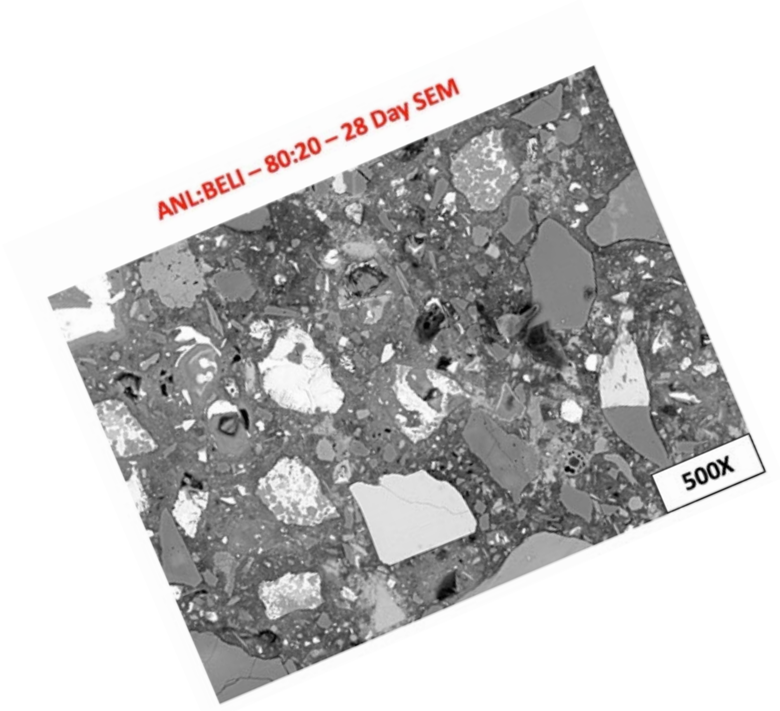
Calcium Sulphoaluminate Cements (CSA) for sustainable shotcreting – pre-study

Kalciumsulfoaluminatcement (CSA) för hållbar sprutbetong – förstudie



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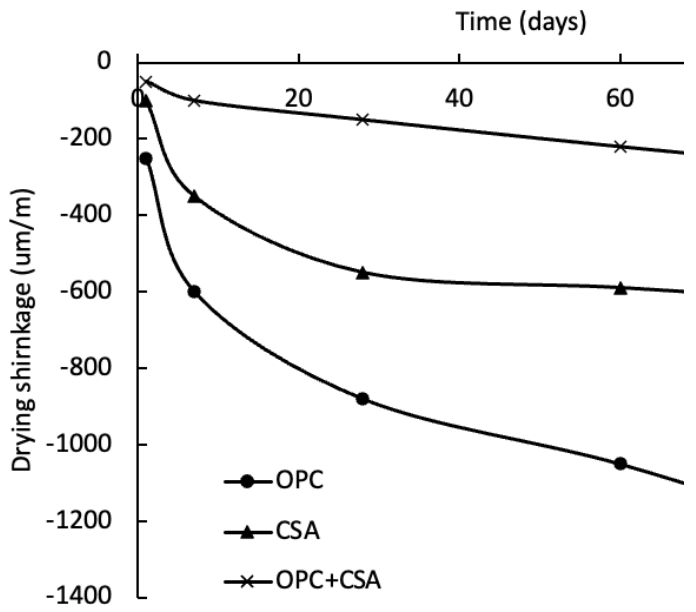
Literature study

Advantages of CSA cements in comparison with OPC :

- Over 30% reduction of the CO_2 footprint
- Shorter initial and final setting times
- Very fast strength development
- Improved adhesion bond between substrate and shotcrete, enabling shotcreting of thicker layers
- Possibility to fully mitigate drying shrinkage by the partial replacement of OPC with CSA.
- Lower crack risk of shotcrete
- Less rebound while shotcreting
- Faster strength development when cured at subfreezing temperature
- Possibility to exclude additional treatments when casting at -5°C
- Lower drying creep



Literature study

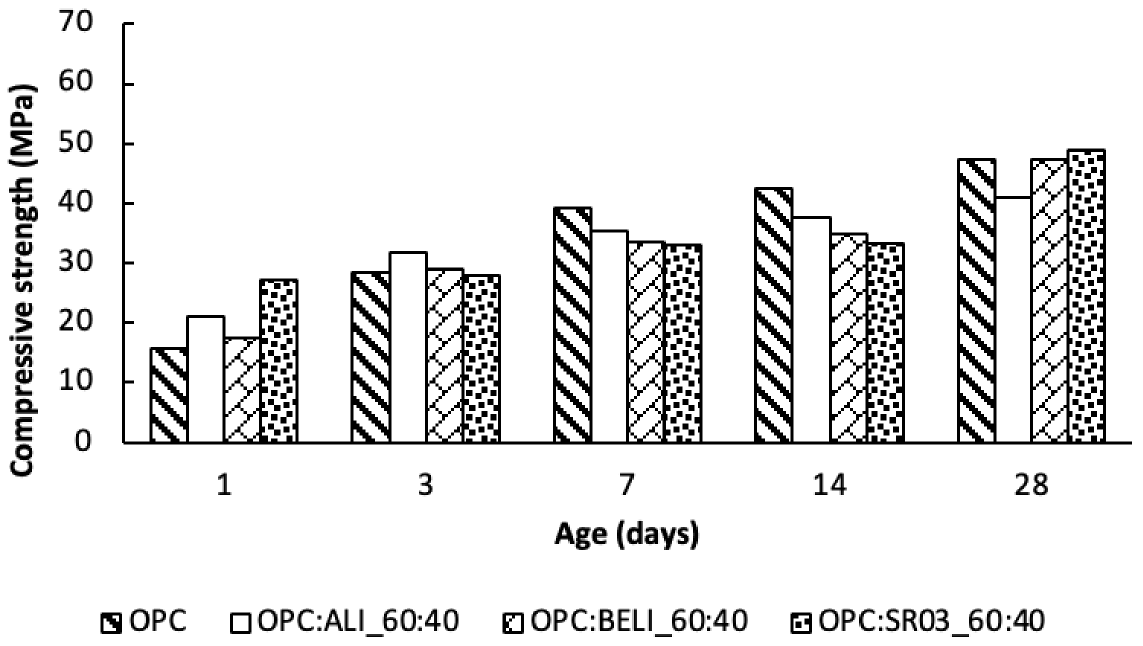
Disadvantages of CSA cements in comparison with OPC:

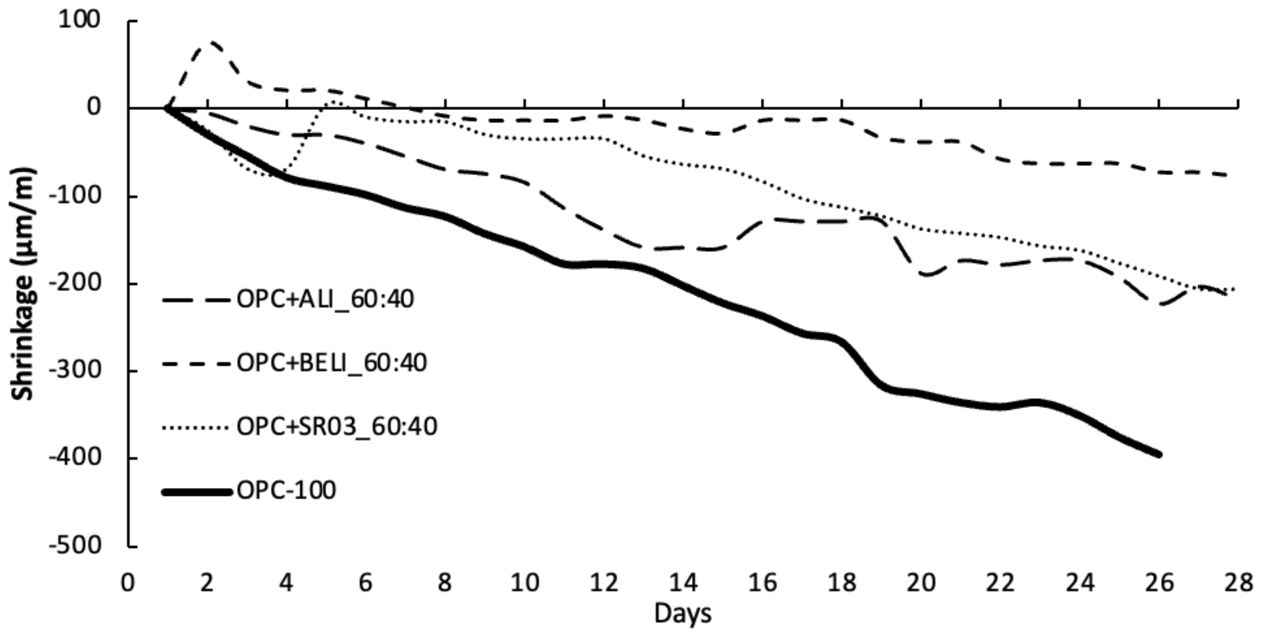
- Higher price compared to OPC
- Strong dependence of fresh and hardened concrete properties on the amount of added gypsum, which in addition to potential benefits can also cause problems if not handled properly
- Limited availability of raw materials containing aluminum
- Lower pH of the pore solution
- Lower strength when exposed to high temperatures
- Possibly a slightly higher risk of reinforcement corrosion in concretes containing only CSA cement, but lower in comparison with ecological concretes containing OPC with limestone
- Possibly worse frost durability of some mixes containing CSA
- Possibly increased risk of the delayed Ettringite formation

Laboratory testing

(selected results)

- Partial replacement of OPC with CSA cement shortened the initial setting time significantly, in the most extreme case from 187 minutes (for OPC) to 4 minutes (for mix containing 40 wt.% of CSA BELI cement).
- The maximum compressive strength and the compressive strength development were comparable between all tested binder combinations.
- The drying shrinkage was reduced by up to 80% when 40 wt.% of OPC was replaced with CSA BELI cement.

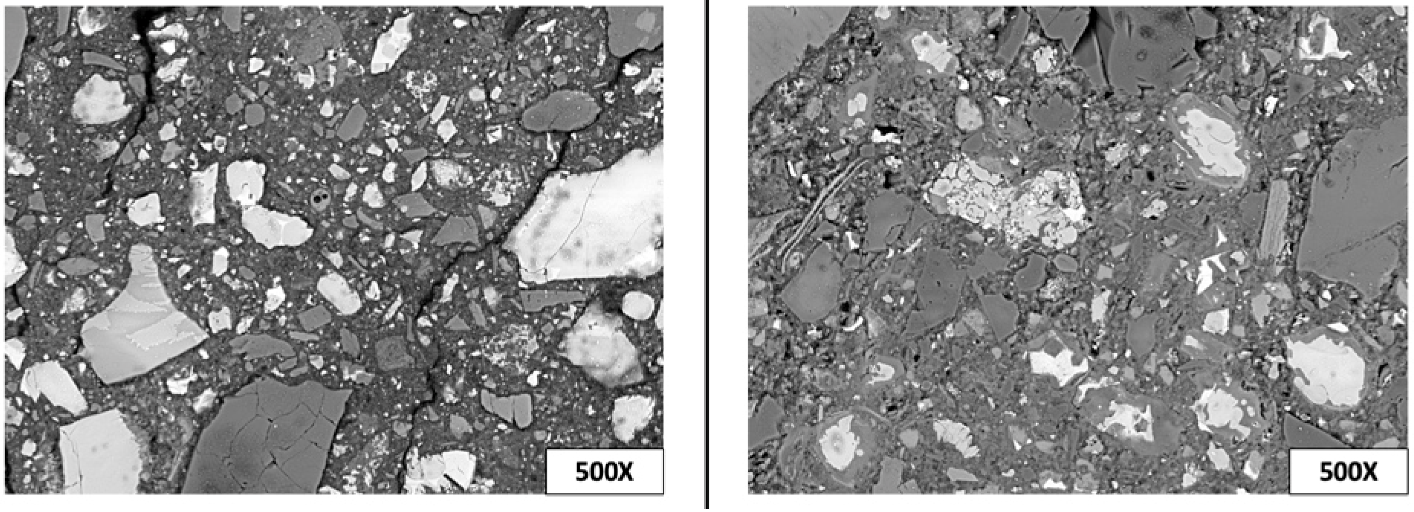




Laboratory testing

(selected results)

- On the contrary the shrinkage increased by up to 178% when 20 wt.% of OPC was replaced with CSA ALI cement.
- The microstructure of the solidified binder matrixes appeared to be dense and homogenous for all concretes containing CSA cements. No enhanced macrocracking or ITZ having increased porosity were observed.



SEM images at 500X magnification of concretes based on hybrid OPC/CSA binder. Left 60 wt.% of OPC + 40 wt.% of ANL:ALI, right 80 wt.% of OPC + 20 wt.% of ANL:ALI

Sustainability

- The CO_2 footprint of concretes containing CSA cements was reduced by up to 28%

Mix	OPC (kg/m³)	OPC ($kgCO_2/m^3$)	CSA - type	CSA (kg/m³)	CSA ($kgCO_2/m^3$)	Total ($kgCO_2/m^3$)	Reduction (%/m³)
OPC	430	337	Anl	0	0	337	0
OPC:BELI_80:20	344	269	BELI	82	19	290	-14
OPC:BELI_60:40	258	202	BELI	172	40	242	-28
OPC:ALI_80:20	344	269	ALI	82	19	290	-14
OPC:ALI_60:40	258	202	ALI	172	40	242	-28
OPC:SR03_80:20	344	269	SR03	82	19	289	-14
OPC:SR03_60:40	258	202	SR03	172	40	242	-28

- Costs for replacing OPC with CSA cement varied between an increase by 78% and a reduction by 24%.

Mix	OPC (kg/m³)	Price (€/m³)	CSA-type	CSA (kg/m³)	Price (€/m³)	Total price (€/m³)	Difference (%)
OPC	430	473		0	0	473	0
OPC:ALI_80:20	344	378	ALI	86	123	501	+6
OPC:ALI_60:40	258	284	ALI	172	246	530	+12
OPC:SR03_80:20	344	378	SR03	86	89	468	-1
OPC:SR03_60:40	258	284	SR03	172	179	463	-2

Mix	OPC (kg/m³)	Price (€/m³)	CSA-type	CSA (kg/m³)	Price (€/m³)	Total price (€/m³)	Difference (%)
OPC	430	65		0	0	65	0
OPC:BELI_80:20	344	52	BELI	86	38	90	+39
OPC:BELI_60:40	258	39	BELI	172	76	115	+78

Future research and open questions

- How autogenous shrinkage develops in the first minutes after shotcreting?
- How shotcreting conditions affect shrinkage?
- What is the risk of cracking in various conditions and for different binder combinations?
- How CSA influences fresh concrete properties, which are specific for shotcreting, e.g., rebound, dusting, bond strength with substrate, maximum layer thickness?
- Is it possible to delay setting after mixing and before shotcreting operation?
- Is it possible, technologically, and logistically, for the contractor to add anhydrite on-site?
- How addition of various fibers affects properties of CSA/OPC concretes?
- How the partial replacement of OPC with CSA affects durability structure, especially including frost, fire, carbonation, chloride penetration, reinforcement corrosion, alkali silica reaction?
- Is it possible to produce shotcrete incorporating OPC+CSA and certain industrial and communal wastes to reduce its price and to enhance sustainability?
- What are advantages and possible problems (application technology, sustainability, price, and durability) related to the usage of SCMs in OPC+CSA systems.