Properties of Solidia® Cement and Concrete

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Solidia Cement®: a Low-Calcium Silicate Cement (CSC)

Who is Solidia®?

A cement and concrete technology company:

1. **A low-carbon, non-hydrating binder that reacts with CO_2**
2. **Concrete curing technology enabling carbonation of concrete**

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Solidia Technologies Solution

- Same raw materials

- Same kiln

- Same mix components
- Same mixer
- Same cycle time

- Same forming casting
- Same cycle time

- CO_2-Curing
- Reduced curing times (24 hours vs. 28 days)

Solidia Cement™

CO_2 emissions at cement plant reduced by 250 kg (per ton of clinker)

Solidia Concrete™

Up to 300 kg of CO_2 permanently stored in concrete (per ton of cement used)

From partnership to commercial agreement

Partnership LafargeHolcim / Solidia Technologies

- Step 1 – August 2013: JDA between Lafarge and Solidia Technologies
- Step 2 – January 2015: Commercial agreement

Commitments Lafarge/Solidia : 5 + 5 years

Feasibility study
Pilot trial
August 2013

Industrial Demonstration
March 2014

Business Model (binder)
January 2015

Commercial agreement
December 2016

20t IbuTec

5000t WHL

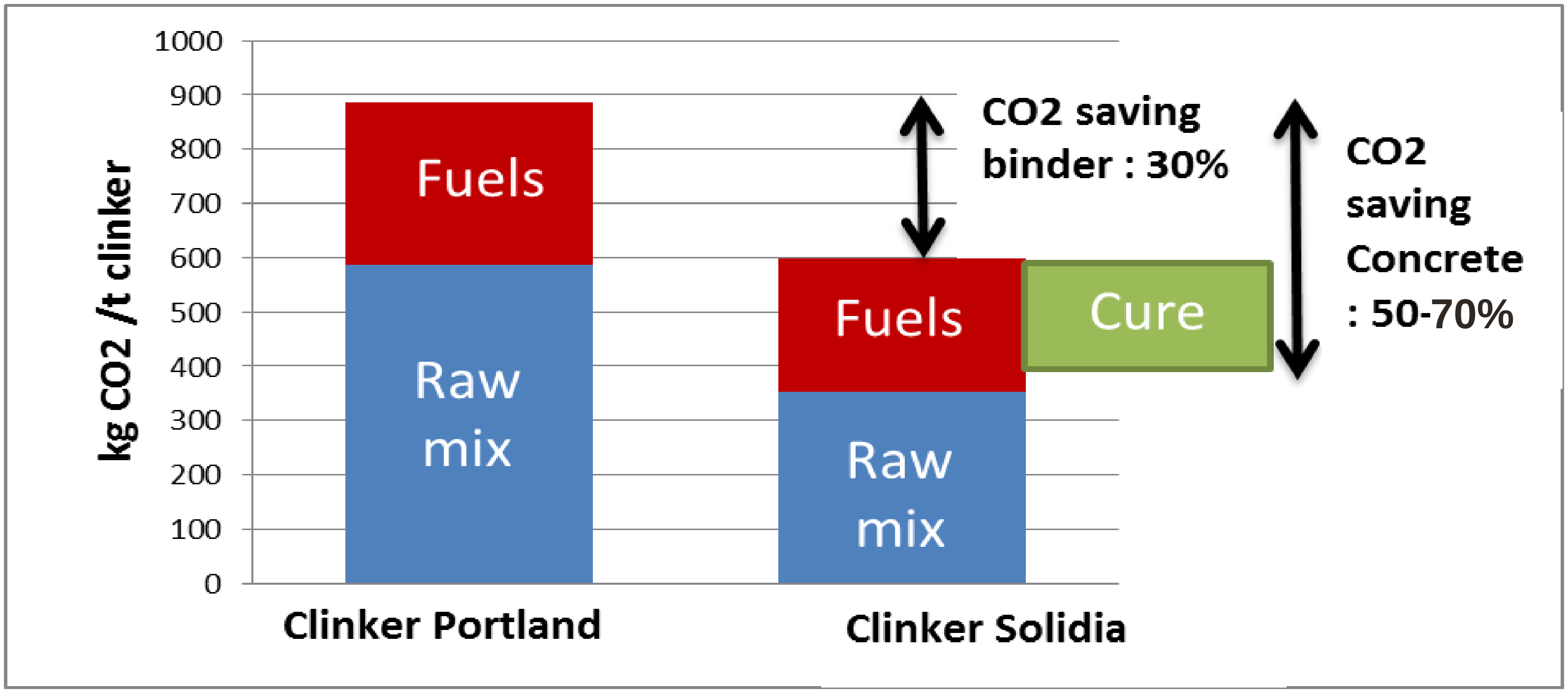
5000t PECS

5000t WHL

Solidia® Solution

Technical solution: CO_2 emissions reductions

- Clinker composition: Wollastonite (CS), Rankinite (C_3S_2) & Belite (C_2S)
  - Different raw mix: Target – 1:1 C/S molar ratio ➔ less limestone used
  - Lower clinkering T°C than for OPC: 1250°C // 1450°C



Solidia Cement production

Cement production in Whitehall plant (USA)

- Raw materials used are available in the quarry:
  - Quarry rock: limestone containing some silica and minor elements (Al_2O_3, Fe_2O_3, MgO, SO_3)
  - Sand: mainly SiO_2
- Fuels used: Petcoke / Coal / Plastics
- 4-stage preheater kiln

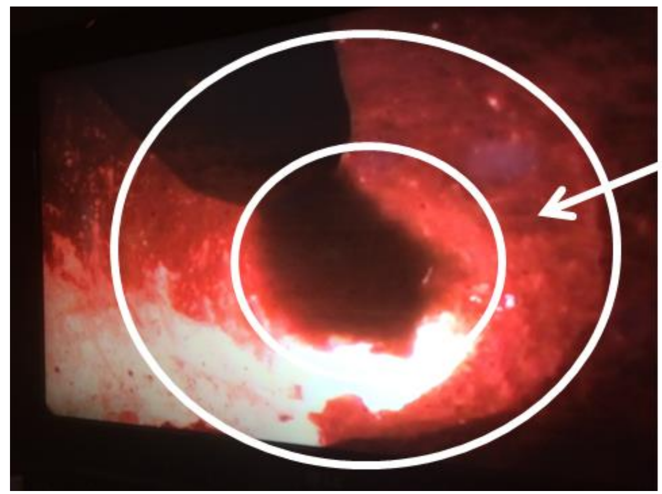
		PC clinker	Solidia Clinker
Period		Normal production	Stable production period
Specific heat consumption (SHC)	GJ/t ck	3.89	3.16
Stack CO_2	%	24.4	14.2
CO_2 emissions	Nm^3/t ck	474	334

30% emissions reductions

Solidia Cement production

Cement production in Whitehall plant (USA)

- Potential future improvements:
  - Throughput of the kiln need to be optimized
  - Different behaviour in the kiln than OPC clinker
    - New operational conditions to follow
    - Clinkering habits to be adapted and changed
  - Good compromise to be found in between quality and behavior in the kiln
    - Avoid over burning ➔ rings formation
    - Potential kiln stops
  - Grindability equivalent to OPC
- **Even all these production aspects, this first industrial trial proved 30% CO_2 emissions reduction**



Ring formed and gummy material going through

Solidia Concrete

CO_2 footprint reduction due to concrete uptake

- Two applications tested:
  - Pavers
  - Hollow cores

Press machine

Fresh Solidia Concrete

CO_2 curing

Fresh Solidia Concrete in contact with CO_2 (24h)

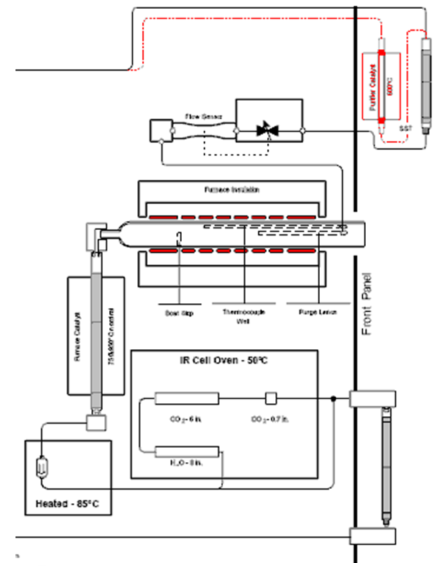
Solidia Concrete

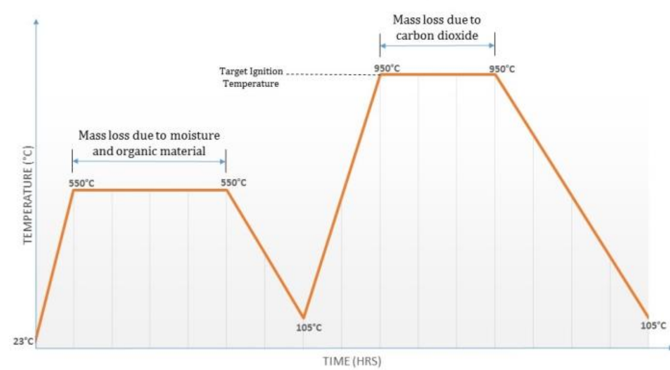
CO_2 footprint reduction due to concrete uptake

- Carbonation efficiency followed by mass gain (CO_2 uptake)

Concrete Product	Mass Gain (CO_2 uptake), %
Paver	3.4
Hollow Core	3.3

- Lab C and H measurements in a oven coupled to IR cell vs. temperature profile

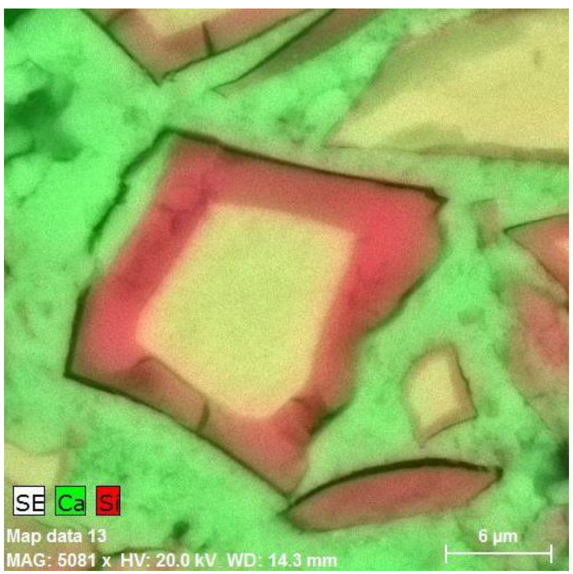




CS = $CaSiO_3$

Si = Silica

Ca = $CaCO_3$



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Solidia Concrete

Total CO_2 savings

Concrete Product	Mass Gain (CO_2 uptake), %	CO_2 Sequestered/t of Cement	CO_2 Savings/t of Cement	Total CO_2 Savings/t of Cement	Total CO_2 Savings, % (vs. 810kg for OPC)
Paver	3.4	236 kg	245 kg	481 kg	**59.4**
Hollow Core	3.3	220 kg	245 kg	465 kg	**57.4**

CO_2 captured in the concrete

CO_2 saved during clinker production

Two applications within the CO_2 savings announced were proved

Concrete mixes for creep, frost scaling and taber abrasion at BRE (source Solidia)

Mix constituent	PC reference specimens (reference concrete mix)	Solidia binder specimens (test concrete mix)
SC PECS (Solidia Cement) (kg/m^3)	-	350
PC (kg/m^3)	350	-
Construction. Sand (kg/m^3)	821	821
5/10 mm Coarse aggregate (kg/m^3)	414	414
20/10 mm Coarse aggregate (kg/m^3)	737	737
Water (kg/m^3)	136	136
w/c	0.39	0.39

bre

Compression creep BS ISO 1920-9:2009

- Specimens in rigs loaded to 30% of failure load
- 3 rigs per mix type
- Load maintained over 3 months
- “unloaded” specimens to correct strains to allow for drying shrinkage

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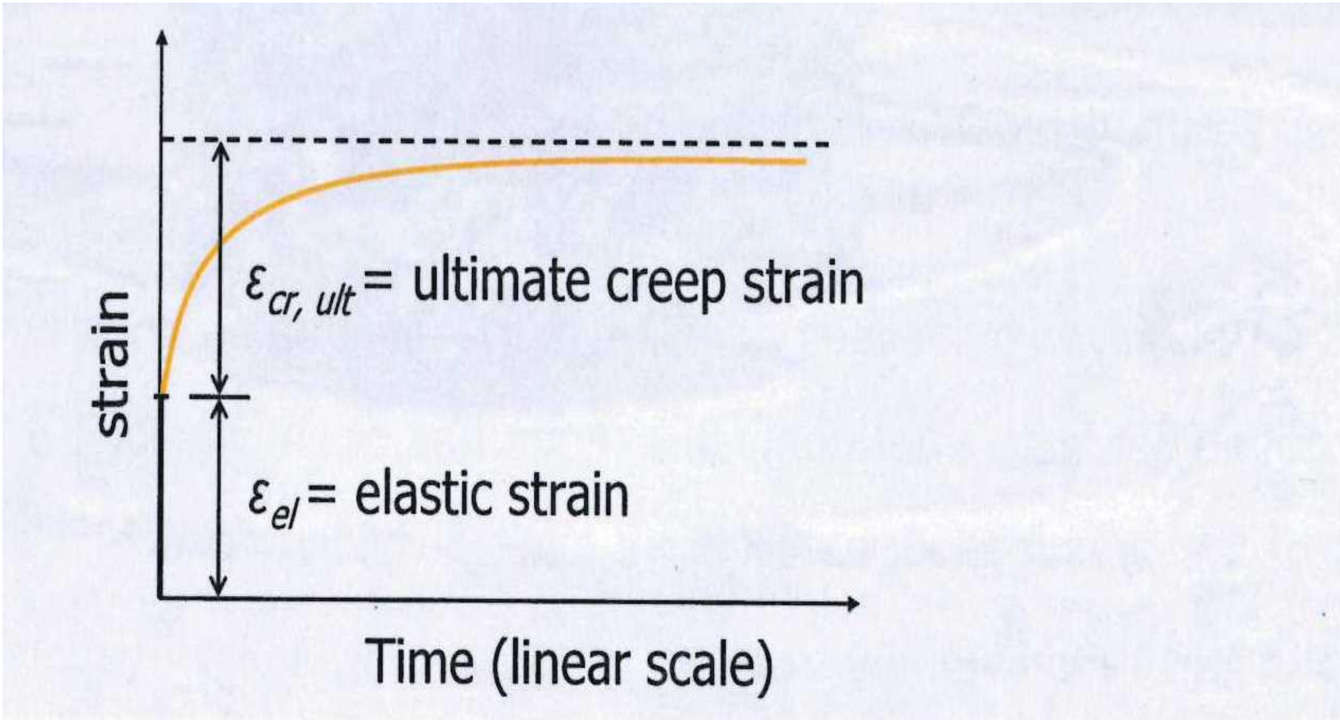
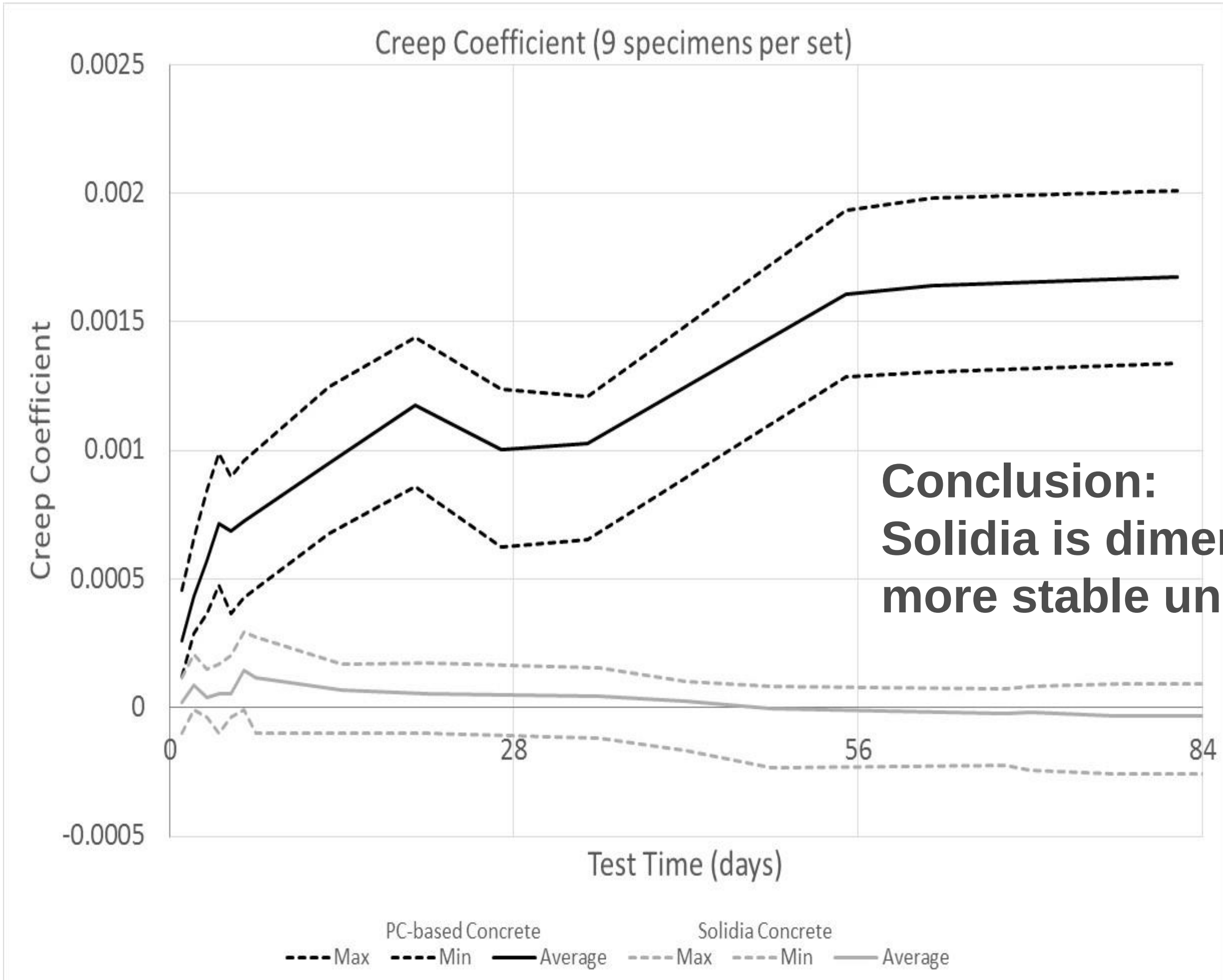
Creep coefficient



Variation of strain with time for concrete under compression

– The ratio of the <u>ultimate creep strain</u> to the <u>elastic strain</u> is the **creep coefficient θ**

Creep Test Results



Conclusion:
Solidia is dimensionally more stable under load

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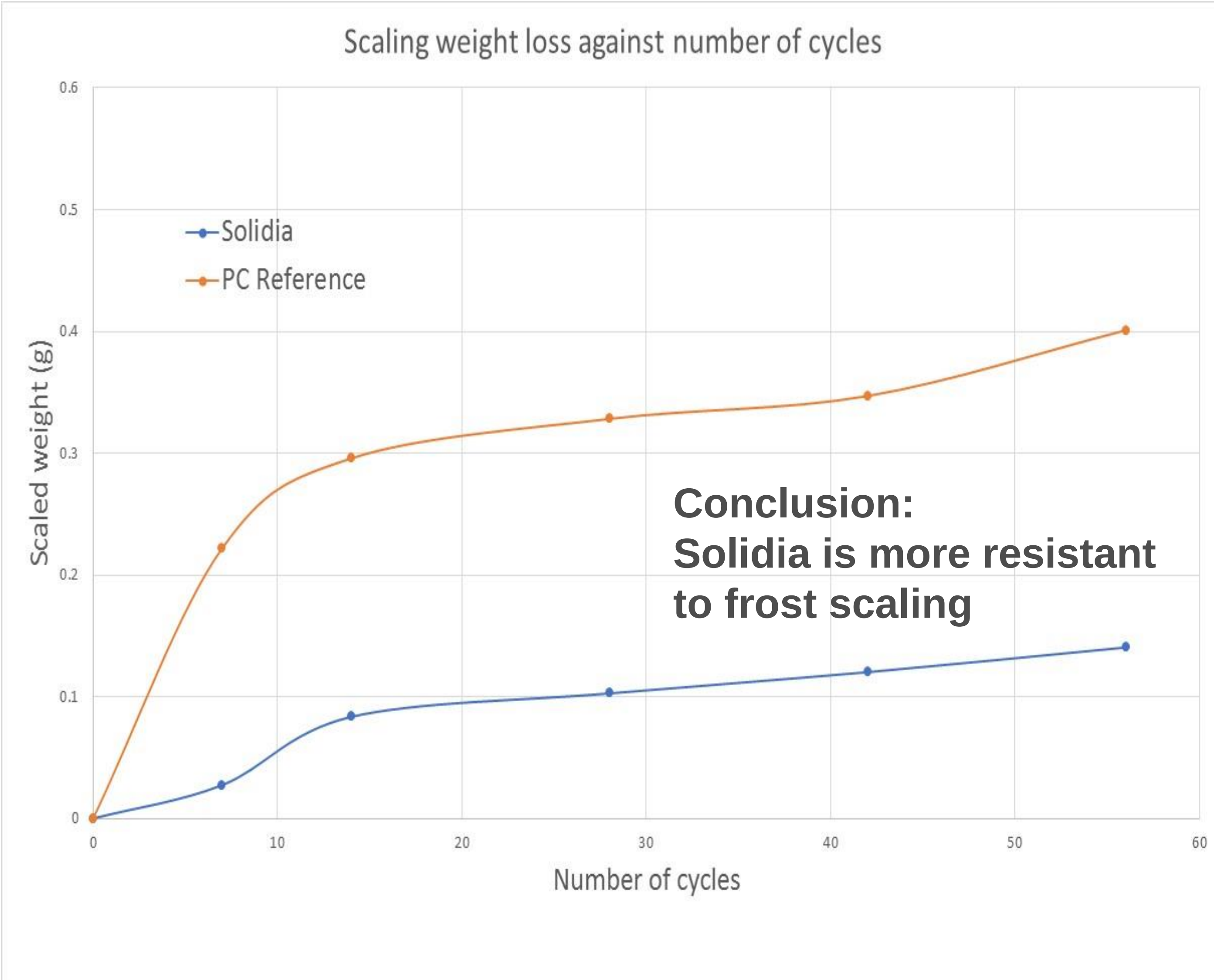
Frost Scaling: Specimens After Exposure

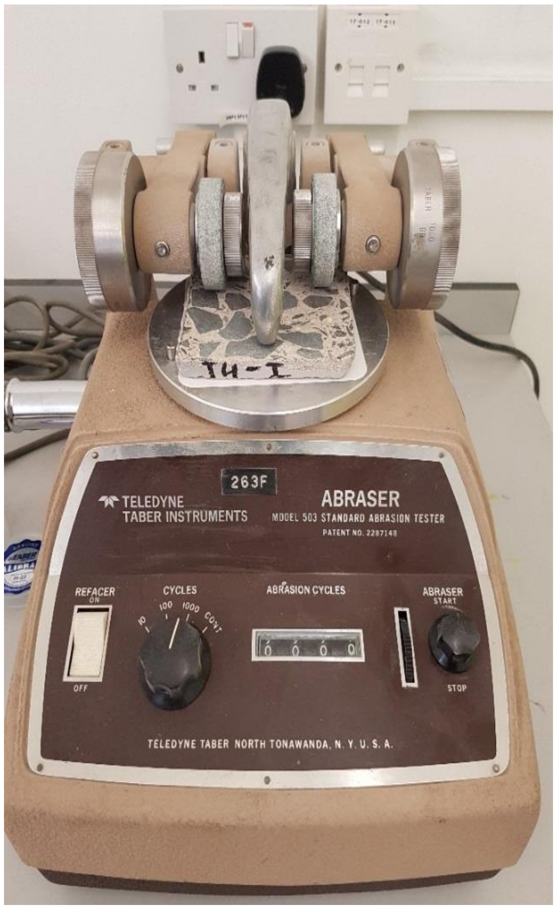
- Specimens prepared as shown (sawn surface)
- Freeze/thaw cabinet-accelerated cycling (56 cycles)
- Scaled mass measured

Frost Scaling Results to 56 Cycles (water)

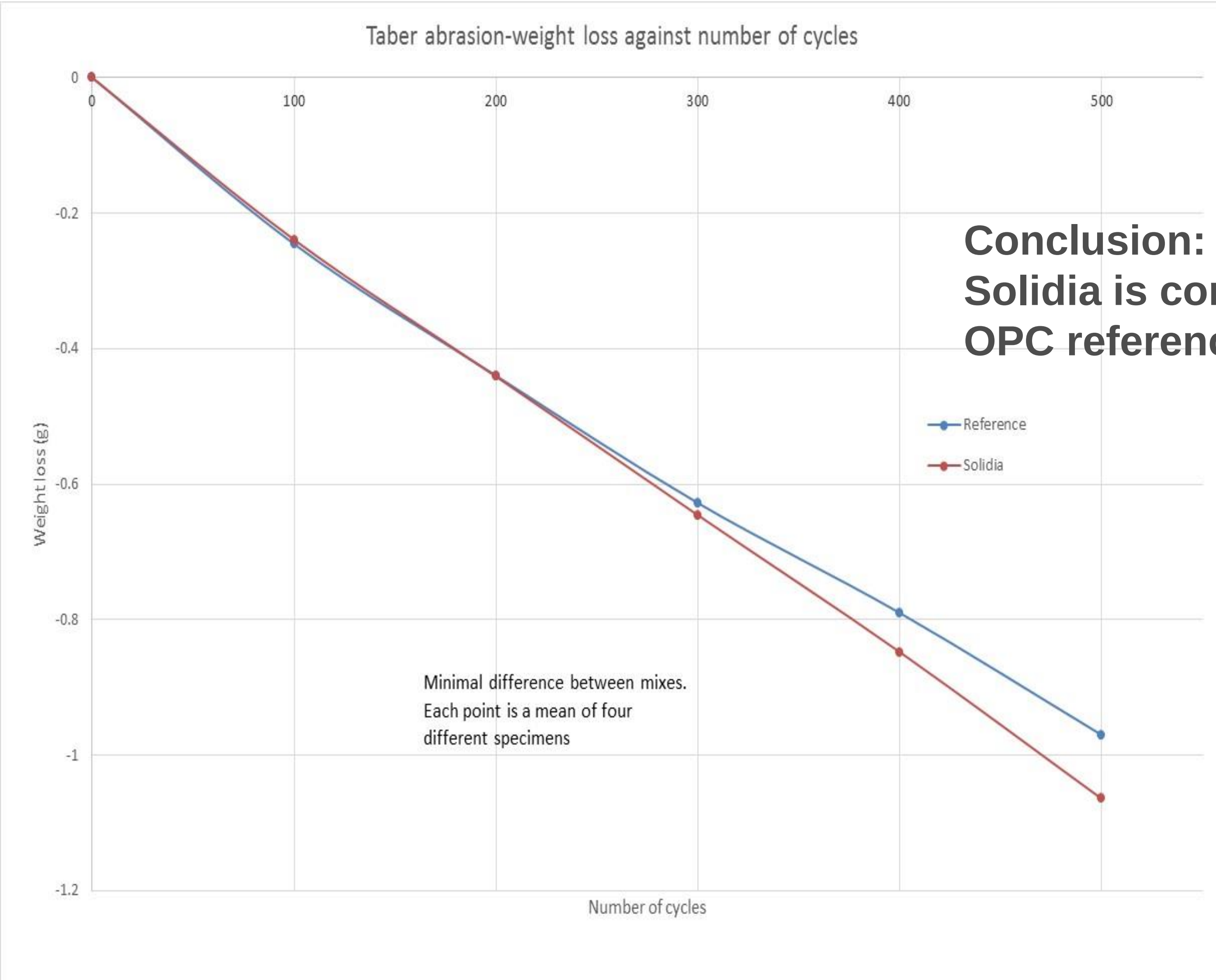


Conclusion:
Solidia is more resistant to frost scaling

Taber Abrasion Results



Taber Abrasion Results (500 cycles, PC reference and Solidia concretes)



Conclusion:
Solidia is comparable to OPC reference concretes

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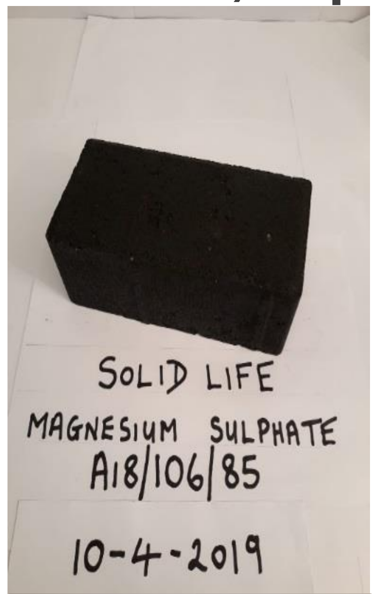
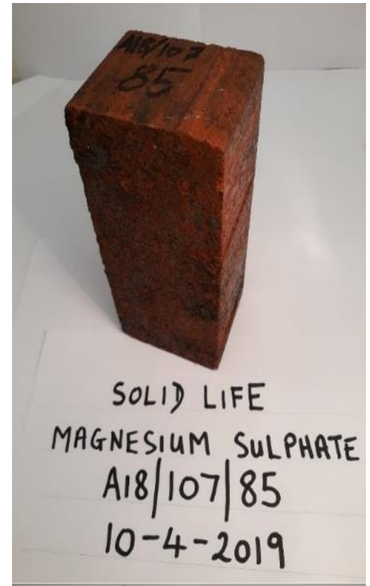
Natural weathering: BRE outdoors exposure sites (inland and coastal)

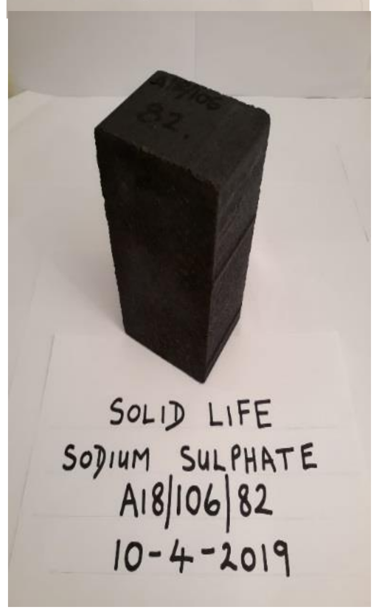
- Tensile splitting strength of concrete block paver specimens from industrial manufacturing trials stored in the above environments (inland and coastal) over time. Also concrete to assess:
  - Exposure to aggressive solutions (eg acid,sulfates)
  - Seawater exposure
  - Drying shrinkage
  - Moisture (dimensional) stability

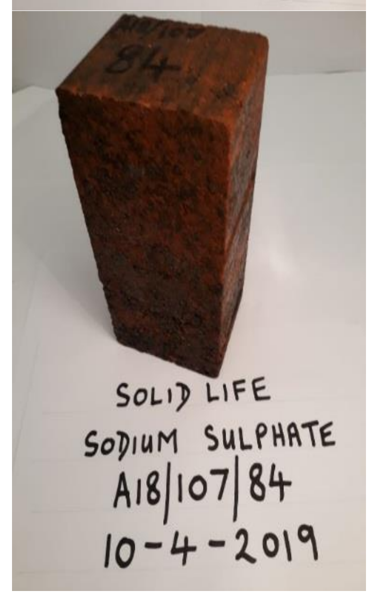
Interim test results: Current condition of block pavers (strong sulfate solutions, exposure to approx. 9 months)

Undamaged edges in all cases





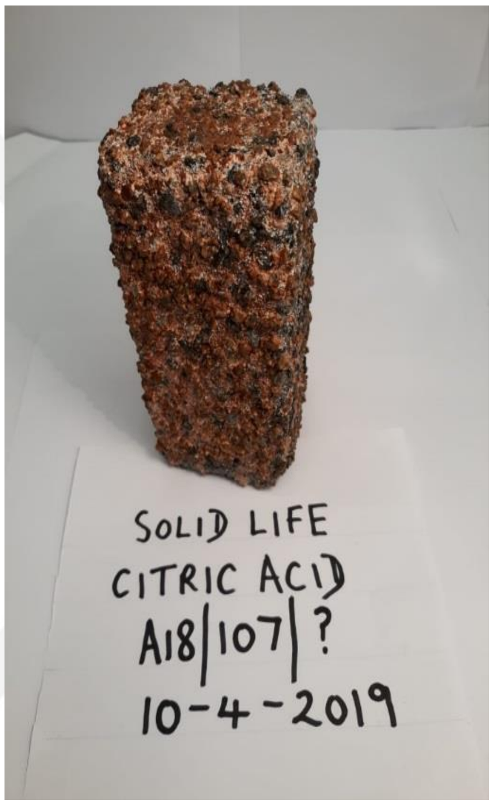


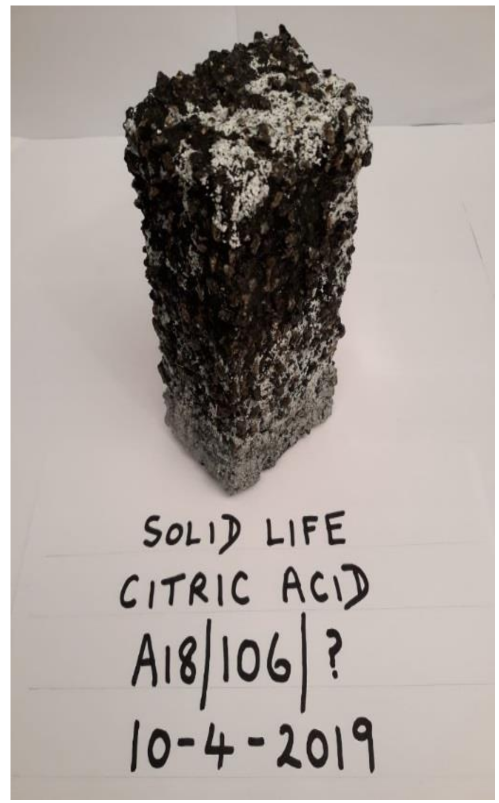


Solid Life Project

Interim test results: Current condition of block pavers (citric acid solution, exposure to approx. 9 months)

Similar degree of attack in both cases





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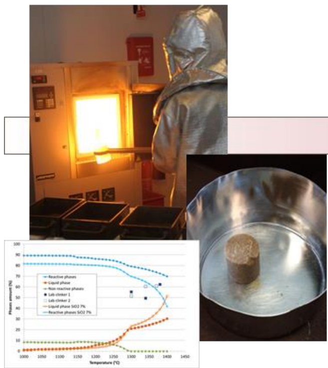
Conclusions

What has been developed to date?

- ***On the cement side:***

Lab scale



More than 30 plants assessed at lab scale

Pilot scale

4 plants assessed at pilot scale

Industrial scale

3 times 5000t produced worldwide

- ***On the concrete side:***

More than 50 pilot tests worldwide

3 industrial pilots installations

Durability & Market Acceptance:

- ETA for the cement on-going
- Long-term durability assessment

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Thank you for your attention,
Questions?

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www.solidlife.eu

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