Concrete : How Green can we get?

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Objectives

1. Understand the basics of SCM replacement in concrete mixtures.
2. At the conclusion of the presentation, participants will have a better understanding of what is being done to make concrete construction more environmentally friendly.
3. Learn where the concrete construction industry might be headed with regards to green building and sustainability.
4. Understand the problems in the realization of and potential barriers to green concrete construction

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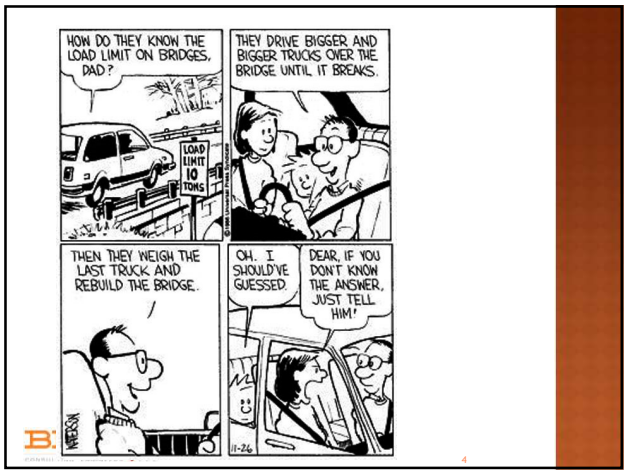

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What is Concrete?

- Portland Cement, Water, Air, Aggregates to make synthetic rock
- Add SCM's ca 1980
- Add admixtures ca 1970
- Fibres
- Corrosion Inhibition ca 1980

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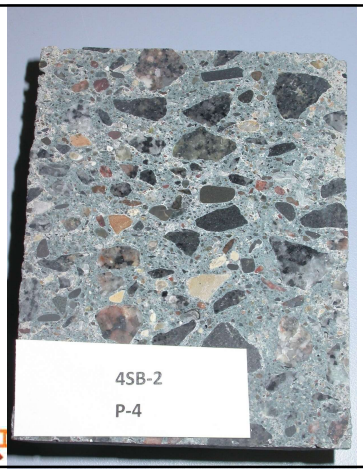

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What is Concrete?

- A two-phase composite – one phase continuous, the other discrete
- A binder that is activated to make a glue that has desirable and predictable properties in the plastic and hardened state

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What is Concrete

- A binder that sets and binds aggregate materials.
- Generally a plastic or flowing mixture. Hydraulic cements will set by chemical action and the products remain insoluble in water.
- Portland Cement has filled this role well with the exception of the embodied energy and emissions
- A number of older systems and newer systems are available

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Approaches to Green Concrete

- Reduce the amount of concrete being used
- Reduce the amount of clinker in concrete
- Eliminate clinker all together
- Increase the lifecycle of the structure
- Know about and measure the inputs and outputs from the built environment

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Pozzolanic / Latent Hydraulic / Catalytic /

- Clay/Mineral Mix Nucleation/dispersion
- Gypsum
- Glass
- Recycled Concrete
- GGBFS
- Wollastanite nucleation accelerator
- Micro Silica / Metakaolin

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Approaches now and in the Wings

- Pozzolans
- Latently hydraulic materials
- Type I L cement
- Limestone, Clinker and Calcined Clay (LC3)
- Alkali activation
- Geopolymers
- Synthetic Aggregate that is made from atmospheric CO_2

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Pozzolan Reaction

C2S,C3S,C3A, C4AF + water → Glue +CH

CH+Pozzolan → Glue

Quantity of CH depends on clinker content and degree of reaction (Partially controlled by w/cm ratio)

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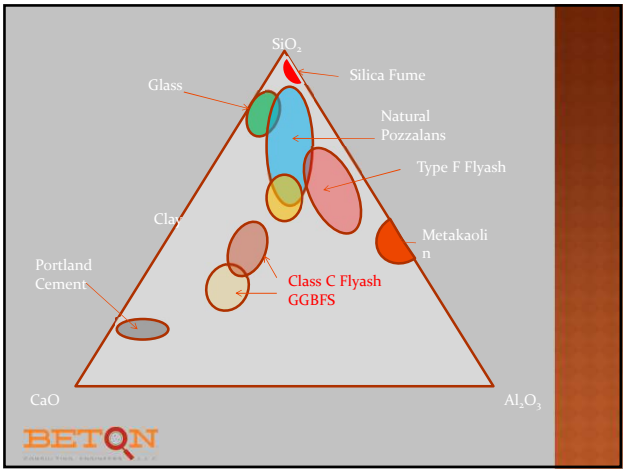

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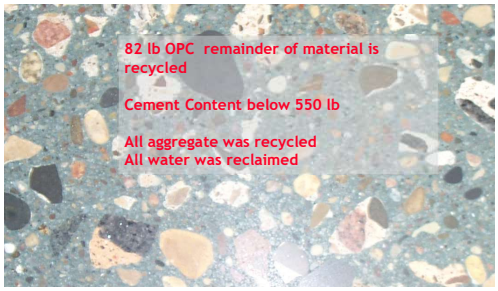
Extreme Example



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AET 4060

- RCP at 84 days 490 Coulombs passed
- Setting Time 4:30 Initial Set
- Air Void System
  - Air Content 5.5 percent
  - Spacing Factor 0.008 in
  - Specific Surface 600 in^2 /in^3
- Shrinkage 0.005 percent at 28 days
- Strength Gain

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Annealing - old term for curing (1900)

- Heat Treating to get desirable Properties
- Mixtures are *Self-Annealing* when insulated
- Need to control temperature not to prevent freezing but to increase rate of hydration

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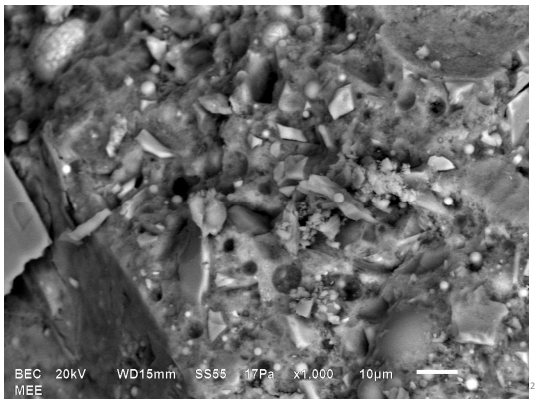

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Type I L Cement

- Intergrind limestone into the cement
- Improves the cement and reduces the emissions and energy

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Pre-Carbonation

- Aqueous solution saturated with free lime reacts with carbonic acid to become calcium carbonate (insoluble)
- Can be cementing
- Process is natural – limestone and dolostone are made this way
- Can be used to make in-situ nucleation

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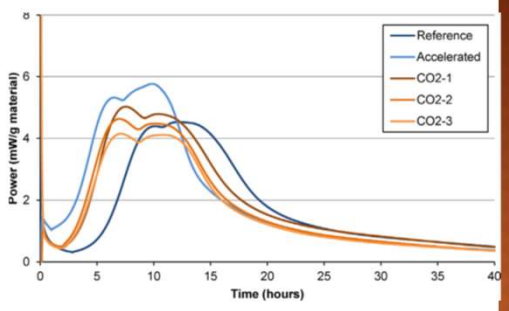

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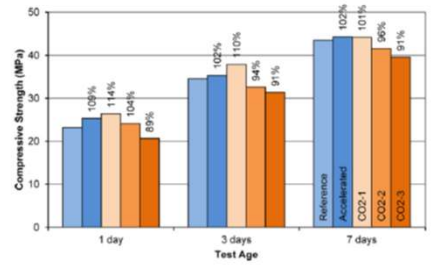

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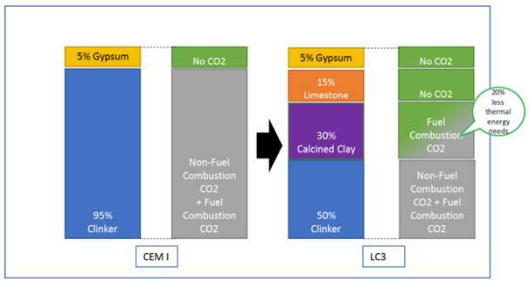
LC3 – Limestone, Calcined Clay and Clinker



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Alternate Binders

- Magnesium Carbonates
- (2)Mg(OH)2 + CO2 + 3H2O → MgCO3.3H2O (nesquehonite)
- (3)5 Mg(OH)2 + 4CO2 → 4MgCO3.Mg(OH)2.4H2O (hydromagnesite)
- Sorel Cement
- MgO +MgCl2 → Magnesium OxyChlorides

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Magnesium Phosphates

- $MgO + NH_4H_2PO_4 + 5H_2O \rightarrow NH_4MgPO_4 \cdot 6H_2O$
- $3MgO + 2NH_4H_2PO_4 + H_2O \rightarrow Mg_3(PO_4)_2 \cdot 4H_2O + 2NH_3$
- $MgO + NH_4H_2PO_4 \rightarrow NH_4MgPO_4 \cdot H_2O$

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Alkali Activated Materials

- No Clinker
- Using Flyash, Slag, Glass, other forms of Amorphous silica and Alumina
- Activate with high Alkalinity Materials:
  - Sodium Hydroxide
  - Sodium carbonate
  - Sodium Silicate
  - (Potasium)

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Alkali Activated Materials

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Port of Trajan at Portus

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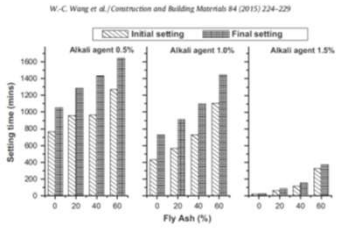

Fig. 5. Setting time of slag based geopolymer pastes.

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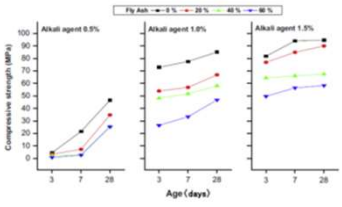

Fig. 6. Compressive strength of slag based geopolymer pastes.

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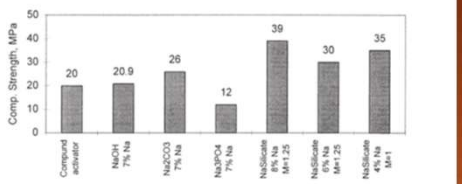

Fig. 1. The 28-day compressive strength of alkali-activated slag pastes.

Cement and Concrete Research 29 (1999) 113–120

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Synthetic Aggregates

- Pre-Carbonation
- Pressure or Sintering
- Biochar – will hold water (internal curing) but will also absorb admixtures that rely on hydrophobic mechanisms

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Recycled Aggregate

- Concrete Aggregate Quality Requirements are high
- Most recycled concrete is fill (low value reuse)

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Quality – Sustainability link

- Improved quality results in:
  - Fewer instances of incorrect materials accepted, batching errors
  - Less time spent on mix adjustments
  - Less returned concrete
  - Fewer callbacks due to concrete performance
- All of the above will result in
  - Less energy and resources, less repair/removal/replacement

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Improved quality helps target a low S

- Lower CO_2
- Conserves natural resources

QC Standards (ACI 214R)	Excellent	V Good	Good	Fair	Poor		
S, psi	350	450	550	650	750	950	1250
f'_{cr}, psi	4470	4600	4780	5020	5250	5710	6410
CM, lb/yd³	447	460	478	502	525	571	641
CO_2, lb/yd³	463	476	494	518	541	587	657

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Durability

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But will it be durable?

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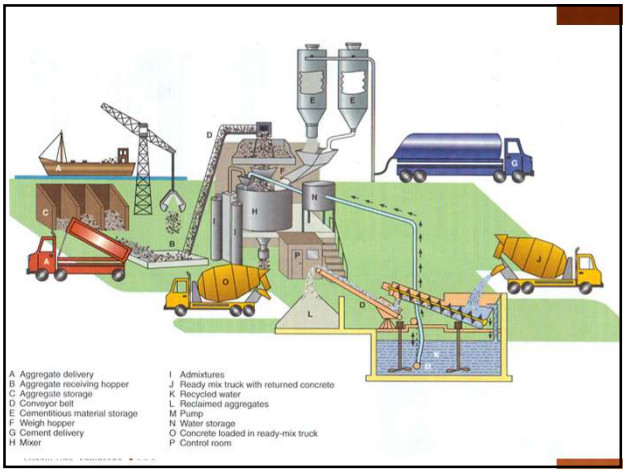

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Corrosion Prevention is Easy

- a. If there will be corrosion:
  - Change the material
  - Change the environment
  - Isolate the material and the environment
- If that doesn't work see a.

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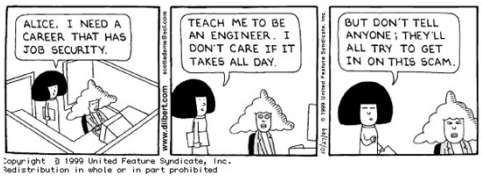
ACI 318 – Written to the Designer



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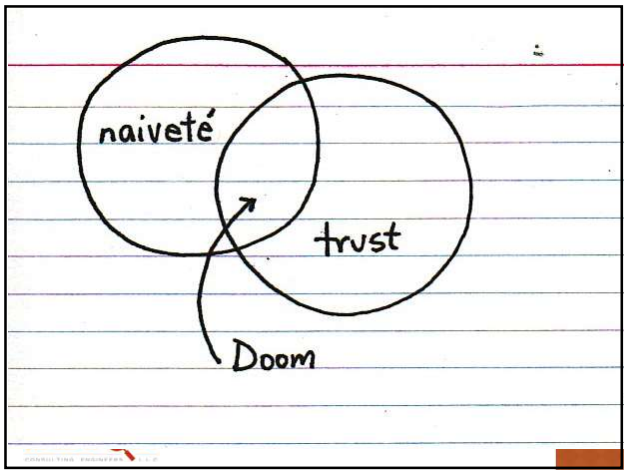

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Obstacles

- We are developing new technologies and new materials
- New processes and new construction methods
- Doing so not to improve construction or performance – to reduce / eliminate emissions and reduce energy needs
- History tells us that there will be problems and they will be discovered in practice.

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Conclusions

- Concrete is rapidly changing – codes are not (cannot)
- We need to reduce or eliminate the clinker content of our concrete.
- We can currently use high volume replacement with pozzolan
- We are on the cusp of using materials that would require massive infrastructure investment (Plants, Equipment, People)
- Construction and Design methods will likely chage as we adopt new materials

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Questions

- Thank you for your time and attention!

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