Use of stone dust for the production of low CO_2 cements

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Use of marble and kota stone dust in limestone calcined clay cement (LC^3)

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Hydration kinetics and mechanisms of carbonates from stone wastes in ternary blends with calcined clay

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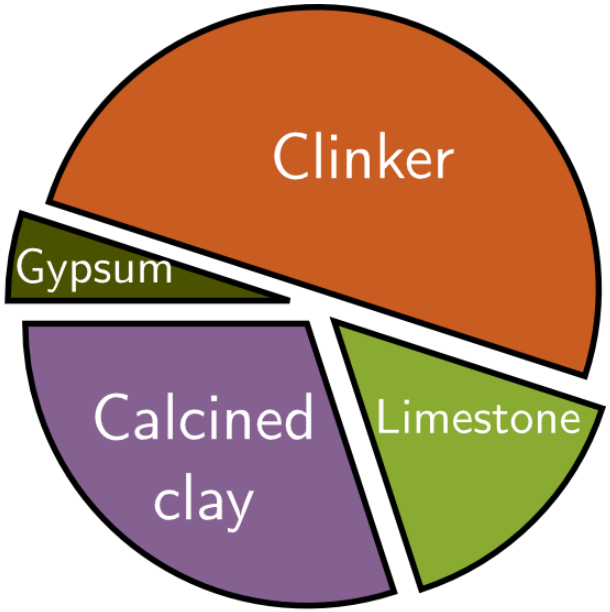
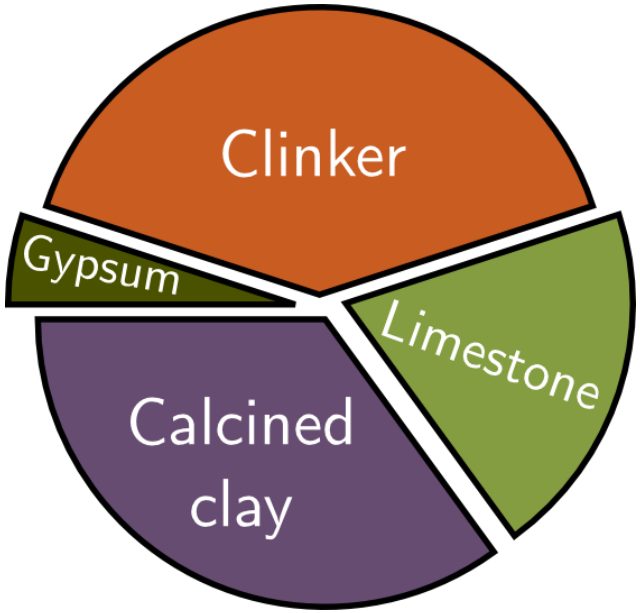
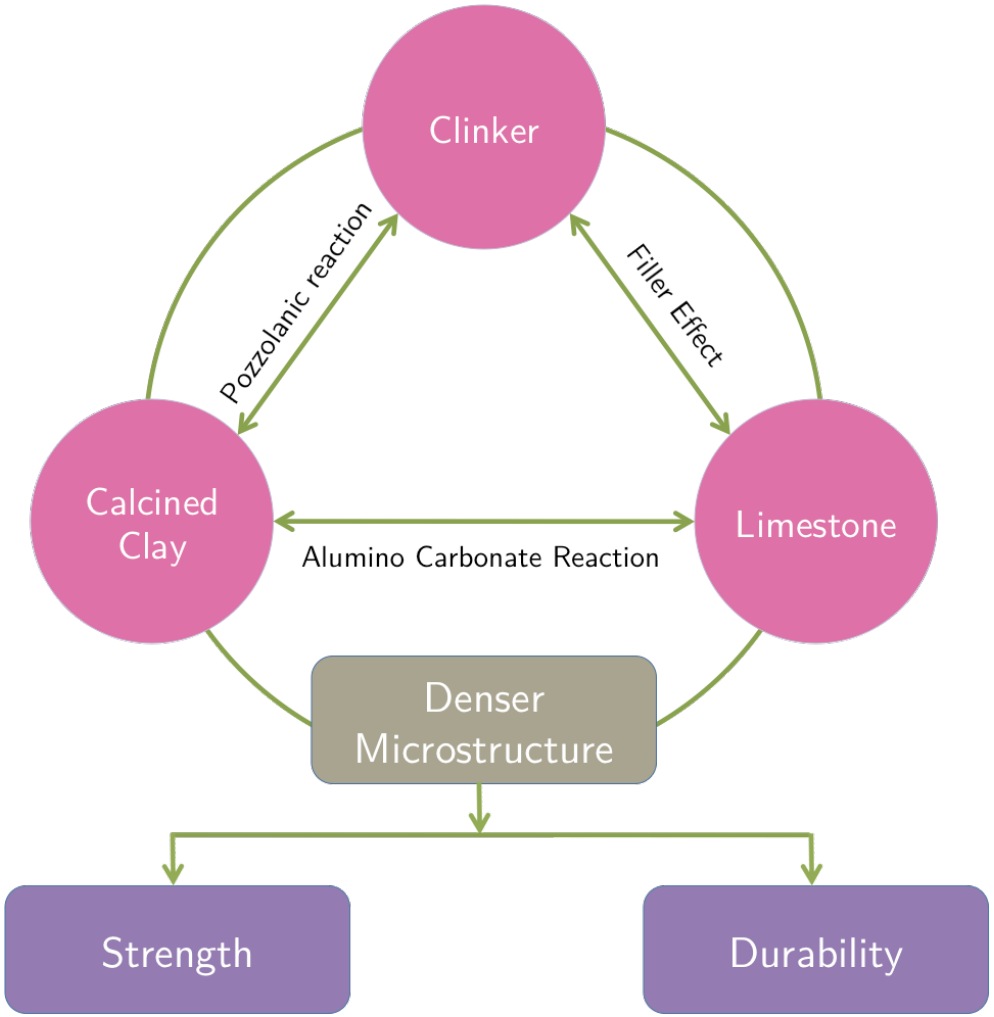
What is LC^3?

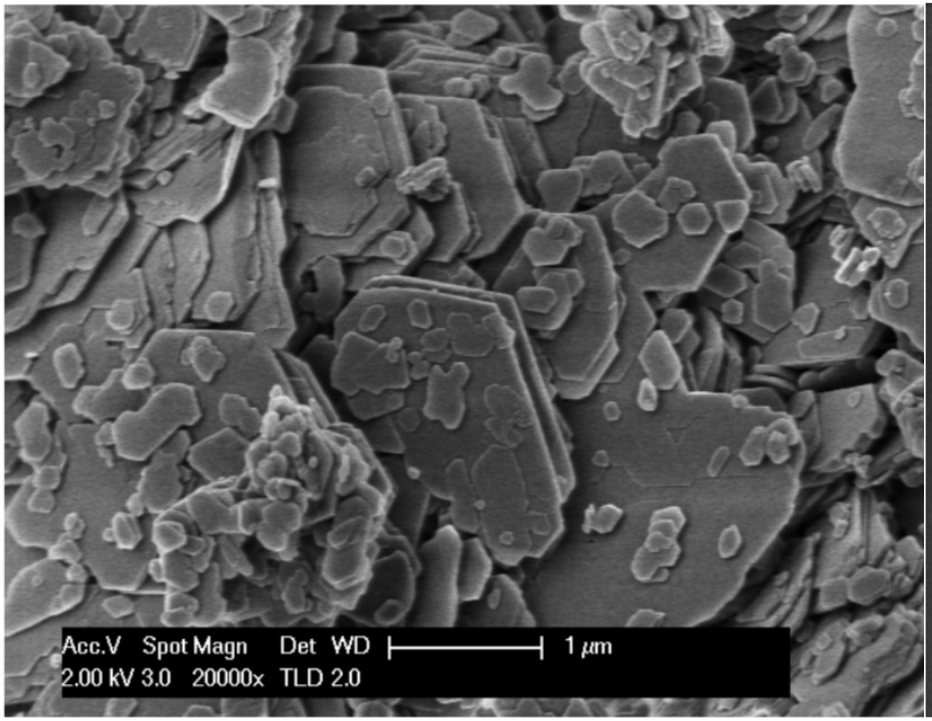

Clinker
Gypsum
Calcined clay
Limestone


Clinker
Gypsum
Limestone
Calcined clay

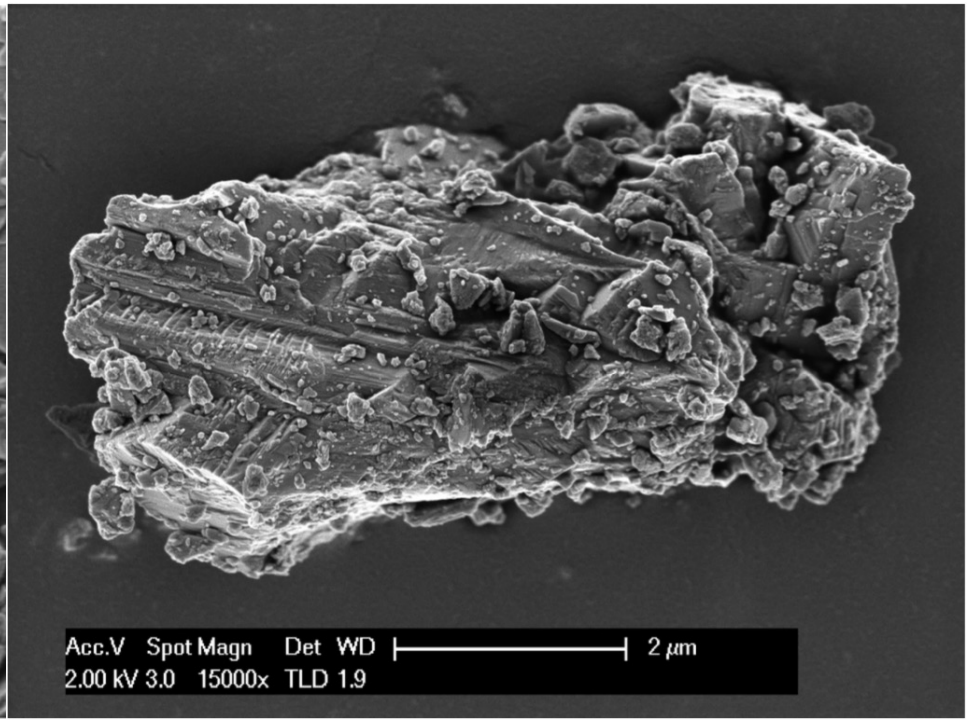
Synergy


Clinker
Pozzolanic reaction
Filler Effect
Calcined Clay
Alumino Carbonate Reaction
Limestone
Denser Microstructure
Strength
Durability

Physical influence



Calcined clay



Limestone

What do clay and limestone do?

- Calcined clay is known to have a pozzolanic reaction
- Limestone acts as filler
  - Improves rheology,
  - Finer microstructure
- Calcined clay + Limestone:
  - $(Al_2O_3) : 2{\cdot}(SiO_2) \;+\; CaCO_3$
  - $Al_2O_3 + CaCO_3 + Ca^{2+} + OH^- \Rightarrow C_4A\underline{C}H_{11}$

The strength of LC^3

- Uses raw materials familiar to cement industry
- Raw materials are widely and cheaply available
- Uses available technology commonly used in cement industry
- Use of LC^3 is similar to use of conventional cements
- Lower production cost than other cements in most scenarios

The benefits of LC^3

- Up to 30% lower CO_2 emissions than other cements
- Lower energy consumption in production than other cements
- Faster strength development than other blended cements
- Excellent durability compared to other cements

Economical, strong and durable infrastructure!

Current understanding: Clay

- Large deposits of clays available in India
  - Required kaolinite content: 40% to 60%
  - Iron content not an issue
- Calcination
  - Dehydroxyllation of kaolinite, completed by 800° C
  - Mullite should not form
  - Petcoke can be used as fuel
- Fineness
  - Very fine clay increases water demand
- Characterisation using TGA & XRD

Do we have clays?

- Pure kaolinitic clays are expensive
  - Ceramics
  - Paint
  - Paper
- They are less available
- Coloured clays are not accepted by the industry
- Cement industry is used to high-silica clays!

Rejected clay from a clay mine

Current understanding: Limestone

- Composition: down to 35% CaO content
  - Dolomitic limestone works
  - Siliceous limestone works
  - Stone wastes available
- Improves workability
- Characterisation using TGA & XRD

Reject limestone from cement plant

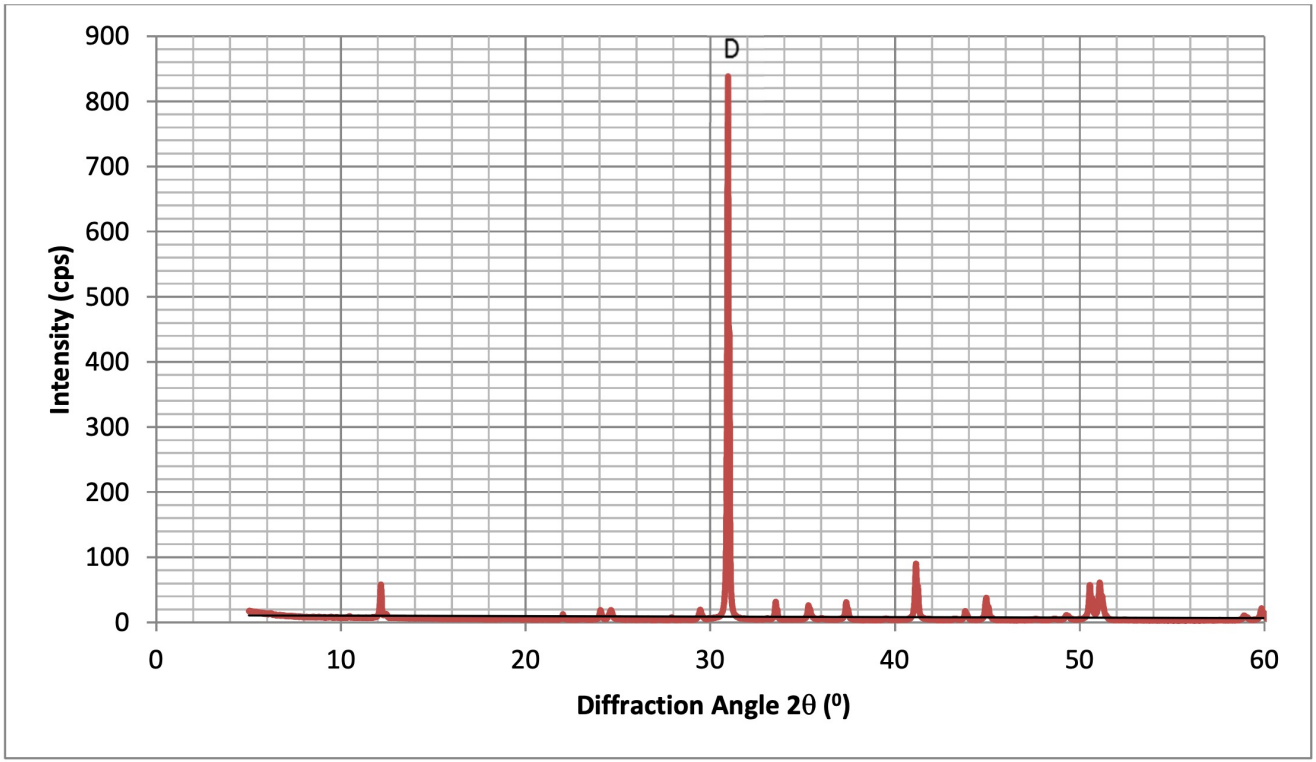
Low grade limestone & stone waste

Compositions

Table 1
Chemical and major phase composition and D_{50} values of the raw materials.

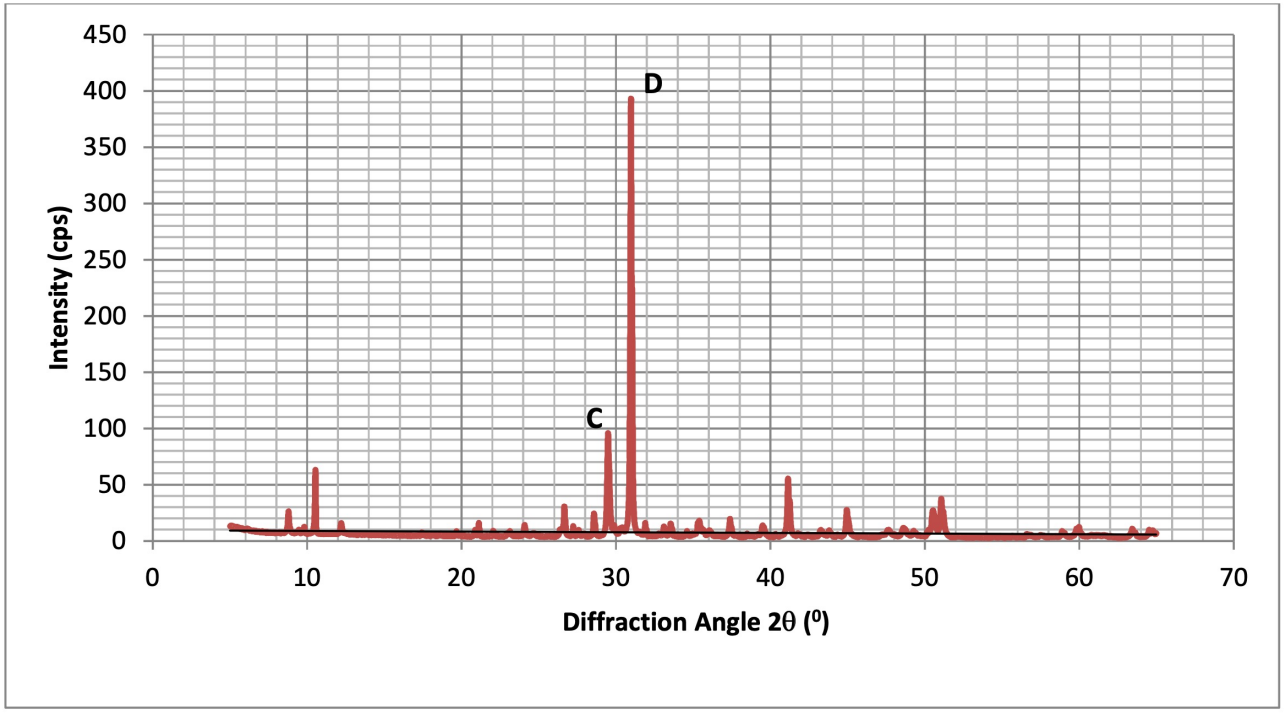
Oxide (%)	OPC	Calcined Clay	BA	KG	KS
SiO_2	22.07	55.11	4.54	7.45	21.96
Fe_2O_3	4.69	4.18	1.41	0.47	0.76
Al_2O_3	3.75	39.89	0.29	0.62	2.98
CaO	63.35	0.09	29.05	42.29	39.40
MgO	1.08	0.02	24.73	5.44	0.67
SO_3	2.09	0.104	0.76	0.10	–
Na_2O	0.32	0.18	0.08	3.57	0.90
K_2O	0.71	0.19	0.08	0.18	0.67
LOI	1.14	–	39.03	39.32	32.94
C_3S	56.56	–	–	–	–
C_2S	23.83	–	–	–	–
C_3A	2.78	–	–	–	–
C_4AF	15.34	–	–	–	–
Calcite	–	–	2.5	75.20	79.11
Dolomite	–	–	95.23	14.69	–
Quartz	–	–	1.42	4.72	20.42
D_{50} (μm)	18.6	19.8	8.13	10.2	7.58

Minerology – Banswara marble



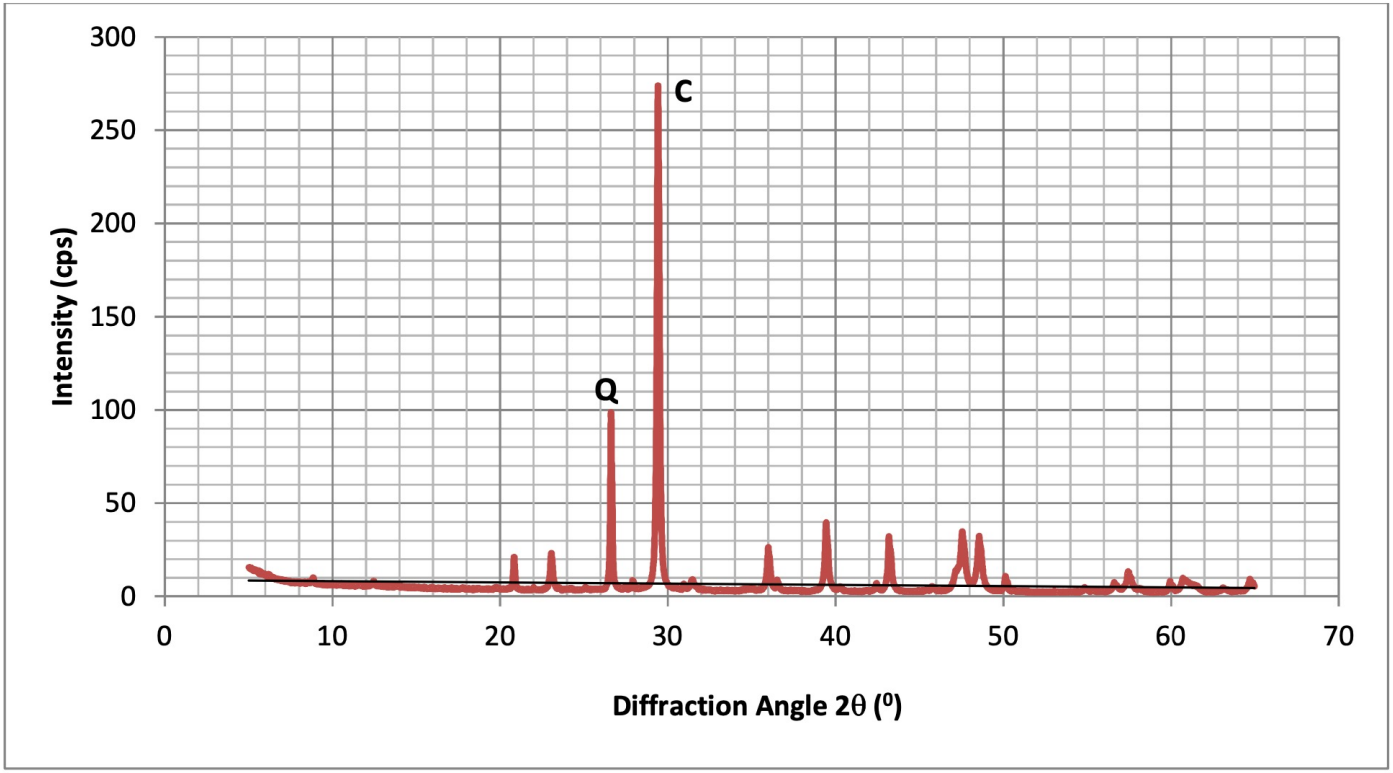
Crystaline Material	Wt% Rietveld
Calcite	3.07
Dolomite	95.62
Quartz	0.08
siderlite	0.57
Calcite Magnesium	0.66

Minerology – Kishangarh marble



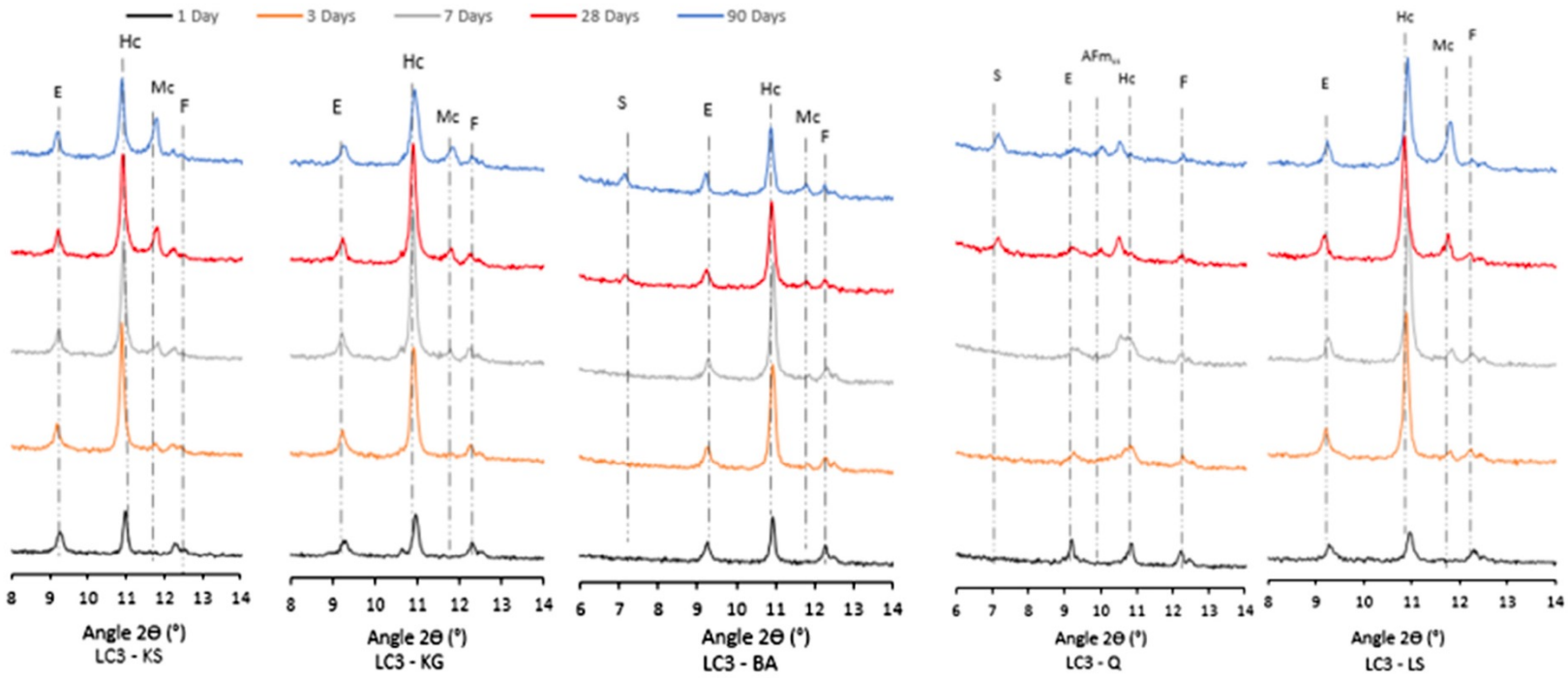
Crystalline material	Wt% Rietveld
Calcite	15.48
Dolomite	73.68
Quartz	3.42
siderlite	0.62
Calcite Magnesium	6.80

Minerology – Kota stone dust



Crystalline Material	Wt% Rietveld
Calcite	80.55
Dolomite	0.28
Quartz	16.55
Calcite Magnesium	2.64

Hydration and phase development



Hydration of clinker phases

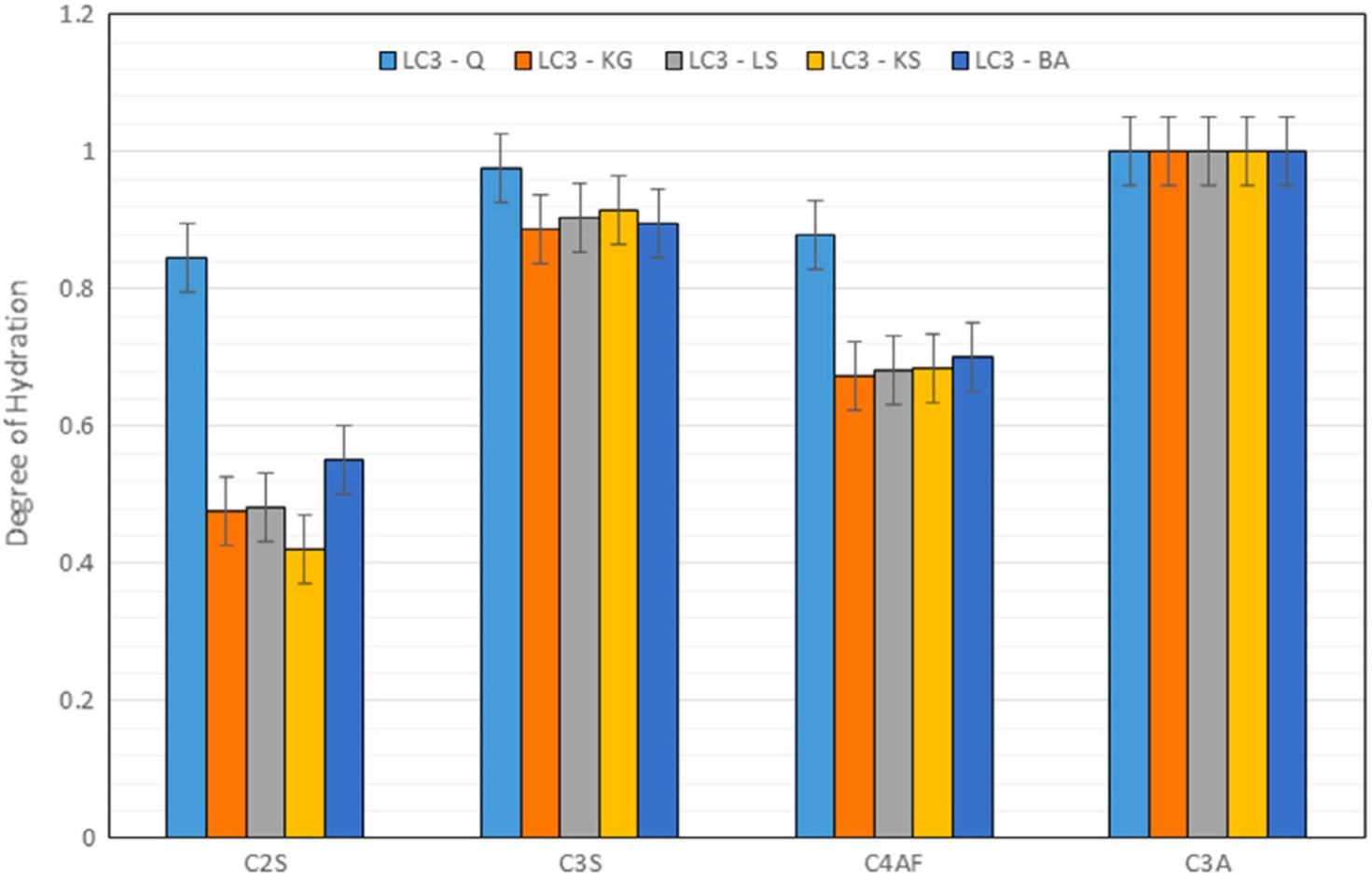
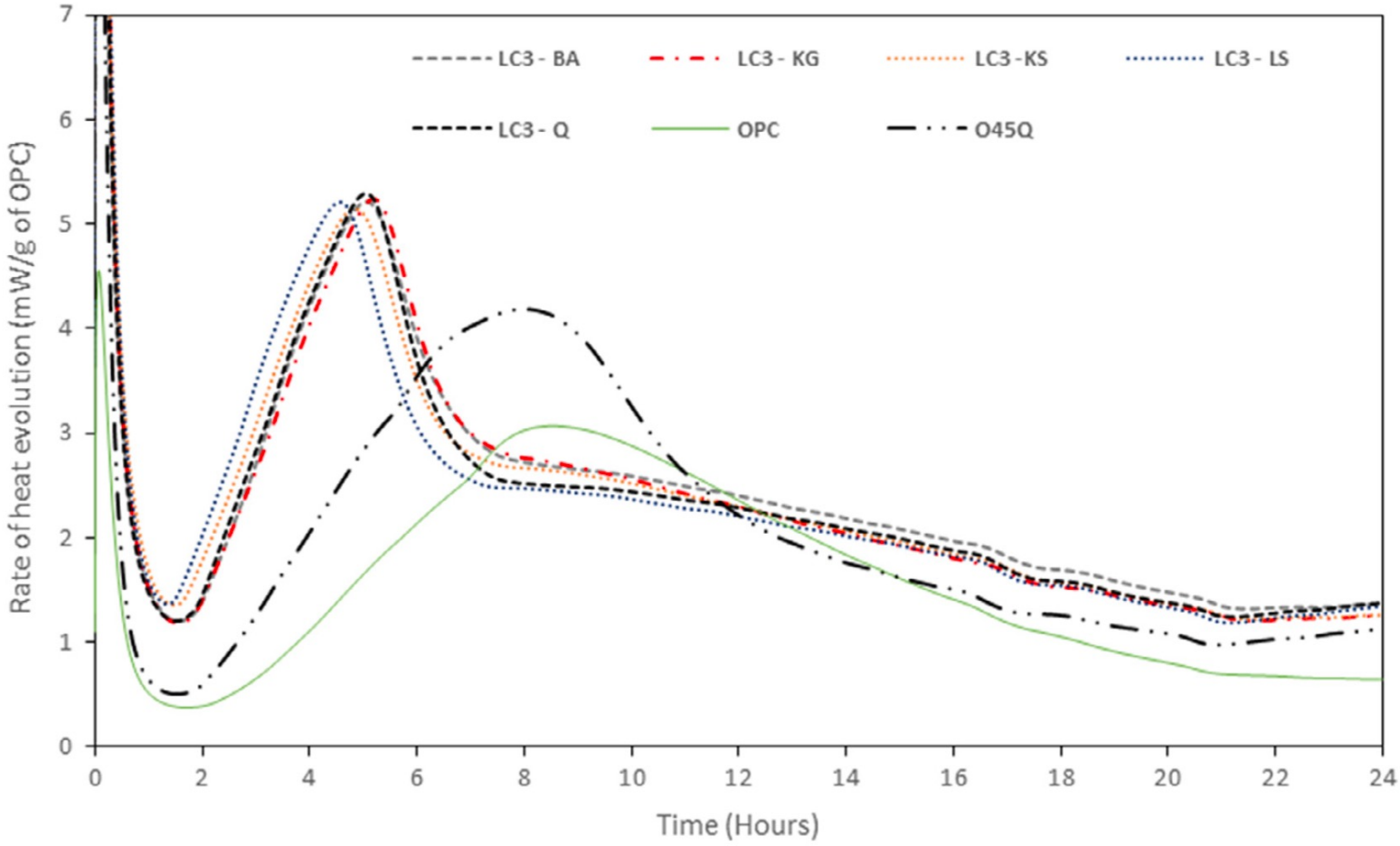
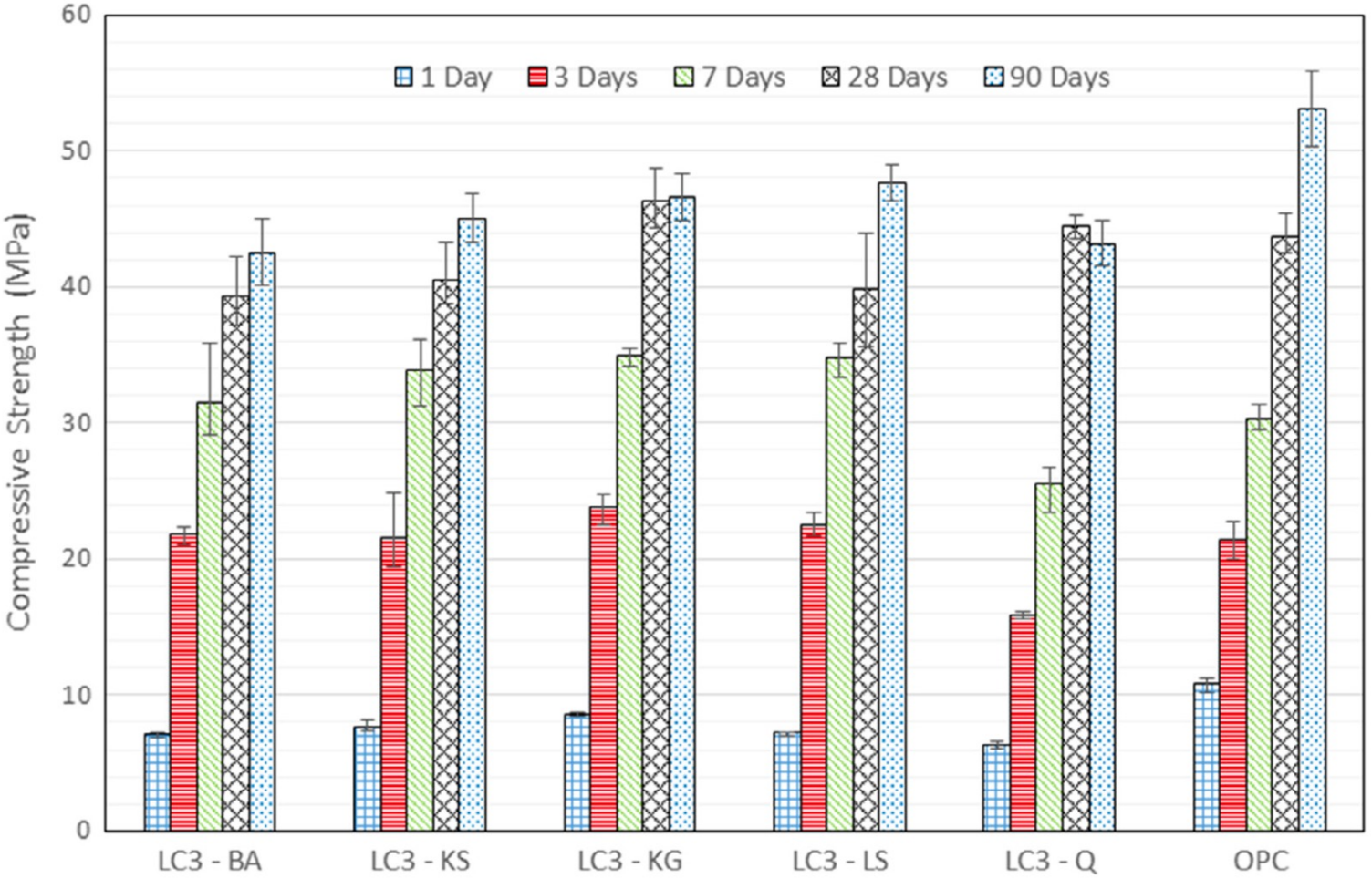


Fig. 7. The final degree of hydration of clinker phases in the blends studied at 90 days.

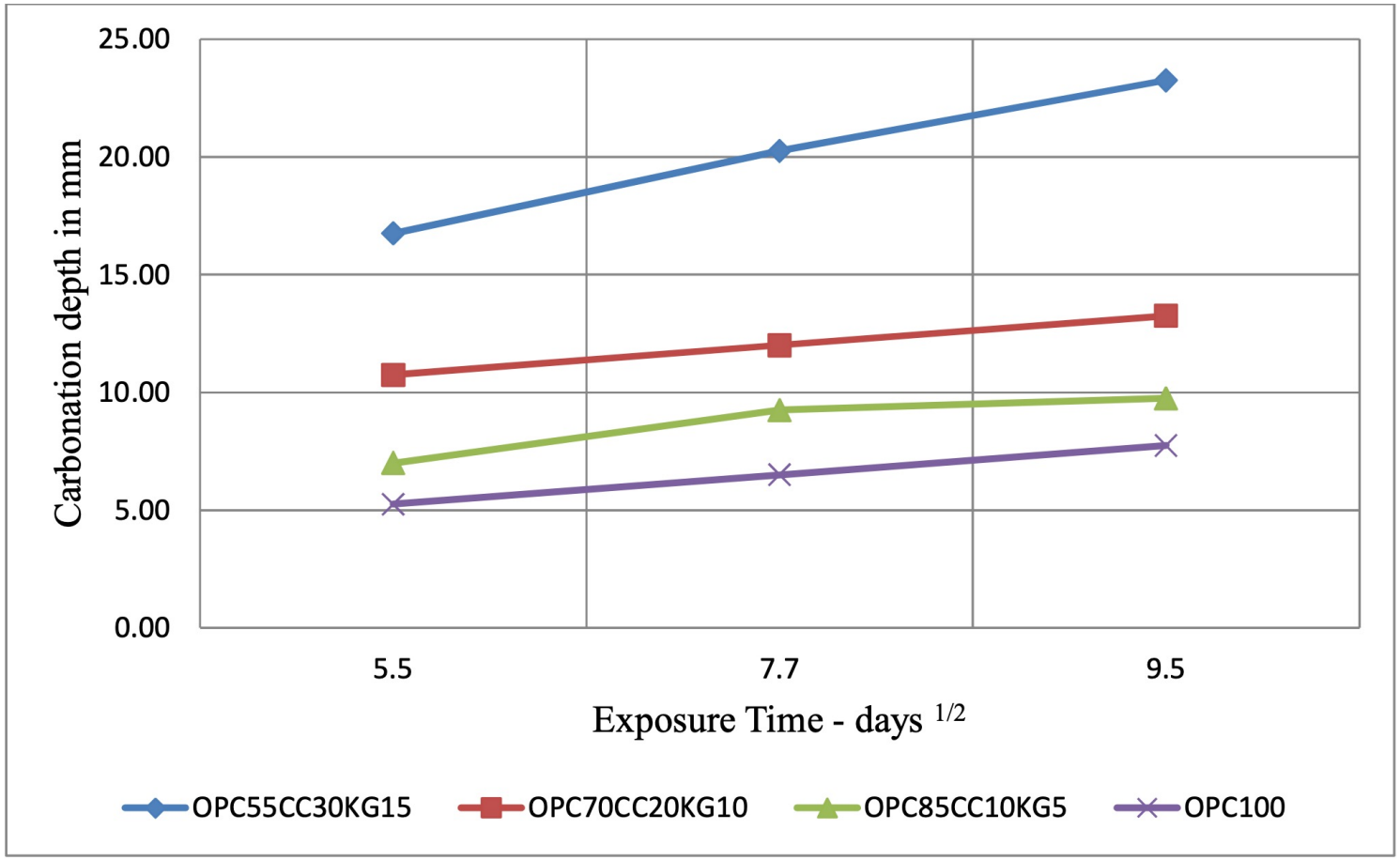
Heat of hydration



Compressive strength



Carbonation of concrete



Lime reactivity test (IS1727)

- 5 cm Cubes of calcium hydroxide and SCM prepared
- Water content based on flow
- Strength measured after curing at 50˚C
- e.g. 4.0 MPa required for pozzolanic clay
  - We find at least 6.0 MPa strength for reactive clays

Traditional & specialised applications

LC^3 building

Field exposure

Pavers

SDC building (Swiss Embassy)

Blocks and tiles

Grinding

Current status

- The draft standard of LC^3 to be released by BIS
- Technology is ready for commercialisation
- LC^3 is commercially available in 3 countries
- Should be available in 20 to 25 more countries within a year…

Summary

- Limestone calcined clay cement
- Use of stone dusts in LC^3

Thank you!