EcoSmart™ Concrete Project
a concrete contribution to the environment™

EcoSmart Concrete Project And the Little Mountain Reservoir Case Study

Roy Sage, Climate Change Action Plan 2000
Michel de Spot, P.Eng., EcoSmart™
A.P. Sukumar, P.Eng., GVRD
John Sherstobitoff, P.Eng., Sandwell Engineering
Daniel St-Pierre, P.Eng., Lafarge
Rob Karchewski, P.Eng., Graham Construction
Phil Seabrook, P.Eng., Levelton Engineering

BC Construction Show
Vancouver, February 25, 2004

Climate Change Action Plan 2000

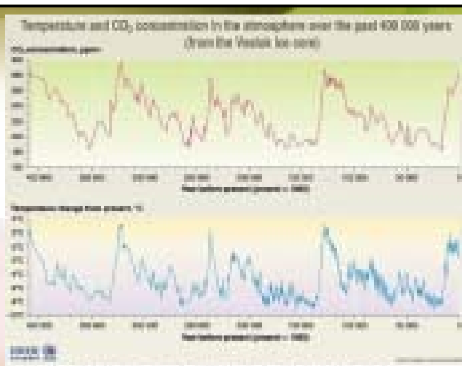
Roy Sage

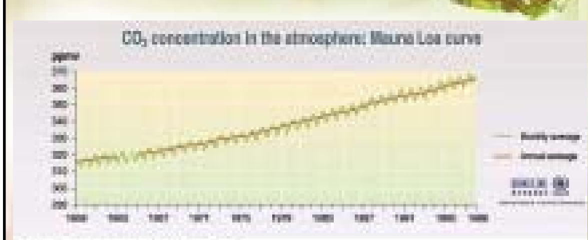
Action Plan 2000 – Minerals and Metals Part of Canada's National Action Plan on Climate Change

Roy Sage
Natural Resources Canada

Is climate change real?

- There is a greenhouse gas effect
  - Water vapor
  - Carbon dioxide
  - Methane
  - PFCs, SF_6, NO_2

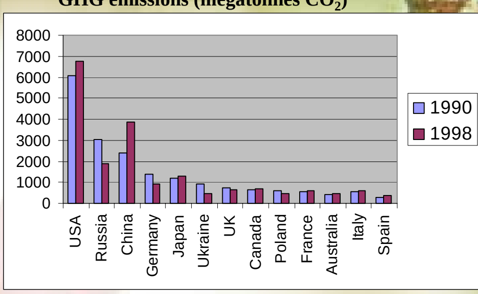




What is Canada's role?

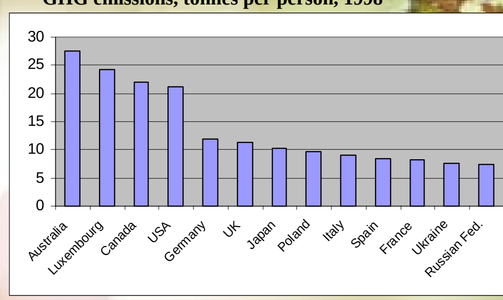
- **We are both a small and a large country**
  - Few people – 30 million, about 0.6% of global total
  - Very large land mass
- **Large GHG emitter**
  - About fifth or sixth in world (comparable to UK)
  - Third in terms of GHG per person

GHG emissions (megatonnes CO_2)



Source: Jean-Marc Jancovici, L'Avenir Climatique, 2003

GHG emissions, tonnes per person, 1998

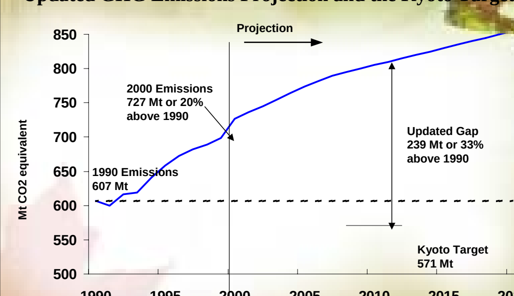


Source: Australia Institute 2001

Canada's climate change action plan

- **Canada believes:**
  - the potential impact of human-induced climate change is serious and likely to be true
  - the global community community should act now to reduce emissions of greenhouse gases.
- **In consultation with provinces, municipalities, NGOs, industry, Canada has developed a multi-stage Action Plan**
  - Also ratified the Kyoto accord

Updated GHG Emissions Projection and the Kyoto Target

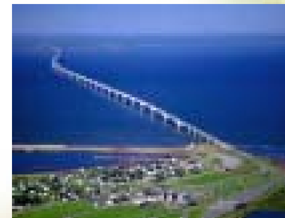


Cement

- **Globally, cement manufacture accounts for release of more than 5% of total CO_2 emissions.**
- **In Canada, total emissions are about 12 million tonnes CO_2 per year**
- **Well-established that supplementary cementing materials – SCMs – can partially replace cement in many applications**
  - Requires careful engineering and control
  - Around 10% of Canada's cement requirement is already met this way.

Cement industry position

- **Excellent acceptance that SCMs are important**
  - Green buildings
  - Reduce associated CO_2 emissions
  - Used properly, result in higher quality concrete
- **Can often reduce total cost of concrete**



Goal

- **Action Plan 2002 believes use in Canada can increase to average 25%**
  - Increase would displace about 1.8 million tonnes of cement per year
  - Would reduce GHG emissions by up to 1.5 million tpy
- **AP 2000 has supported EcoSmart in western Canada**
- **Now looking to expand EcoSmart across Canada.**

EcoSmart Presentation

Michel de Spot, P.Eng.

About EcoSmart

Climate Change

Technological Innovation and Deployment

Industry - Government Partnership

- Industry Canada, Environment Canada, CANMET, PWSC, GVRD
- Lafarge, Lehigh, CAC, Pre-cast industry
- Engineers, Architects

EcoSmart Objectives

To minimize GHG "signature" of concrete
by optimizing replacement of Portland cement with SCM
while improving or maintaining

- Cost
- Performance
- Constructability

The Strategy

Case studies
SCM's* investigations
Risk abatement
Knowledge management

* Supplementary Cementing Material

Case Studies

Maximum:	Exploring the boundaries - 50%
Optimum:	Adapted mix design
Average:	One-fits-all, "Universal" mixes

The Waterfall Studios

50% fly ash

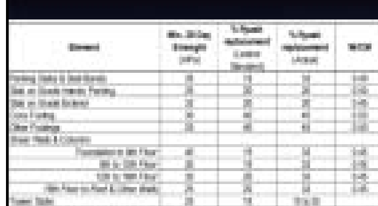
Cranberry Commons Townhouse

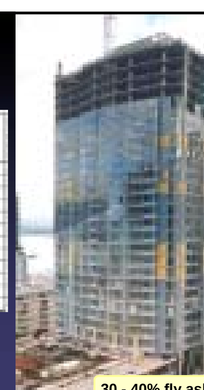
50% fly ash

York University Computer Science Building

50% fly ash

Bayview High Rise Building

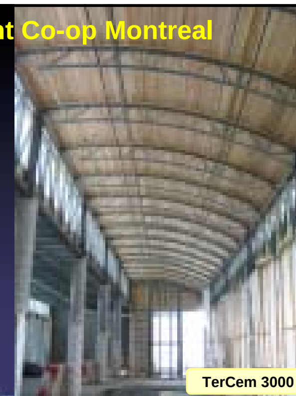




30 - 40% fly ash

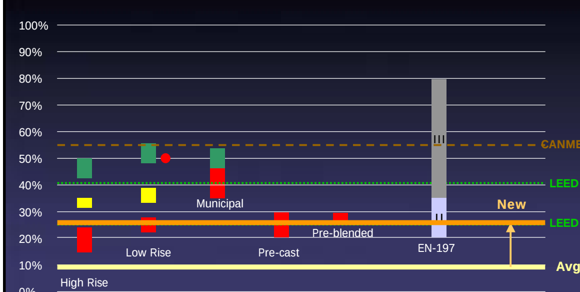
High-Rise Study

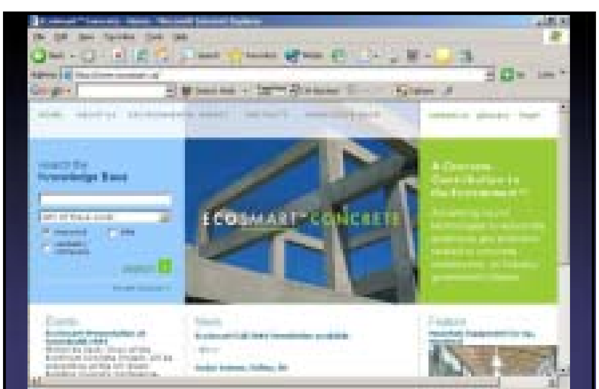
Mountain Equipment Co-op Montreal



Brentwood SkyTrain Station

How Much?





The Little Mountain Reservoir Reconstruction Case Study

– EcoSmart Concrete in Action

The Owner's Perspective

A.P. Sukumar, P.Eng.

SUSTAINABILITY IN ACTION
LITTLE MOUNTAIN RESERVOIR RECONSTRUCTION

GVRD's Sustainable Region Initiative:
A framework and action plan for the present and the future of Greater Vancouver..

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People

- Partnership
- Partnering
- Public Consultation
- Impact Mitigation
- Communication

Environment

- Recycling
- 'Green' Construction
- Environmental Monitoring
- Tree Protection & Replanting

Resources

- Safety & Reliability
- Optimumization
- Minimum Life cycle Cost
- State of the art
- Long Term
- Multiple use

Integration of enhanced public safety, and reliability of infrastructure with recreation.

Triple Bottom Line Balance

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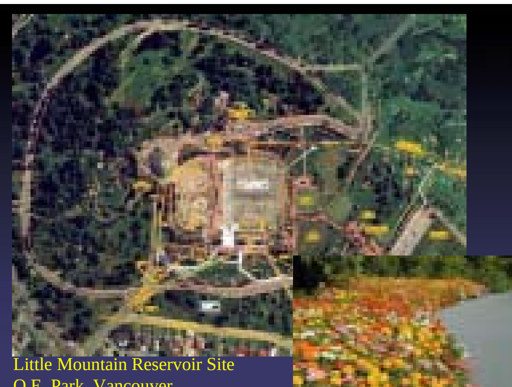

Little Mountain Reservoir Site
Q.E. Park, Vancouver

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LMRR Project in Brief

- 38.5 mil. gal. (175 mil. L) capacity
- More than 2 football fields in area
- Two independent reservoir cells
- Public Consultation & Openhouse 2001-2003, 2004
- Demolished in September 2002
- Critical Milestone (Cell #1) in June 2003
- Construction is now 99% complete
- Roof top Redevelopment in 2004 by VPB
- Budget: $37.6 million.
- **Project on Schedule, *within* budget**
- **EcoSmart Concrete +/– 27,000 Cu.m**
- **Concrete with 40 to 58% Fly Ash**

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Demolition & Recycling
•On-site separation of concrete and steel
•Concrete sent to plants making concrete lock blocks
•Rebar sent to a recycling plant
Concrete Crusher on site
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LITTLE MOUNTAIN RESERVOIR RECONSTRUCTION *in Progress*
July 2003
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Roof slab and columns
Reservoir walls
High Quality Concrete (27,000 (+/-) Cu.m) Finish Using EcoSmart™ Concrete
Prevented 3700 (+/-) Tonnes of CO_2 emissions
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Canada


Integration
Public safety
Reliability
Communication
Environmental Stewardship
Resource Optimization
Innovative Technologies
Public Engagement
Partnership
Multiple Use
Continuous Improvement
In Summary….
Project – Infrastructure Renewal
Mission- Sustainable Development
Strategy- Sustainability in Action
Partners – Public
Project Team- Stewards
Result– A Sustainable Facility
LITTLE MOUNTAIN RESERVOIR RECONSTRUCTION
APEGBC Sustainability 2003 Award Winning Project
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LITTLE MOUNTAIN RESERVOIR, Q.E. Park, 1910
Photo taken in 1940
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LITTLE MOUNTAIN RESERVOIR, Q.E. Park, 1966
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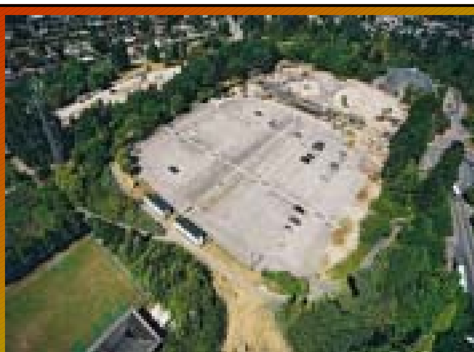
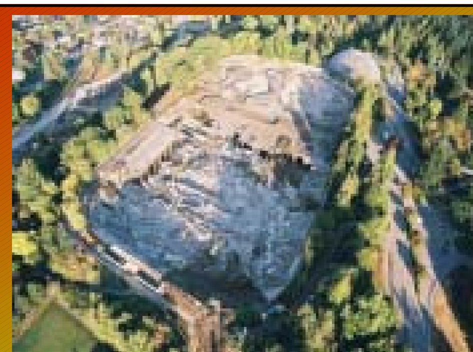
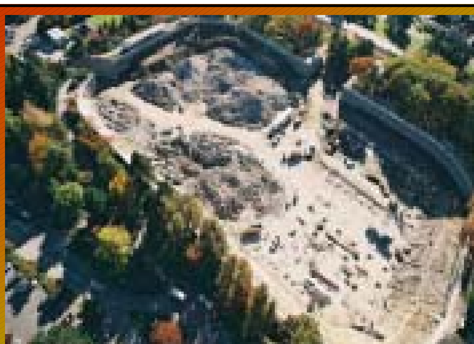


LITTLE MOUNTAIN RESERVOIR RECONSTRUCTION
August 2002



LITTLE MOUNTAIN RESERVOIR RECONSTRUCTION
September 2002

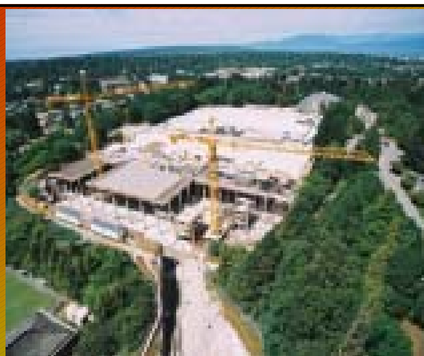


LITTLE MOUNTAIN RESERVOIR RECONSTRUCTION
October 2002

LITTLE MOUNTAIN RESERVOIR RECONSTRUCTION
January 2003

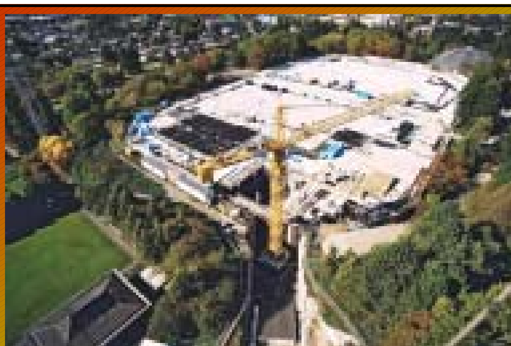
LITTLE MOUNTAIN RESERVOIR RECONSTRUCTION
May 2003

LITTLE MOUNTAIN RESERVOIR RECONSTRUCTION
June 2003



LITTLE MOUNTAIN RESERVOIR RECONSTRUCTION
July 2003

LITTLE MOUNTAIN RESERVOIR RECONSTRUCTION
September 2003



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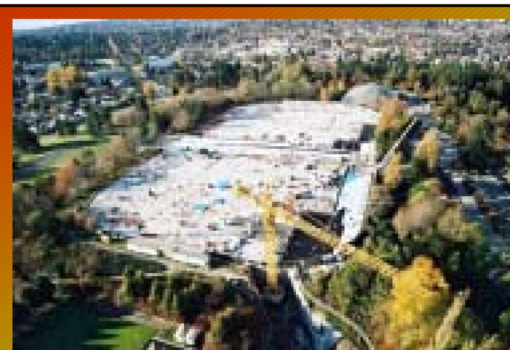
October 2003



LITTLE MOUNTAIN RESERVOIR RECONSTRUCTION
November 2003

The Designer's Perspective

John Sherstobitoff, P.Eng.

Structural Concept

- Monolithic Base Slab, Walls & Roof
  - No expansion joints
  - Advantages
    - Efficiently resist high seismic demands
    - Eliminate high maintenance movement joints

Design Issues

- Challenge: Control temperature and shrinkage effects
- Uncontrolled Cracks = Leakage and loss of durability

Mitigate Shrinkage Effects

- Optimize concrete mix design
  - EcoSmart concrete (plus Shrinkage Reducing Admixtures in base slab)
  - Establish construction procedures
    - Curing & temperature controls

Concrete Performance Requirements

- Long term durability
- Low permeability
- Strength without undue impact on schedule
- Placeability
- Limit all cracks to < 0.2mm (but still anticipate significant crack injection)

Previous Experience

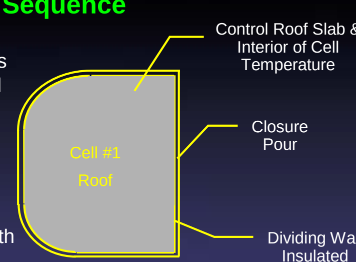
- Good performance using EcoSmart concrete on massive pour for TG foundation
- Significant reduced heat of hydration
- Minimal cost/schedule impact

Design Procedures

- Retain materials specialist intimately familiar with performance and project
- Ensure formwork feasible for full height pours (9m to 13m)
- Detailed concrete specifications
- QA/QC specifications

Construction Sequence

- Base Slab and Walls cast in checkerboard fashion
- Roof slab cast independent of walls with closure pour at perimeter
- Closure pour cast with roof temperature controlled



Construction Aspects

- Partnering with contractor
- Enforce QA/QC specs
- Flexibility to accommodate changes

Sandwell

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Conclusions

- Far fewer cracks exceeding 0.2mm than anticipated (save $)
- Passed hydrostatic leak test with flying colors
- Recommend future use

Sandwell

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The Concrete Supplier's Perspective

Daniel St-Pierre, P.Eng.

LAFARGE

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LAFARGE

LMRR Project

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LAFARGE

OUTLINE

- Project Specification
- Concrete Mixtures
- Flyash Content
- Pre Pour Meeting
- Concrete Testing
- Challenges
- Communication

LLMR Project – Little Mountain Reservoir Reconstruction

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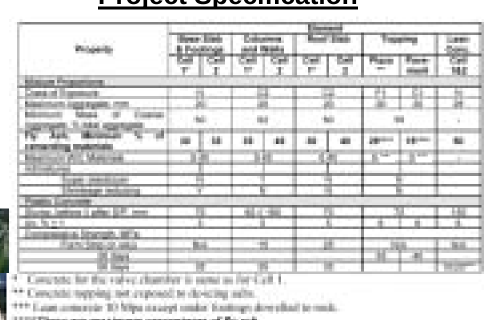
LAFARGE

Project Specification



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Concrete Mixtures

- 2 sets of Concrete Mixtures were designed to address the winter/spring pour on Cell 1 and the Summer/Fall pour on Cell 2.
- Shrinkage Reducing Admixtures were used on the project and tested in accordance with ASTM C157 as per the Project Concrete Specification.
- The Specification required much higher Flyash percentage than what is normally used in the GVA. The determination and firm effort from all parties (GVRD, Design Engineer and QA Engineer) to maintain the Flyash percentages paid off for a successful completion of the project.

Flyash Content

- The weighted average overall Flyash content on the project for all mix designs used on the project is slightly over 44 % for a total volume of concrete exceeding 27,000 m^3.
- Concrete strengths were designed at 56 days.


Pre Pour Meeting – Highly Recommended

- Numerous Pre Pour Meetings took place between Graham, GVRD, Lafarge, Levelton, Sandwell & Metro Testing at the beginning and throughout the project. The key groups are as follows:
  - Supplier.
  - Superintendent & forming crew.
  - Concrete placement crew.
  - Pumping contractor.
  - Engineer / Architect.
  - Testing lab.

Concrete Testing

- Lafarge did internal QA testing on site to complement the main QC testing conducted by Metro Testing and to maintain the Mix Quality.

Concrete Strength Summary at 56 days

	Slab Concrete	Wall Concrete
No. of Test Sets	65	48
Max, MPa	60.7	59.2
Min, MPa	40.2	35.2
Standard Deviation, MPa	4.1	4.8
Coefficient of Variation, %	8.8	10.1
ACI 214Uniformity Rating, based on Coefficient of Variation	Very good	Good

(Extract from Sukumar, Seabrook, Sherstobitoff and Huber's paper for 8th CANMET / ACI International Conference on FA, SF, Slag and Natural Pozzolan in concrete)

Challenges

- High Flyash content for concrete mix design placed during winter conditions.
- Demands for water addition to the concrete mixes.
- Time constraint for research & testing on mix designs prior to the start of the project.
- Communication on any project is a team effort.
- Constructability.

Communication

Proper communication helps to ensure that surprises are not an option.

- **Discuss your expectations.**
- **Insist on a trial pour.**
- **Good upfront communication was a key on this project.**
- **There was no finger pointing.**

Thank You!

The Contractor's Perspective

Rob Karchewski, P.Eng.

GRAHAM

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Overview

- 27000m³ of concrete poured on this project
- Fly ash ranged from 40 to 58%
- Concrete was poured from October 2002 through to October 2003
- High fly ash concrete behaved differently as seasons and temperature changed
- Mix design generally coarse in nature to aid in the reduction of plastic shrinkage

Slab on Grade

- 6300 m³ of concrete in the base slab
- 3% air and at least 40% fly ash
- Slabs were placed using a combination of pump and/or crane and bucket
- Pumped okay over short distances
- Concrete would tend to pile but would flow easily when vibrated
- Could not place at the specified 70 +/- 20mm. May have been partly due to the coarseness of the mix
- Added a minimum of ½ l/m³ of plasticizer to get to an acceptable slump

Slab on Grade

- Very slow set times in winter months
- Pour in late afternoon – Finish the next morning
- Set times in summer months much quicker but slower than non fly ash mixes
- Trowel finish required
- Bleed water was minimal
- Had to fog mist surface to prevent tearing during initial float
- Seemed to have good paste and finished easily after the initial floating operation

Structural Slab

- 6800 m³ of concrete poured in the structural roof slab
- 5% air and at least 45% fly ash
- Difficult to line pump over 60-70m – Again may be mostly due to coarseness of the mix
- Added plasticizer up to 1 l/m³
- Same type of placing characteristic as the slab on grade
- Float finish required
- Set times not a factor due to the float finish
- Had sufficient strength gain to strip false work after 6 days

Walls

- 5800m³ with at least 40% fly ash
- Reservoir walls - 30 feet high
- Valve chamber - 40 feet high
- 158,000 sf of wall formwork
- Formwork designed for 1000 psf with a pour rate of 6'/hr
- Rebar – 25m at approximately 75mm O.C. each way

Walls

- Concrete was placed using crane and bucket
- Specifications dictated that walls must be poured continuously full height at a 150mm slump
- Used plasticizer to bring slump to 150mm for the first wall pour only
- Remaining pours were placed at 40-60mm slump
- Lower slump preferred to try to accelerate initial set times
- Concrete flowed well when consolidated – No honeycomb

Walls

- Achieved an average pour rate of approximately 4'/hr adding 2 ½ hours or 50% more time to the wall pours in cold weather
- In cooler weather, had to hoard the wall and introduce heat to accelerate initial set.
- Achieved the design pour rate of 6'/hr during summer months
- Wall reasonably easy to finish – Fewer air pockets

Summary - Slabs

- Had to plasticize this mix to aid in placing
- Slow set times equate to higher finishing costs in cool weather
- Alternate finishing techniques required to float surface (i.e. fog misting surface to prevent tearing)
- Finish very well after initial floating operation

Summary - Walls

- Lower slumps flow well when consolidated
- Slower set times equate to higher placing costs in cool weather
- Initial set times acceptable in warmer temperatures
- Good finish on end product – Less air pockets
- Minimal shrinkage cracks in end product

The Materials Engineer's Perspective

Phil Seabrook, P.Eng.

Specification for EcoSmart Concrete

Property	Element								
	Base Slab & Footings		Columns and Walls		Roof Slab		Topping		Lean Conc.
	Cell 1*	Cell 2	Cell 1*	Cell 2	Cell 1*	Cell 2	Plaza **	Pave-ment	Cell 1&2
Mixture Proportions									
Class of Exposure	N		C2		C2		F1	C1	N
Maximum Aggregate, mm	20		20		20		20	20	28
Minimum Mass of Coarse Aggregate, % total aggregate	60		62		60		58		-
Fly Ash, Minimum % of cementing materials	30	35	35	45	30	40	25	15	50
Maximum Water:Cementing Materials	0.45		0.45		0.45		0.45	0.40	-
Admixtures									
Superplasticizer	N		Y		N		N		
Shrinkage reducing	Y		N		N		N		
Plastic Concrete									
Slump, before // after S/P, mm	70		60 // 180		70		70		150
Air, % ± 1	3		5		5		6	6	6
Compressive Strength, MPa									
Form Strip (in situ)	N/A		15		25		N/A		N/A
28 days							35	40	
56 days	35		35		35				10/20***

* Cell 1 = winter construction; Cell 2 = summer construction

How Concrete Design Principles Were Achieved

Design Principle	Specification	Achieved
Durability	**(100-year Service Life)**	
Freeze-thaw + deicing salts	Air entrainment @ 6%	Adequate hardened air voids
	Reduce FA	Improve scaling resistance
Fresh water leaching	Low W/CM (< 0.45)	Actual < 0.40
	FA replace cement	> 35% typical
Impermeability	Low W/CM (< 0.45)	RCP < 1200 Coulombs
	FA replace cement	Absorption < 6%
Rebar corrosion resistance	Low W/CM (< 0.45)	Resistivity > 15,000 ohm-cm
	FA replace cement	
Compressive Strength	> 35 MPa @ 56 days	> 41 MPa @ 56 days

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How Concrete Design Principles Were Achieved

Design Principle	Specification	Achieved
Minimize Cracks		
Walls	Min. stone content	> 60% stone
	Low W/CM (< 0.45)	< 0.40
	Design @ 0.045% shrinkage	Few cracks > 0.2 mm
		Shrinkage 0.04 – 0.05%
	Reduce heat by high FA	Max. temp. < 35ºC
Slabs	Require < 0.03% by SRA	Approx. 0.03%

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How Concrete Design Principles Were Achieved

Design Principle	Specification	Achieved
Constructability		
Pumpability	FA > 35%	Excellent
Placeability in 10 m high walls	FA > 35%	Minor honeycomb
	Superplasticizer to 180 mm slump	
Void-free formed surfaces	FA > 35%	Excellent – largely free of bug holes
Trowelability	Reduce FA	Slow setting
Minimize control joints	Reduce shrinkage as above	Little cracking
Cold weather – slow setting	Reduce min. FA content	Reduce rate of pour to control form pressure

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Thank You

Please visit us at

www.ecosmart.ca

Information?

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