Sustainable Concrete Construction – more than CO_2 reduction in cement

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Elkem AS Silicon Materials

Scope

- Sustainability discussions have a tendency to gravitate towards CO_2 release during cement and concrete production and means to reduce this.
- The concept of more sustainable construction obviously is more complex than this. E.g.
  - Raw material resources,
  - LCA and
  - LCCA.
  - Reduce embodied energy
  - Reduce water use
  - Increase the use of recycled material
  - Reduce materials to landfill
  - Reduce use of non-recycled material

Basic

- Sustainability concerns:
- availability of materials, testing of alternate supplementary cementing materials, binder optimization and the minimization of concrete consumption as a means to save resources and minimize environmental impact.

Raw Materials

- Concrete needs:
  - Cement
  - Aggregates
  - Addition and admixtures
  - Water

- So what are the concerns?

Cement - Availability of raw materials

- Calcium and silica apparently abundant!

- Not so necessarily
- Issues
  - Quality
  - Location/transport
  - Environmental issues including landscape protection

Consequences for cement production

- As good, original, sources get exhausted, transport gets into the picture
  - New sources can be diffucult to exploit – for location, environment etc
- Citizen pressures can force closure of plants
- Ditto hinder new plants

- On a medium timescale, availability of raw materials, in particular limestone will be increasingly challenging
  - E.g. India: half the charted limestone reserves are in natural preserves
  - Even in Scandinavia, limestone supply is becoming an issue

Aggregates

- A pressing problem in many localities
- Key issue is natural aggregates (mainly sand)
  - Quality
    - Strength
    - Reactivity
  - Environmental
    - Landscape protection
    - Particle pollution of water
    - Citizen’s protests
    - Example: RMC producer in Mumbai: Previously 2 km to go; now 130 km to go for sand

- Coarse aggregates less of a problem

The CO_2 challenge

- Current main approach
  - Dilution of binder using mainly SCM's and/or fillers
  - How sustainable is that approach?

Need

- A change in attitude to concrete structures and their design
    - Use high strength to minimize concrete volume
    - Ensure flexible-use structures with long service life
    - Targets; Authorities, owners and designers!
    - Carrot and stick?
- For concrete materials
    - Develop use of manufactured sand
    - Develop alternate sources of large-volume SCM
    - Accelerate and focus development of binders with less CO_2, (geopolymers?)
    - Develop optimized mixes; ternary/quaternary etc

Ensure flexible-use structures with long service life

- Abysmal quality and short service lives cause a significant part of present day demand for new concrete

Example: China

Visiting an Institute in Nanjing, 4 year old concrete building, through cracks in the stairwell outside wall

In Shenyang; at the University, a few year old structures: Outdoor columns cracked at corners, large wall panels had “beautiful” D-cracking

Statement by senior Chinese: Residential construction often has service life of only 5-10 years

Authorities, owners and designers!

- Carrot and stick?
  - Premium for sustainable design – i.e.
    - High strength, long service life
  - Refuse building permits for other structures
  - Or
  - Fees depending on estimated service life
  - Or
  - ????

Develop use of manufactured sand

- Natural sand is running out
- “Machine sand” is used today, but often cause huge challenges
- Equipment, procedures, guidance needed

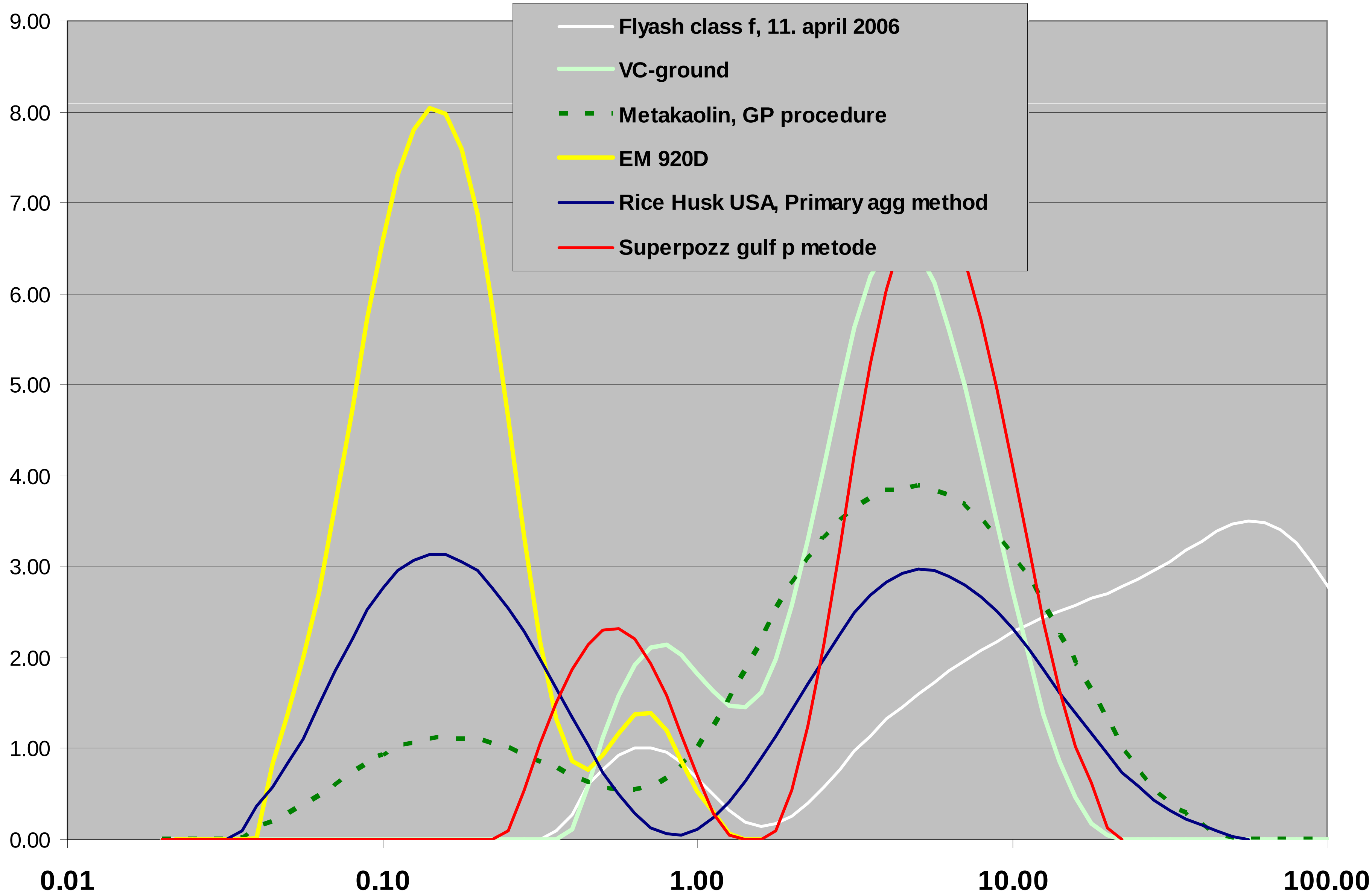
Develop alternate sources of large-volume SCM

- Issue
  - Germany has started investigations into “other” forms of low CO_2 cements; triggered by economic crisis in 2008
    - Energy need down – power plants closed – less fly ash
      - Specified material could not be had
    - Demand for steel down – furnaces closed
      - Specified slag cement unavailable
  - Looking into the future:
    - Slag unavailable (production moved to Asia)
    - Less and less fly ash available
      - Move to renewable energy sources
      - Detrimental production routines in power plants (Mercury etc)

Alternative to by-product SCM's

- We are talking + 15 years horizon
- Totally different cement chemistries
- Natural pozzolans
- Ash from "other" processes
- ????????

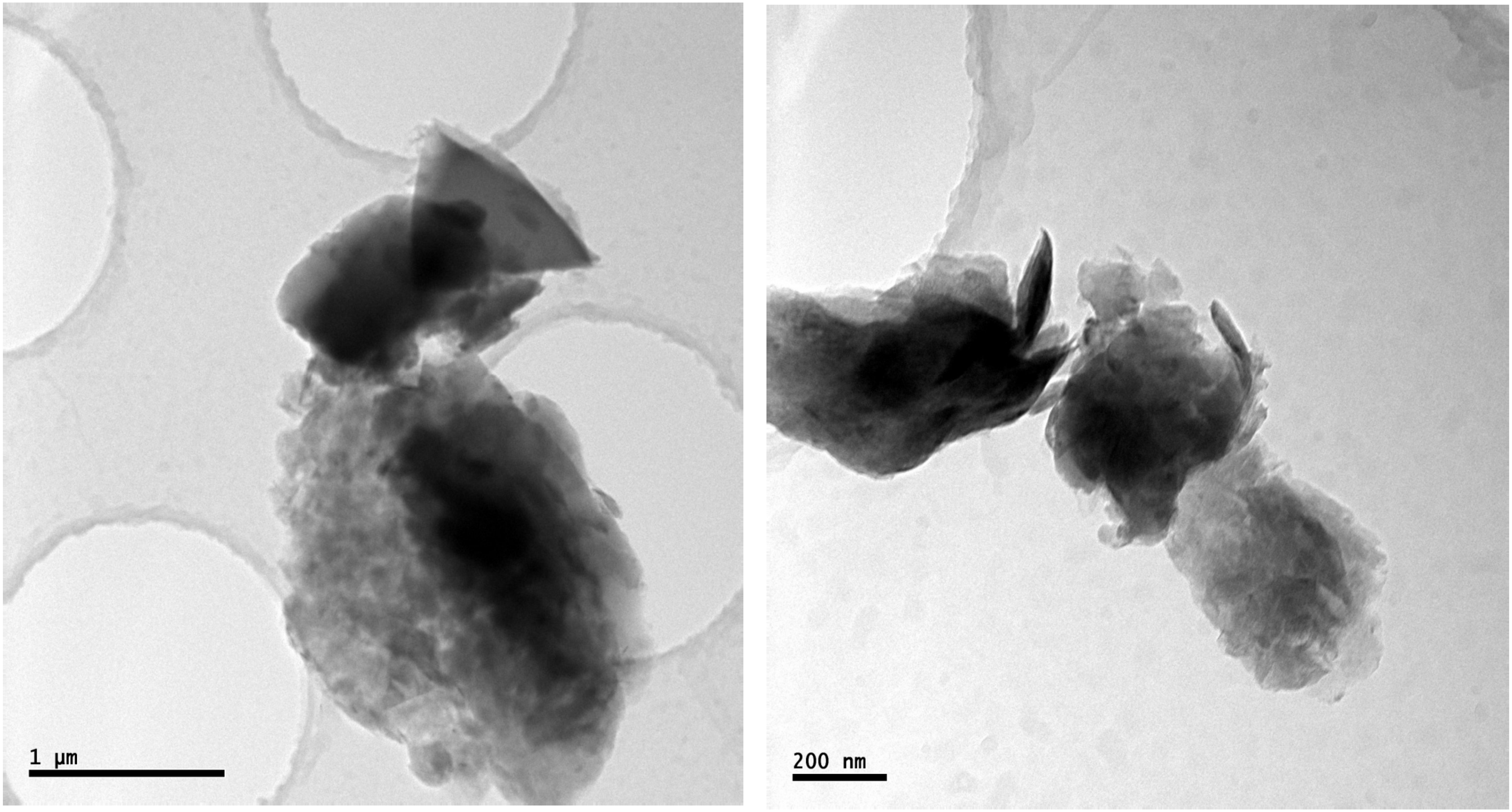
Particle size distributions



Natural pozzolans

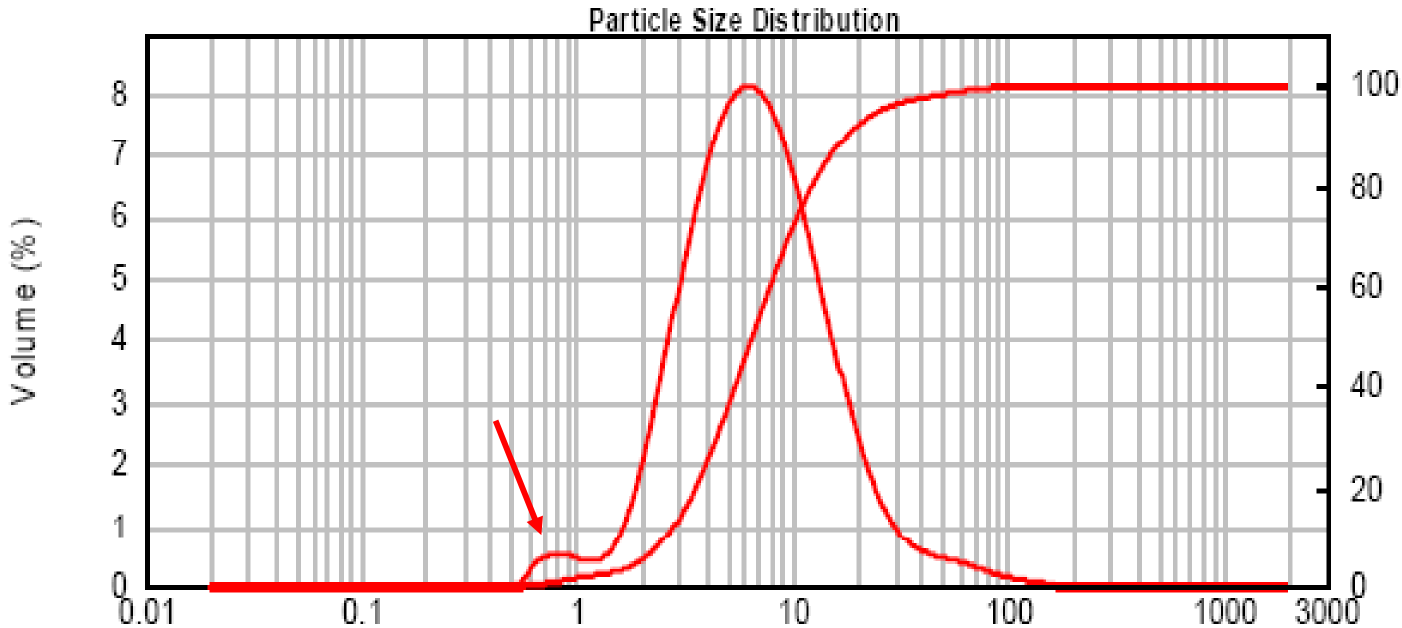
- Calcined (and milled)
  - Metakaolin
  - Marl
  - ……..
  - 4-500 kg CO_2/ton
- Milled only
  - Santorini earth
  - Trass
  - Perlite

MW-Perlite: TEM

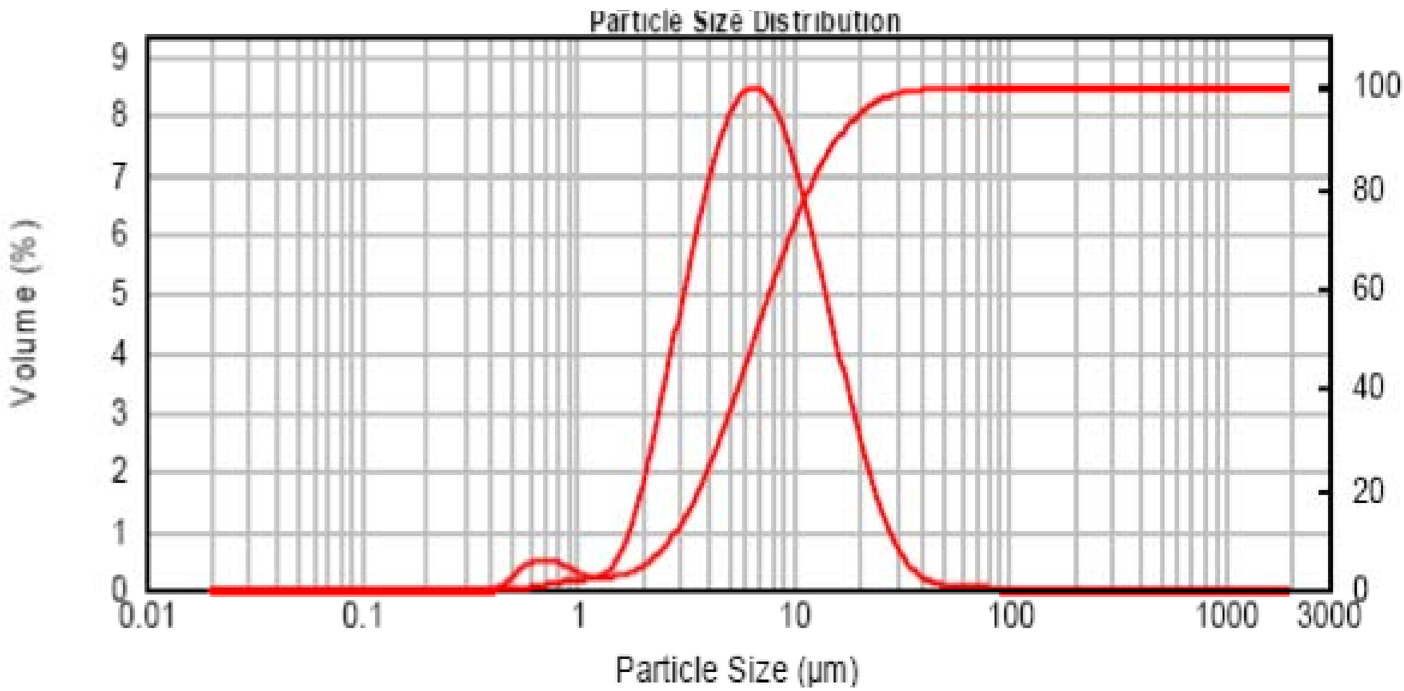


Crystalline and amorphous phases intermixed on a nanoscale

Milled Perlite Typical particle size distribution (?)

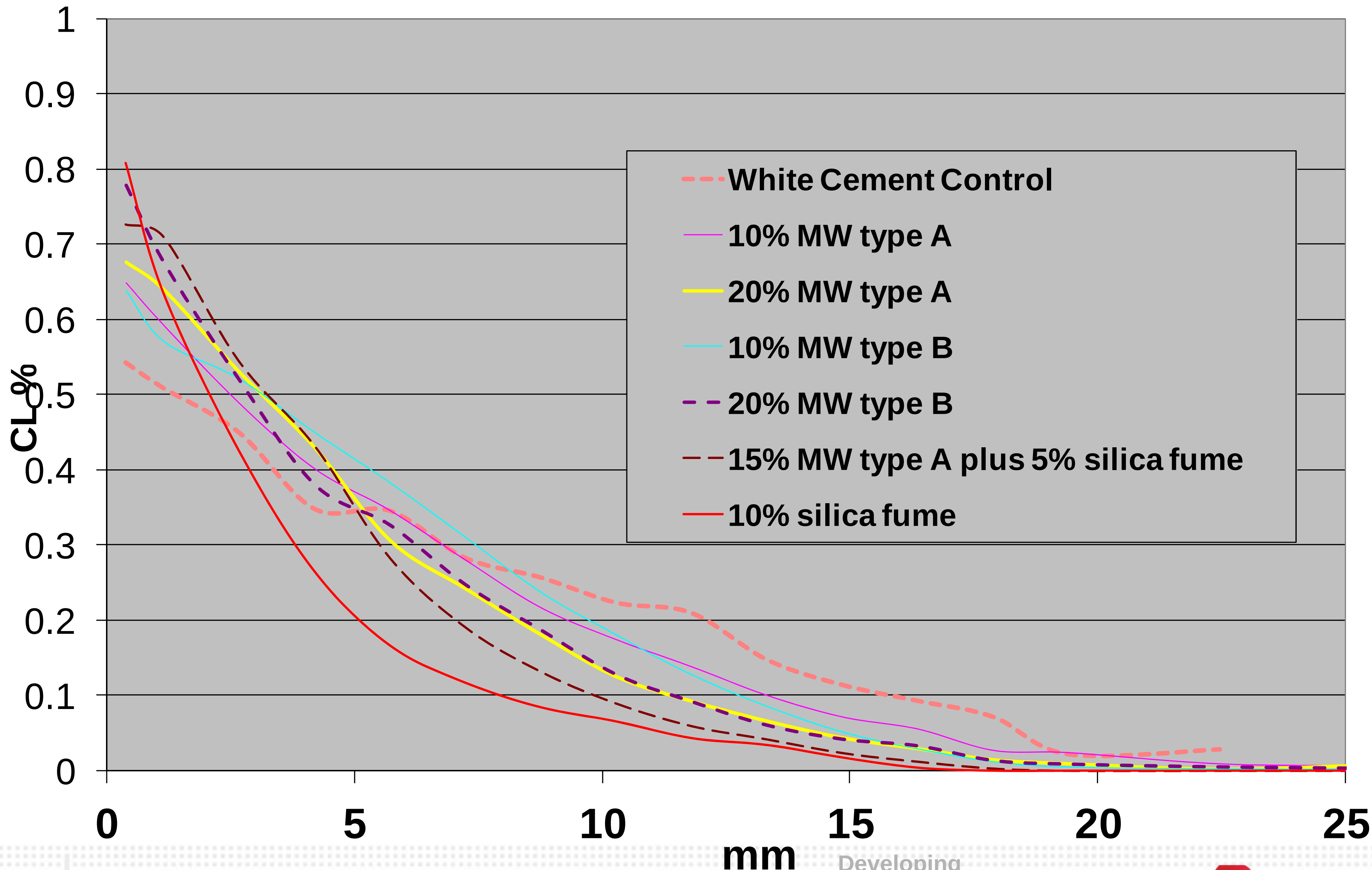


Standard progr.
(30 sec. ultrasound,
25 % amplitude)

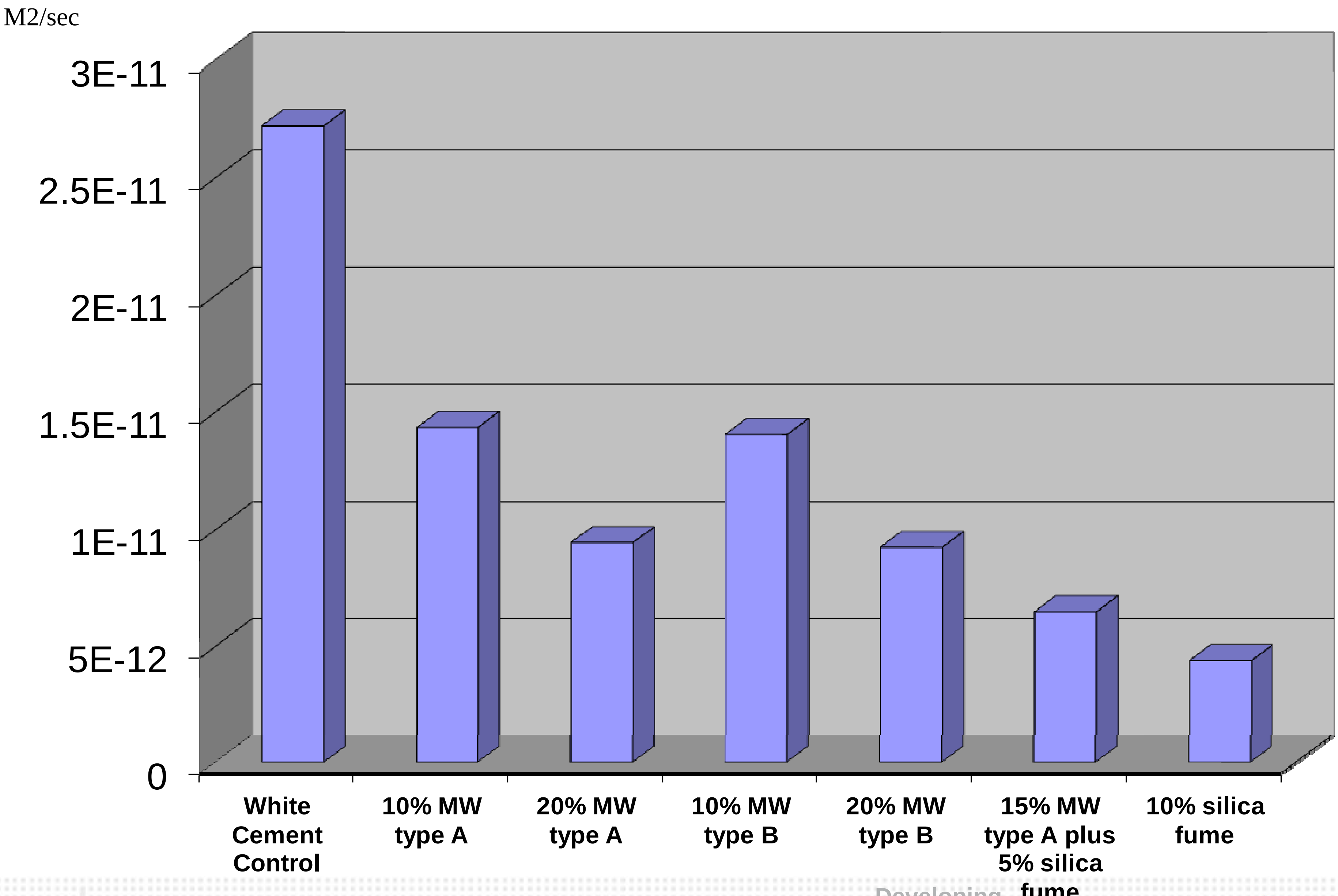


Primary aggl.
(8 min. ultrasound,
100 % amplitude)

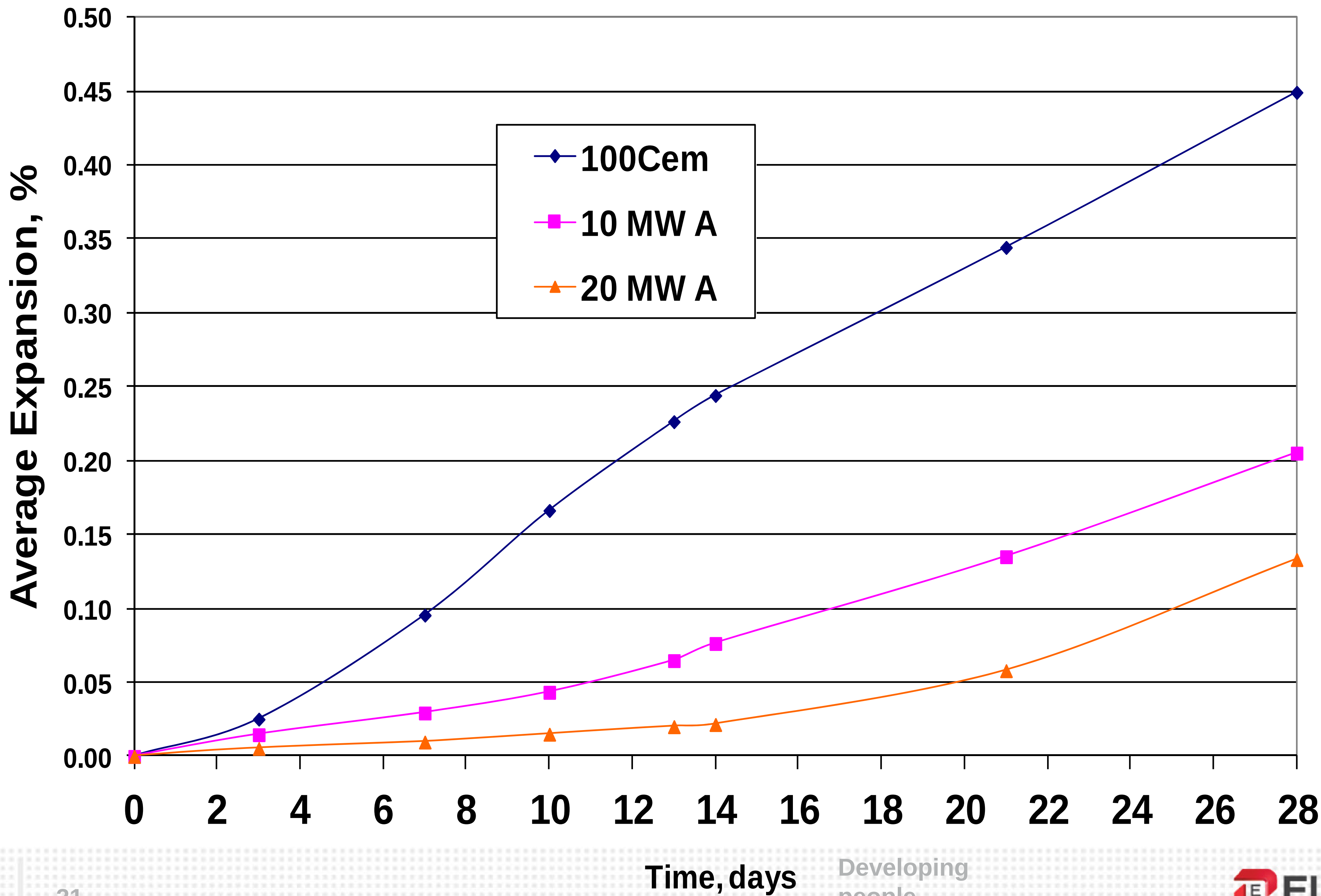
Chloride profiles – Perlite SCM



Diffusion coefficients, Perlite SCM



ASR: ASTM C1567 – Perlite SCM



By Hooton

Developing people - creating value

Elkem
A Bluestar Company

Ash/waste from “other” processes

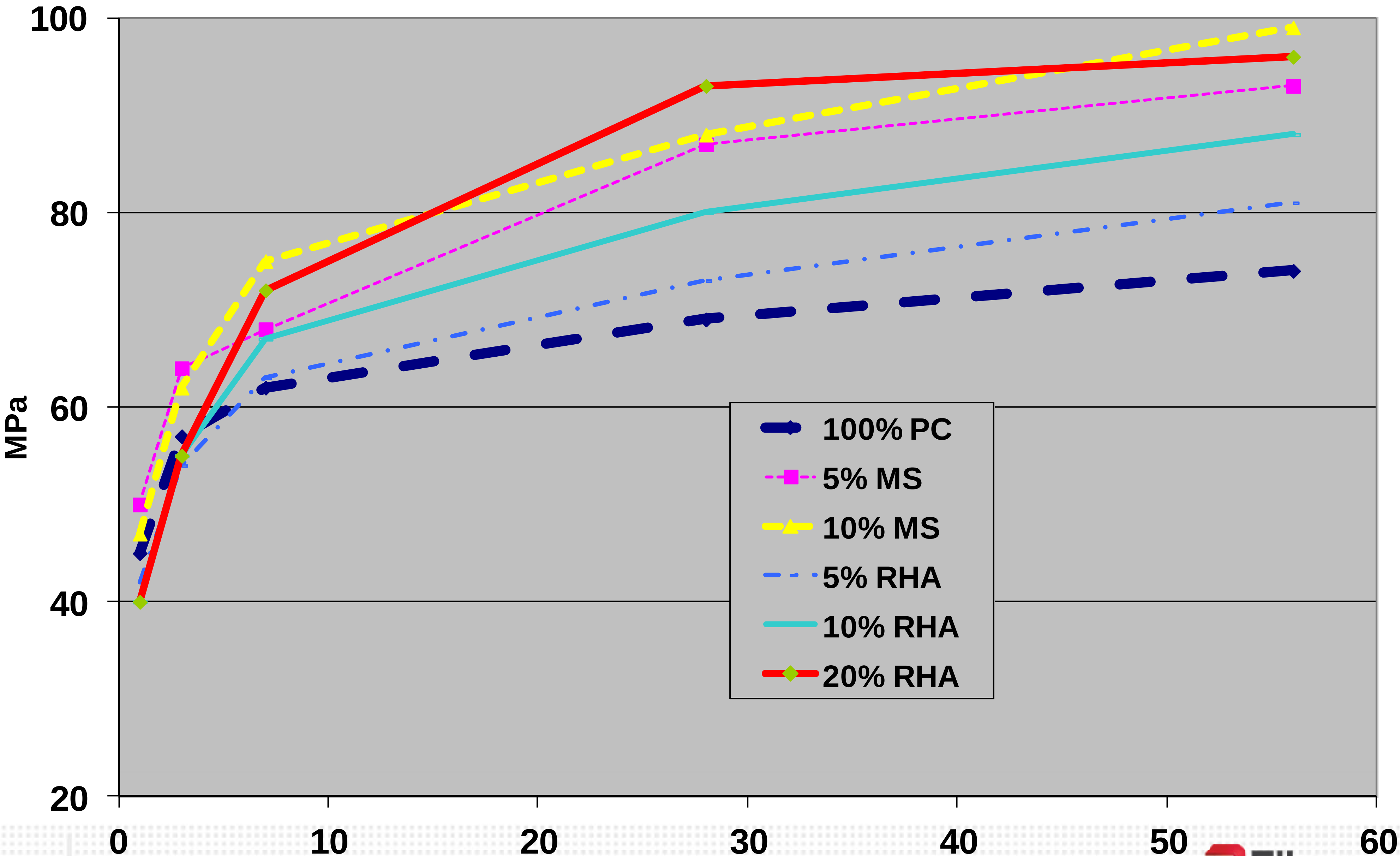
- Rice Husk Ash
- Bagasse ash
- …….

- Municipal waste
- Bioenergy power plants

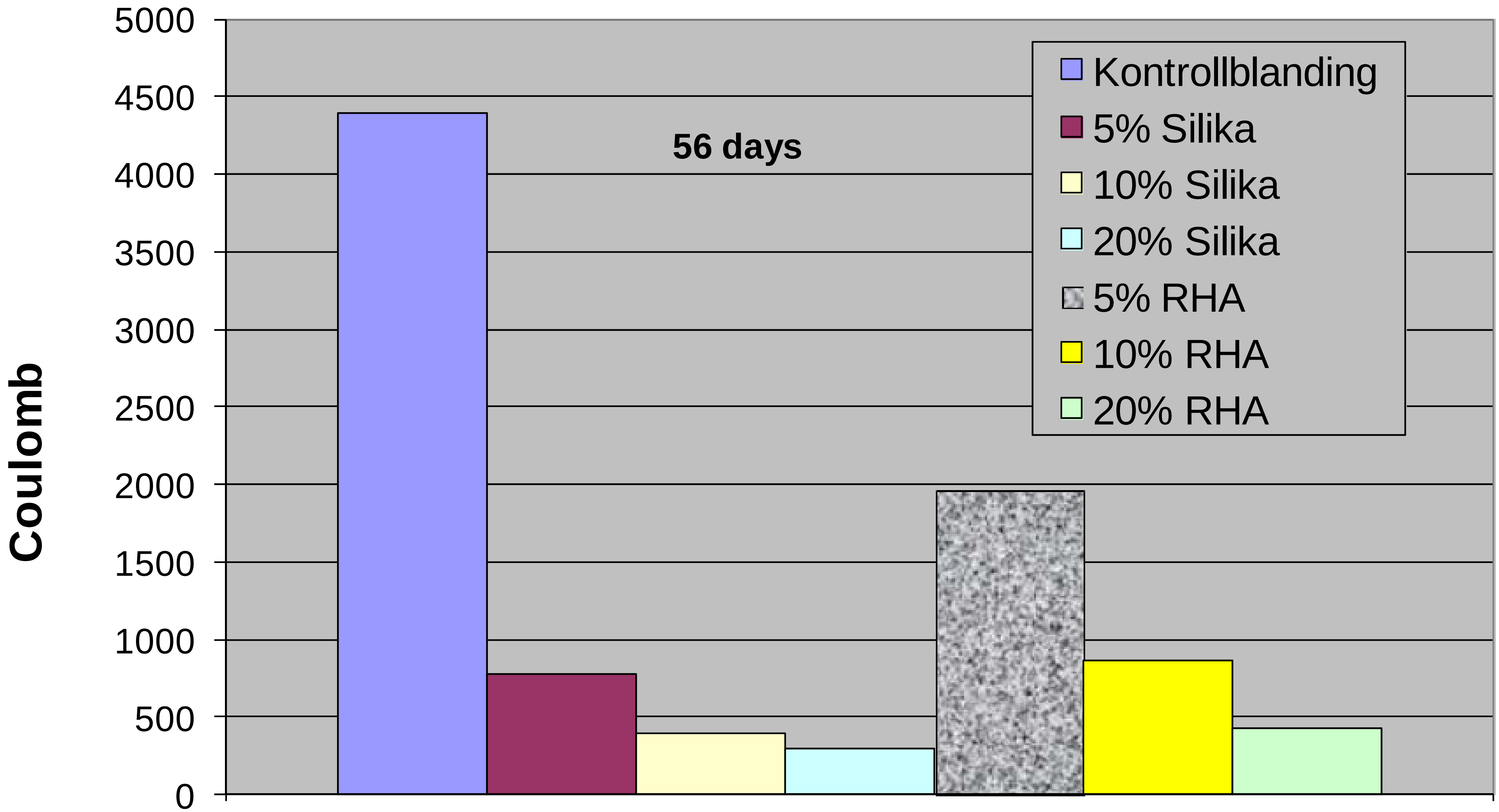
- Ground waste glass
- ……

- Documentation effort needed for all these

Rice Husk Ash and Microsilica - Strength



ASTM C1202



Coulomb
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
56 days
Kontrollblanding
5% Silika
10% Silika
20% Silika
5% RHA
10% RHA
20% RHA

Other SCM's

- Availability?
  - Flyash is available in huge volumes, comparable to clinker consumption
  - RHA only maximum 5 mio tons
  - Natural pozzolans?
    - Global reserves
    - Location
    - Milling
    - Deposit volume

Perlite, app 8 billion tons

1000 tons

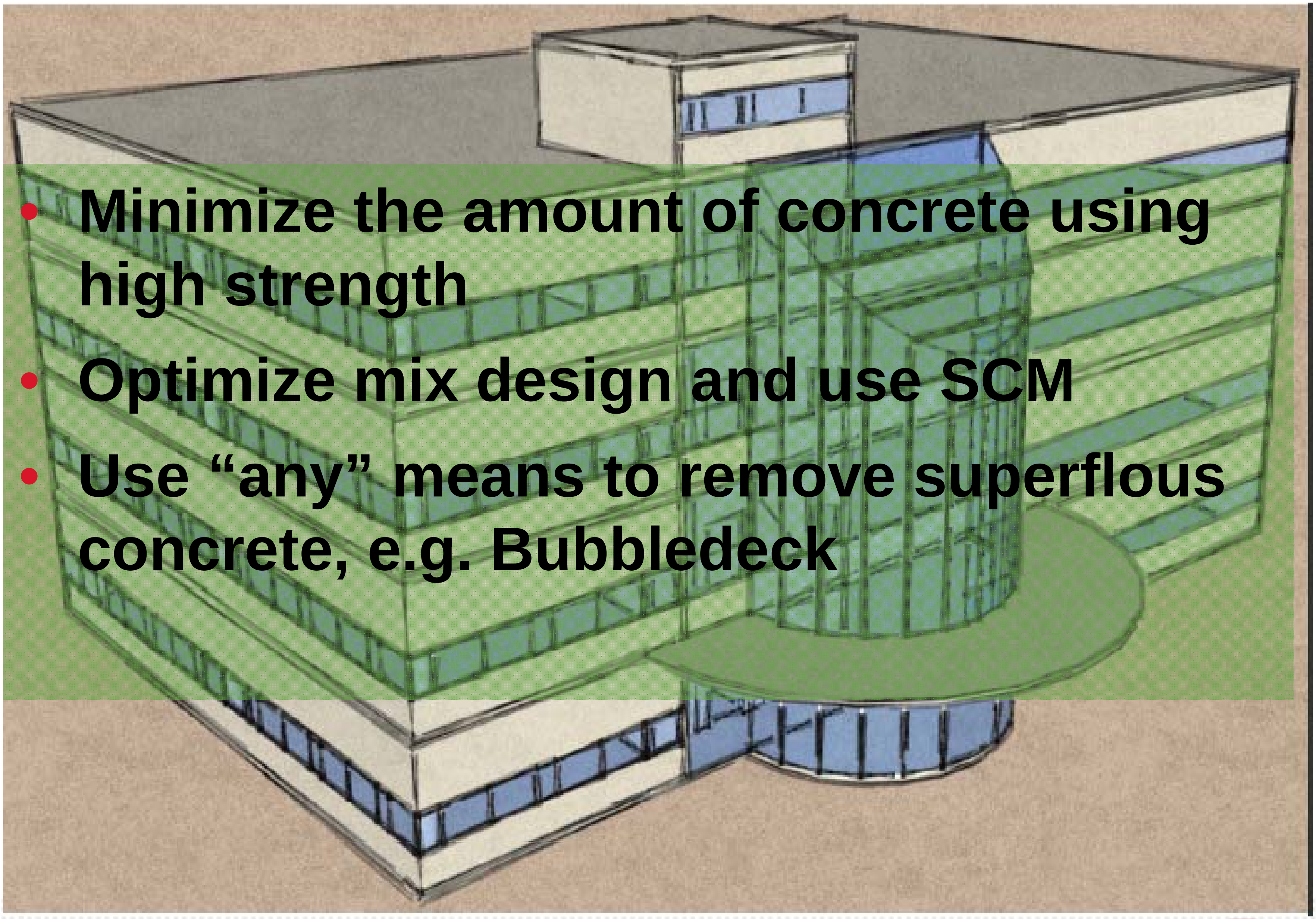
Greece	300 000
Turkey	5 700 000
USA	200 000
Other countries	1 500 000

Accelerate and focus development of binders with less CO_2, (geopolymers?)

- A long development and documentation process
- Technology
- Stable quality
- Long term performance
  - General
  - Structural
  - Durability

- Until then……

Sure steps to remove CO_2:



- **Minimize the amount of concrete using high strength**
- **Optimize mix design and use SCM**
- **Use “any” means to remove superflous concrete, e.g. Bubbledeck**

Sure steps to remove CO_2:

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Sure steps to remove CO_2:

- Exercise done for local structure near University of Agder

	45 Mpa SD	100 Mpa SD	45 Mpa BD	100 Mpa BD
Total cost [MNOK]	5.8	6.6	5.2	5.0
Total CO_2 emissions [tonnes]	532	354	380	242
Service life [yrs.] (Life 365 default situation	53	206+	53	206+

SD: Standard beam/slab deck
BD: Bubbledeck flat deck

Short term

- Use high strength, optimized (ternary) mix
  - Saves raw materials
  - Reduces emissions
- Long term/Urgent R&D needs
  - Alternate SCM’s
  - Ensure fly ash useful
  - New binders with proven performance