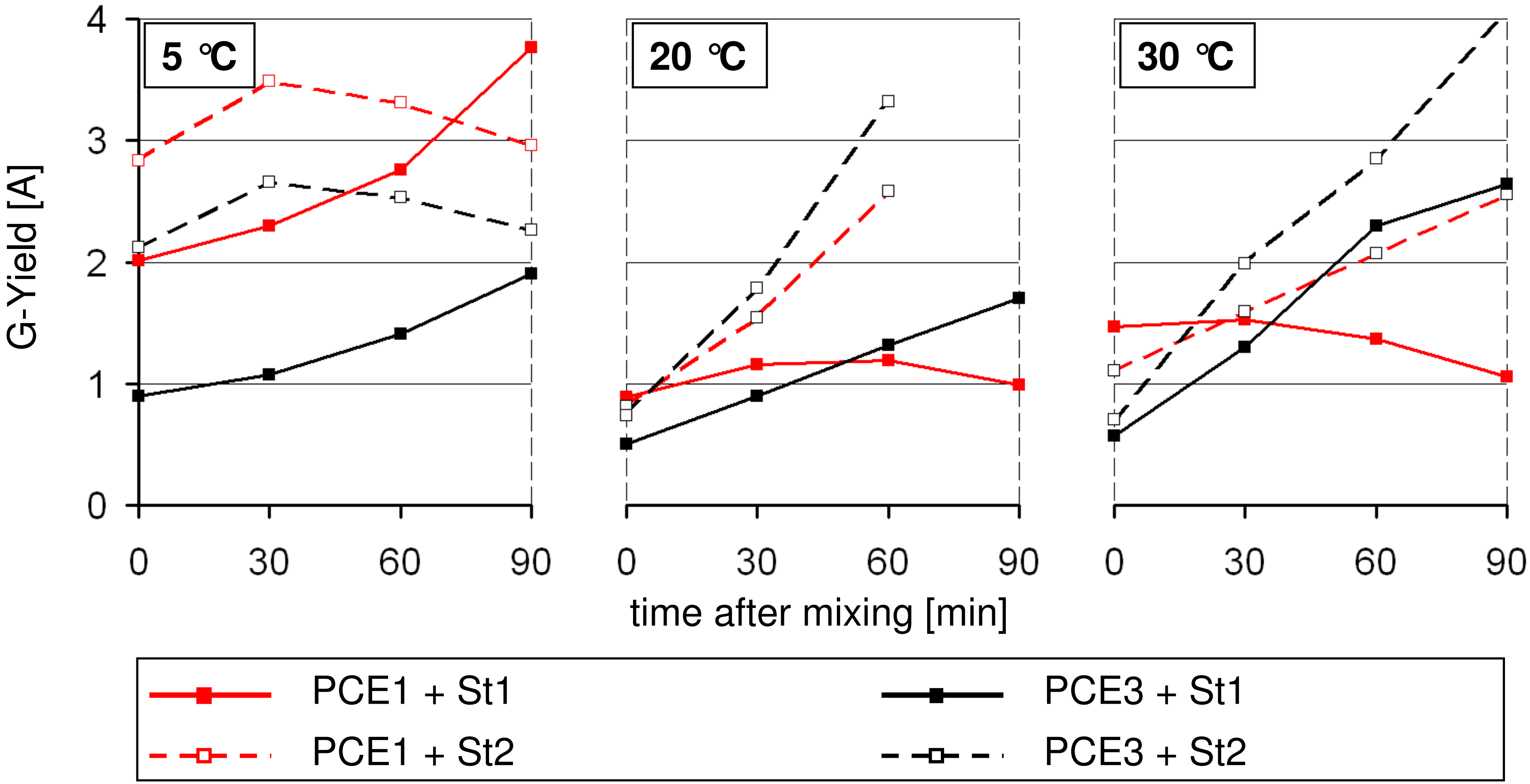
Influence of PCE

Powder type SCC



Influence of PCE

Combination type SCC



Influence of PCE

Interim results:

- Powder type SCC:
  - Temperature effects are caused mainly by PCE type.
  - High robustness against PCE effects at low temperature
  - Poor robustness against PCE effects at high temperature
- Combination type SCC:
  - Temperature effects are caused by PCE and stabilising agent.
  - Effects of PCE and stabilising agent superpose
  - At low temperatures, a high charge backbone polymer is required
  - At high temperatures the robustness against PCE type effects is higher than of powder type SCC

Conclusions and recommendations

Conclusions

- Limestone filler (or other additions that interact with PCE) can help improving the robustness against temperature variations.
- Stabilising agents can have a strong impact on the temperature dependent performance.
- Effects of stabilising agent and PCE superpose each other.
- The temperature dependent PCE cement interaction is strongly depending on the ionic strength of the backbones.
- Depending on PCE type and mixture composition, cold as well as warm temperatures, can increase or decrease flow properties.

Recommendations

At given PCE:

- At low temperatures, the powder type SCC provides high robustness.
- At high temperatures, the combination type SCC provides higher robustness than the powder type.

If PCE can be adjusted:

- At low temperatures, a high backbone charge density PCE should be chosen in order to provide good flow properties at all.
- At high temperatures, a low backbone charge density PCE should be chosen, when performance retention is required.

Thank you very much

for your kind attention!