SUSTAINABLE DESIGN USING SUPPLEMENTARY CEMENTING MATERIALS

Case Studies

" The World will not evolve past its current state of crisis by using the same thinking that created the situation."

~ Albert Einstein

KRISTY NEISH, LEED™ AP, P. ENG.
Read Jones Christoffersen Ltd.

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WHY USE SCM'S?

- **Good Design**
  - Durable, adaptable buildings
  - Efficient use of materials
- **Owner Goals**
  - LEED credits
  - Economic/Green Balance

USE OF FLY ASH

Target Levels of Fly Ash:

- Highest in footings
  - 40% – 50%
- Mid-Range in vertical elements
  - 35% – 50% in walls and columns
- Lower in horizontal elements
  - 25% – 40 % in slabs
- Low in C1 exposure class (max 15%)

- Greatest concrete component is often slabs
  - up to 40% volume of typical highrise

CASE STUDIES

The Use of Fly Ash at:

- Bison Courtyard (Courtyard on Bear), Banff
- Cave Avenue Housing, Banff
- Bridges – The Vento, Calgary

CASE STUDY:

BISON COURTYARD

FLY ASH USE

- 40% cement replacement
  - Footings
  - Walls
- 35% cement replacement
  - Columns
- 30%, 35%, 40% cement replacement
  - Suspended slabs
- 25% cement replacement
  - Parkade slab-on-grade

Client:	Arctos & Bird Management
Project Manager:	PCL Construction
Concept Architect:	William McDonough + Partners
Primary Architect:	Zeidler Carruthers & Associates
Structural Engineer:	Read Jones Christoffersen Ltd.

CASE STUDY:

CAVE AVENUE HOUSING

FLY ASH USE

- 40% cement replacement
  - Footings
  - Walls
- 35% cement replacement
  - Columns
- 30% cement replacement
  - Suspended Slabs
- 25% cement replacement
  - Parkade slab-on-grade

Client:	Arctos & Bird Management
Project Manager:	Rescom Construction
Concept Architect:	William McDonough + Partners
Primary Architect:	IBI Group
Structural Engineer:	Read Jones Christoffersen Ltd.

CASE STUDY:
BRIDGES – THE VENTO

FLY ASH USE

- 50% cement replacement
  - Footings
  - Columns
- 45% cement replacement
  - Walls
- 40% cement replacement
  - Suspended slabs
  - Slabs-on-grade

Client: Windmill Developments
Project Manager: Stuart Olson Contracting Inc.
Architect: Busby, Perkins + Will
Structural Engineer: Read Jones Christoffersen Ltd.

SPECIFYING THE USE OF SCM'S

Element	Min. Strength (MPa)	Slump (mm)	Max. Agg. (mm)	Exposure Class
Slabs, Slab Bands, & Beams	30	70	20	N
Interior Walls	25	80	20	N
Interior Columns	30	80	20	N
Slab-on-grade (Interior Parking)	32	70	20	C-4
Exterior S.O.G, Sidewalks	32	70	20	C-2
Footings	30	80	40	N
Foundation Walls	30	80	20	F-2
Exterior Columns	30	80	20	F-2
Parkade Ramp	35	70	20	C-1
Footings	25	80	40	N
Foundation Walls	25	80	20	N
S.O.G (Interior No Parking)	25	70	20	N

- Specifications
  - Minimum fly ash targets
  - Curing requirements
  - Trial Mixes
- General Notes Drawings
  - Performance information
  - Curing requirements
- Pre-Construction Meeting
  - Review and clarify requirements
  - Be open for change

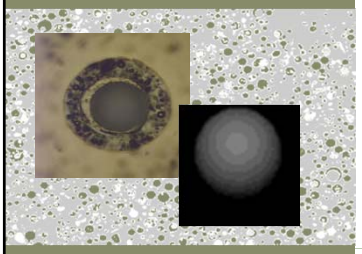
CEMENT REPLACEMENT

Why not always use 50% cement replacement?

- Exposure
- Initial set time for finishing
- Early strength gain
  - Stripping formwork

- Mix designs driven by early strength gain

CEMENT REPLACEMENT



% Fly Ash = % Cement Reduction?

- Not necessarily…
  - Standard Mix – 300 kg cement
    - 40% cement replacement = 120 kg
  - "40% Fly Ash Mix"

144 kg fly ash

<u>216 kg cement</u>

360 kg total CM

Actual cement reduction = 84 kg

(only a 28% reduction)

CEMENT REPLACEMENT – BANFF PROJECT MIXES

Element	Strength at 28/56 days (MPa)	%Fly ash/Total Cementitious Material and Total Cementitious Material (kg/m^3)		
		Mix A Standard	Mix B Summer	Mix C Winter
Suspended Slabs	30	25% 285 kg/m^3	35% 271 kg/m^3	30% 271 kg/m^3
Interior Walls	25	25% 260 kg/m^3	45% 247 kg/m^3	35% 247 kg/m^3
Interior Columns	30	25% 285 kg/m^3	45% 271 kg/m^3	35% 271 kg/m^3
Footings	30	25% 285 kg/m^3	50% 270 kg/m^3	40% 270 kg/m^3
Foundation Walls	30	25% 328 kg/m^3	45% 311 kg/m^3	40% 311 kg/m^3
Slab-on-grade (Interior No Parking)	25	25% 260 kg/m^3	35% 247 kg/m^3	30% 247 kg/m^3

CEMENT REPLACEMENT

Every experience is different:

- Aggregate source
- Cement source
- Fly ash source
- Curing temperature, conditions

Trial mixes help resolve these uncertainties

LEED ™ LEADERSHIP IN ENERGY AND ENVIRONMENTAL DESIGN

How does fly ash impact LEED™?

- LEED™Canada provides new incentive
- Concrete as a building material

LEED™ MR Credit 4.1

- Uses ***cement reduction*** rather than ***% fly ash***
- Provides a bench mark for a standard mix

USING SCM'S: THE BENEFITS

- Environmental benefits
- Greater long-term strength
- Greater durability (less permeable)
- Better workability
- Aesthetics

USING SCM'S:
THE CHALLENGES

- Slower initial set
  - Time pours to allow for delay
  - Decrease W/CM
- Slower early strength gain
  - Formwork scheduling
  - Accelerators
- Winter construction
  - Heating and hoarding

CASE STUDY

BISON COURTYARD, BANFF, ALBERTA 2004

Client:	Arctos & Bird Enterprises
Primary Architect:	Zeidler Carruthers & Assoc. Arch.
Design Architect:	William McDonough + Partners
Structural Eng:	Read Jones Christoffersen Ltd.
Materials Eng:	McIntosh Lalani Engineering
Contractor:	PCL-Maxam, A Joint Venture
Concrete Supply:	Lafarge Canada Inc.

HVFA Concrete use in winter pouring

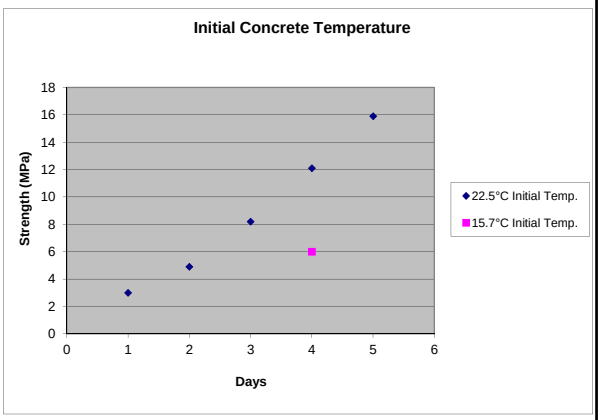
- Determine % of fly ash in concrete for cold temperatures (Av. Ambient temp = -25)
- Obtain information on the use of accelerators in HVFA concrete
- Compare energy consumption of heating and hoarding of HVFA concrete relative to standard concrete

CASE STUDY

BISON COURTYARD
BANFF, ALBERTA 2004

Concrete temperature arriving on site:

- Half the strength gain of warmer concrete

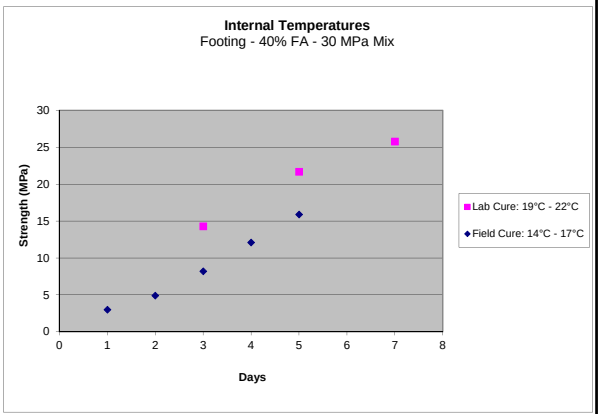


CASE STUDY

BISON COURTYARD
BANFF, ALBERTA 2004

Concrete temperature during curing:

- 5°C difference slowed strength gain up to 70%

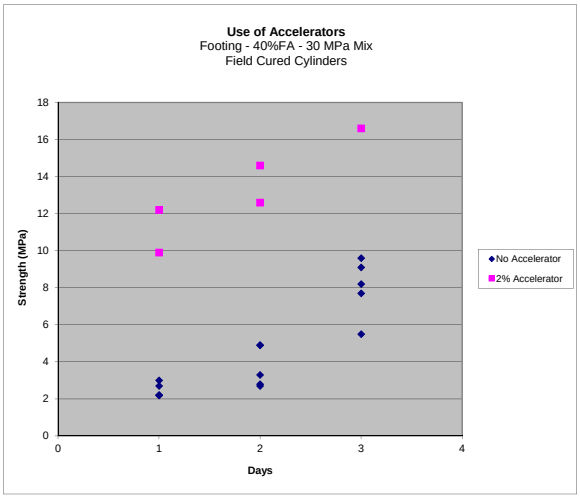


CASE STUDY

BISON COURTYARD
BANFF, ALBERTA 2004

Use of accelerators:

- Doubled strength gain in first three days



CASE STUDY

BISON COURTYARD
BANFF, ALBERTA 2004

Suspended Slabs:

- Used 30%, 35%, and 40% fly ash
- Heated formwork and rebar prior to pour
- Maintained 20°C to 25°C below slab for curing period (at least 7 days)

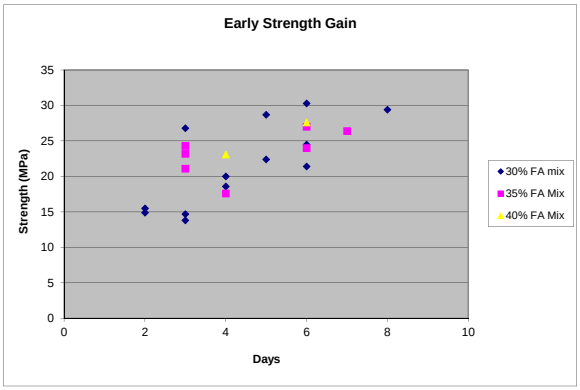
- **Concern with high W/CM**
  - Early strength gain
  - Durability

CASE STUDY

BISON COURTYARD
BANFF, ALBERTA 2004

Suspended Slabs

- Initial strength gain results encouraging
- W/CM did not have a detrimental effect

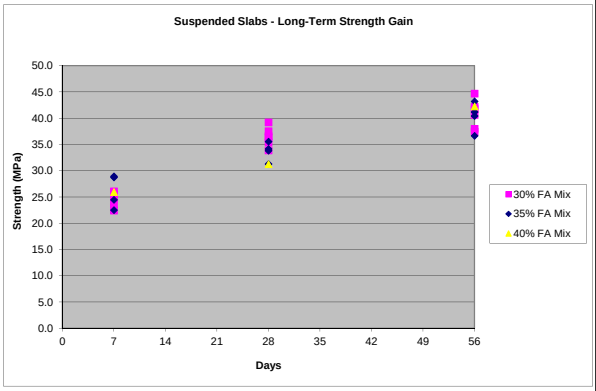


CASE STUDY

BISON COURTYARD
BANFF, ALBERTA 2004

Long-Term Strength Gain

- Suspended slab with 30 MPa design strength:



- Suspended slabs, columns, walls, and footings all had similar long-term strength gains

CASE STUDY

BISON COURTYARD
BANFF, ALBERTA 2004

- Environmental cost of winter construction
  - Heat and hoarding required for HVFA and standard concrete
  - No additional energy penalty for HVFA concrete according to the contractor
  - Winter construction results in increased costs and energy consumption – best solution to schedule concrete pours in summer
- Side effect of winter construction
  - Constant, controlled heat dictated by the contractor to suit construction schedule

CONCRETE STRENGTH MEASUREMENT

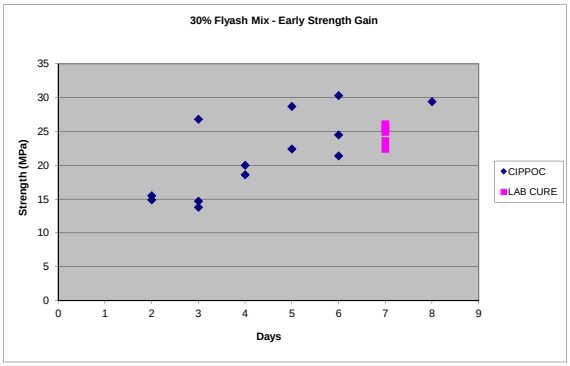
Methods of Testing:

- Lab-cured cylinders
  - Do not reflect site temperatures
  - Use for long term strength measurements
- Traditional field-cured cylinders
  - Sit below hoarding, next to pour
  - Do not benefit from the mass heat
- Lok tests
  - Cast in, measure in-situ strength
  - Measures surface concrete strength
- Cast-in-place punch-out cylinder (CIPPOC) tests
  - Cast in, measure in-situ strength
  - Requires transportation
  - Plastic sleeve blocks some of the mass heat

CONCRETE STRENGTH MEASUREMENT

Comparison of results:

- Similar strength results
- Good heating and curing



CONCLUSIONS

- **Fly ash targets**
  - Vary based on element and weather
- **Trial mixes**
  - Aggregate/Cement/Fly ash combination
  - Lab cure test should simulate site conditions
  - Trial pour to gauge workability
- **Curing**
  - Important for all concrete
  - Especially important for HVFA concrete
- **Testing**
  - CIPPOC and Lok test preferred

THANK YOU

"Meeting the needs of the present generation without compromising the ability of the future generations to meet their needs."

- Oxford 1987, The world commission of environment and development

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