ENERGY EFFICIENT AND SUSTAINABLE CONCRETES for INSULATED CONCRETE FORM CONSTRUCTION

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What is ICF Construction

- **Expanded polystyrene forms and polypropylene webs form "lego blocks"**
- **horizontal & vertical steel reinforcement placed in web spacers**
- **concrete cast into cavity between forming surfaces**

Advantages

- Life cycle energy cost savings
- automatic thermal and sound insulation
- good curing environment for concrete
- shrinkage and thermal cracking of walls reduced or eliminated
- thermal insulation for concrete for cold-weather applications
- Reduction in energy and greenhouse gas emissions if new technology is adopted

Current Disadvantages

- increased initial capital costs
- non-traditional construction method slow to be adopted by practitioners
- Forms hard to handle in high winds
- more steel required in the concrete as per building codes

General Objectives

- Bring Initial Capital Cost of ICF concrete construction down to the level of traditional framed construction.
- Produce more energy-efficient and sustainable solutions for residential and light-commercial construction.
- Improve the quality of construction and increase the service-life of concrete foundations.

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Overall Test Program

- Laboratory Research
  - Develop innovative concrete mix designs for ICF construction
  - Test for fundamental and engineering properties of materials and wall units
    - ⇨strength, shrinkage, soundness, durability, sorptivity, diffusivity, microstructure, chemistry
- Appropriate pilot testing on full-scale implementations
- Construction and performance monitoring of ICF structures

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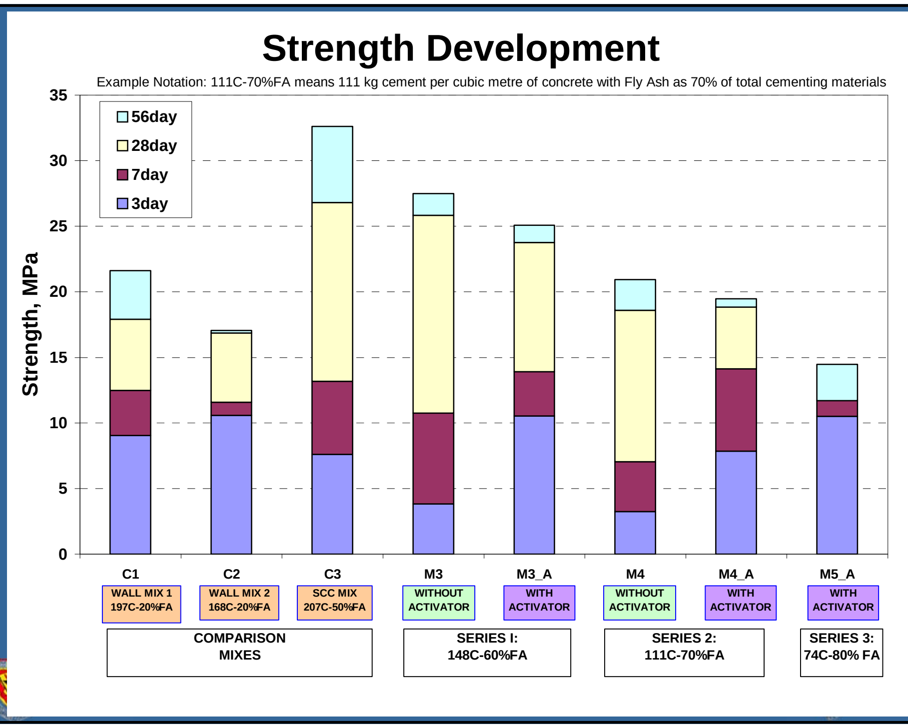
Today's Presentation

- **Development of suitable ICF concrete mixes**
- **Examination of effect of different curing régimes on strength gain**
- **Construction and testing of a full-height ICF wall**

Test Mix Proportions

MIX	DESCRIPTION	Cement kg	Fly ash kg	Total Cementing Materials kg	Fly Ash % of binder	w/cm by mass
C1	STANDARD WALL MIX	197	49	246	20	0.67
C2	SUB STANDARD WALL MIX	168	42	210	20	0.8
C3	MEDIUM STRENGTH SCC MIX	207	207	414	50	0.43
M3	60% ASH SCC MIX NO ACTIVATOR	148	222	370	60	0.57
M3_A	60% ASH SCC MIX WITH ACTIVATOR					
M4	70% ASH SCC MIX NO ACTIVATOR	111	259		70	0.56
M4_A	70% ASH SCC MIX WITH ACTIVATOR					
M5_A	80% ASH SCC MIX WITH ACTIVATOR	74	296		80	0.56



Interim Conclusions from Strength Results

- Self-compacting concretes suitable for ICF construction can be manufactured with very high quantities of fly ash and significantly lower cement contents than traditional wall mixes.
- For concretes with 60 or 70% of the cementing materials as fly ash and low cement contents, an activator can be used to boost early strengths.
- Mix M4_A appears to be the best mix for further study.

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Effect of Curing on Strength Gain

- Five curing régimes used
  - (FOG) -- fog cure until strength test
  - (BURLAP) -- cure under wet burlap and poly for 7 days then expose cylinders to the lab environment
  - (ICF) – cylinders encapsulated in expanded polystyrene from time of casting
  - (COMPD) – cylinders sprayed with curing compound and left in the laboratory
  - (NONE) – cylinders left in laboratory after demoulding (20ºC, 40% rh)

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ICF Curing

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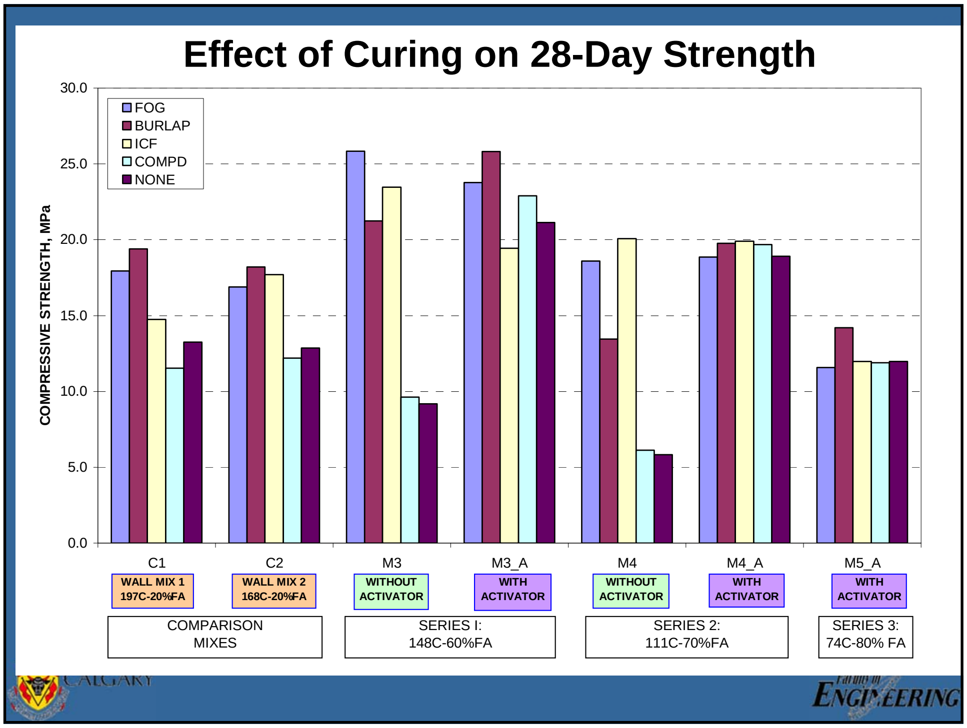
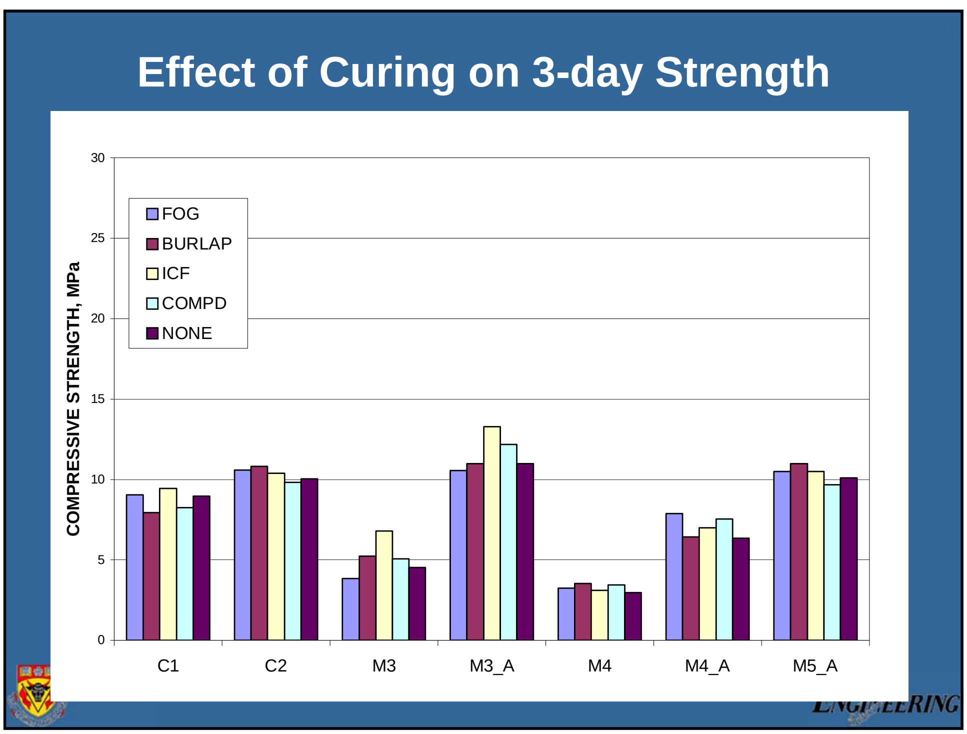

Effect of Curing on 28-Day Strength
COMPRESSIVE STRENGTH, MPa
30.0
25.0
20.0
15.0
10.0
5.0
0.0
FOG
BURLAP
ICF
COMPD
NONE
C1
C2
M3
M3_A
M4
M4_A
M5_A
WALL MIX 1 197C-20%FA
WALL MIX 2 168C-20%FA
WITHOUT ACTIVATOR
WITH ACTIVATOR
WITHOUT ACTIVATOR
WITH ACTIVATOR
WITH ACTIVATOR
COMPARISON MIXES
SERIES I: 148C-60%FA
SERIES 2: 111C-70%FA
SERIES 3: 74C-80% FA


Effect of Curing on 3-day Strength
COMPRESSIVE STRENGTH, MPa
30
25
20
15
10
5
0
FOG
BURLAP
ICF
COMPD
NONE
C1
C2
M3
M3_A
M4
M4_A
M5_A

Wall Cast

- Mix M4_A (111 kg cement, 70% ash) placed by in-line pump
- Horizontal and vertical shrinkage measured for 30 days
- 16 cores taken at 84 days and measured for strength, density, absorption

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Variation of Properties with Wall Height

Height Above Ground (ft)	Density (kg/m^3)	Compressive Strength @ 84 days (MPa)	Immersion Absorption (%)	Volume Permeable Voids (%)
8	2256	17.2	7.5%	16.2%
6	2270	18.6	7.2%	15.7%
4	2284	20.2	7.0%	15.1%
2	2291	24.3	6.7%	14.5%
Average	**2275**	**20.1**	**7.1%**	**15.4%**

Absorption and VPV are similar to that found in a traditional residential foundation concrete

Gradient in properties from bottom to top is similar to that observed in many other wall tests and does not indicate excessive segregation

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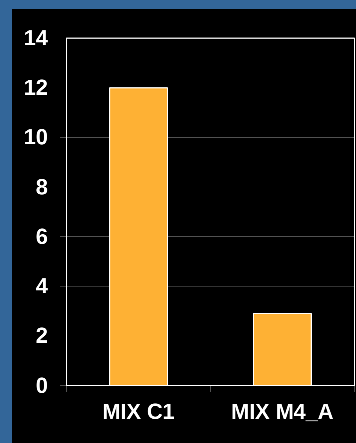
Mass Transport Characteristics
Basement Mix C1 vs. Mix M4_A

Initial Absorption
10^{-3} mm/s$^{1/2}$
age = 3 days at test

Chloride Migration Coefficient
10^{-12} m^2/s
age = 28 days at test



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Potential Energy and GHG Impact by Adoption of High Ash ICF Concretes (life-cycle savings not included)

- Savings per average house with an ICF concrete foundation using Mix 4_A or equivalent:
  - 3 tonnes of cement
  - 2.7 tonnes less GHGs
  - 10.5 GJ of energy
- If in 10 years, ICF foundations enjoy 50% of the overall house construction market:
  - Take Calgary example alone, 13,000 housing starts per year
  - Saving in cement of approximately 19,500 tonnes per year
  - Savings in GHG of 17,500 tonnes per year
  - Savings in Energy of 68,000 GJ per year

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Continuing Research

- Methods for further cost reduction of materials and construction practice
- Alternative methods to enhance reactivity
- Development of suitable floor mixes
  - shrinkage, finishability
- Long-term durability properties of wall sections
- Full-scale implementation pilot studies

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QUESTIONS?

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