Use of Ecosmart Concrete In Multi-Unit Residential Construction

A Case Study:

Cranberry Commons

4272 Albert Street

Vancouver, BC Canada

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1.0 Executive Summary

The Cranberry Commons Cohousing Development Corporation is dedicated to implementing environmentally sustainable building technologies throughout their building located at 4272 Albert Street. Some of these practices include a construction site recycling program; low flow toilets and shower heads; the extensive use of reclaimed lumber and to utilize a high-volume fly ash concrete mix (Ecosmart™ concrete).

The focus of this report is to analyze the ecological, technical and business impacts of using Ecosmart™ concrete in an effort to reduce greenhouse gas emissions. Ecosmart™ concrete was used in footings, columns, walls, slab on grade, suspended slab, and building curbs. We found the Ecosmart concrete was easier to pump, but more difficult to place. We observed that the Ecosmart™ concrete took slightly longer to set because of the cooler temperatures in which we poured, although it did not affect our scheduling in any way.

Economically, the Ecosmart™ concrete cost more than a standard mix of concrete. We needed to add more accelerants because the cooler temperatures adversely effected the setting time during the pour. We had five significant concrete pours that began on December 8th, 2000 and completed February 15th, 2001. Temperatures during our pours in December were between 2° C and 6° C. The temperatures during January and February were between 8° C and 9° C.

The strength level of the Ecosmart™ concrete far exceeded the required specifications as stated by the structural engineer.

Therefore, we believe that in the future a standard 30mpa mix could be substituted with an Ecosmart 25mpa mix, which would allow for cost savings when forced to pour during the winter and early spring. This would also reduce the amount of cement (and fly ash) in the mix.

1.1 Introduction and Background

Cohousing

Cohousing is an alternative approach to housing, which can be pursued by a group of prospective neighbours who value a strong sense of community. It is a concept that originated in Denmark, and has now spread extensively in Europe and North America. Four cohousing communities have already been established in British Columbia.

Cohousing groups are based on private ownership of complete, individual housing units centred around and focused on extensive shared facilities such as a common kitchen, laundry facilities, children's' play spaces, a lounge, etc. Community connection in these developments is supported by the physical layout of the community and the involvement of all members in the development and operation of the community using consensus decision-making.

The Cranberry Commons Project

Cranberry Commons Cohousing Inc. is a not-for-profit corporation, which was formed by future homeowners expressly for the purpose of developing a cohousing community. These future owners are acting as the developer for the project located at 4272 Albert Street in Burnaby, BC, directing the design and development of a 24,500 square foot, 22-unit multi-family residential building.   Construction on the project began in October of 2000 and completion is expected in the summer of 2001.

In addition to its social focus, Cranberry Commons is not unlike many cohousing groups in that it holds respect of the environment as one of its highest values and has attempted to incorporate sustainability into various aspects of the community design. Cranberry Commons has included the following features in an attempt to reduce its ecological impact:

- starting with the selection of the site which was chosen to accommodate members of Cranberry Commons who choose to function with no or minimal use of the automobile. The proximity of public transit, food store, library, green space, pool, schools, senior's centre and other facilities allow the members of the cohousing group to reduce their automobile dependency.
- extensive use of reclaimed lumber for this wood frame construction building;
- implementation of construction site recycling program;
- rain barrels to reduce stormwater run-off and provide gardening manual irrigation water;
- an indigenous landscaping plan to minimize irrigation requirements and to provide urban wildlife habitat;
- long life (40 year) shingles;
- low flow toilets and shower heads;
- an architecture that allows for ground orientation for families but still achieves an FAR/FSR of 1.3 (site is at 44 units per acre, a high density)

The Cranberry Commons cohousing group decided that it would make a concerted effort to reduce the green house gas emissions associated with the development of and operation of their housing project.

To do this, efforts were made to:

1. Increase the energy efficiency of the building by incorporating:
    - a high efficiency central boiler for domestic hot water as well as supply for the in-floor radiant heat system;
    - an energy efficient lighting design;
    - an energy efficient washer/dryer for the common house laundry facility;

2. Allow for pedestrian orientation by including:
    - provision of secure bicycle parking;
    - advanced and adaptable computer wiring to enable work-from-home arrangements;
3. Choose building and maintenance materials which reduce CO_2 emissions and reduce consumption of products requiring embodied energy in their production

It was this focus on choosing materials that reduce CO_2 emissions that lead the cohousing group to specify the use of EcosmartTM concrete[1].

Participants

The following companies were involved in the Cranberry Commons Project:

Architect:	Birmingham & Wood Architects and Planners
Structural Engineer:	Chui, Sandys, Wunsch Engineering
General Contractor:	Artian Construction Ltd.
Concrete Supplier:	Kask Brothers Ready Mix Ltd.
Concrete Placer:	Gastaldo Concrete

High Volume Fly Ash Concrete

Concrete is the most dominant construction material of our day. Having widespread application in almost every significant construction technique, almost 1 M tonnes of cement is used annually in BC. So widespread is the use of concrete that the production of cement has become a significant source of CO_2 emissions which strongly contributes to the greenhouse effect and to global warming. Each tonne of cement produced releases about 1 tonne of CO_2 into the environment. It has been estimated that as much as 12.5% of the CO_2 produced in the Lower Mainland region of BC is as a result of cement production.

In this report the term Ecosmart™ concrete refers to concrete that is produced by replacing cement with a maximum percentage of fly ash within the parameters of cost effectiveness, constructability and performance

Fly Ash is a waste product of coal-fired power plants that can be substituted for cement in concrete mixes. Both Alberta and Washington State produce large volumes of fly ash and are presently disposing of 75% of the fly ash they produce.

Historically BC concrete producers have been replacing 15% to 18 % of cement with fly ash. If the fly ash content could be increased to 40% (an slight optimistic goal) CO_2 emissions could be reduced by 225,000 tonnes annually.

Cranberry Commons Cohousing project would required 241 metric tonnes of cement (most of which would be used in the construction of the associated underground parkade.) After some deliberations with the ready-mix supplier, a goal of a 50% reduction in cement usage was set which if met would mean a 98.75 tonne reduction in CO_2 emissions.

Concrete volumes and cement usage

Concrete location & type	Building Curbs (25 mpa)	Slab on grade (30ap)	Suspended slab (30 mpa)	Parkade walls (25 mpa)	Footing and posts (25 mpa)
Volume	12 m^3	158 m^3	477 m^3	155 m^3	151 m^3
Cement content (per m^3f concrete)	140kg	241kg	241kg	140kg	140kg
Total cement usage (Vol. kg) tonnes	1.68	38.07	114.9	21.7	21.14
After 50% reduction	.84	19.04	57.45	10.85	10.57
Total cement usage reduction (tonnes)	98.75				

2 Objective

Within the development/construction industry there is a significant resistance to the use of new materials or techniques. The concerns are multi-faceted: will the new product cost more? Is the new application technique going to cause scheduling delays? Will the sub-contractors be able to adapt to the new approach? The object of this report is to provide an increased understanding of Ecosmart Concrete technology and thus increase usage. Both anecdotal information and detailed lab reports will be used to convey the challenges to increased fly ash use.

3 Detailed Report

3.1 Quantity and Mix Design

The goal of the project was to use Ecosmart Concrete in all typical concrete applications. It was particularly hoped that Ecosmart concrete could be used for the underground parkades' suspended slab (ceiling), as the suspended slab constitutes the projects single largest requirement for concrete.

Table A: Concrete volumes for the project:

Building Curbs (25 mpa)	Slab on grade (30map)	Suspended slab (30 mpa)	Parkade walls (25 mpa)	Footings (25 mpa)	Total Concrete
12 m^3	158 m^3	477 m^3	155 m^3	151 m^3	953m^3

To identify the environmental benefit associated with substituting Ecosmart™ concrete for the typical concrete mixes one must determine the decrease in cement content associated with the substitution.

Table B: Mix designs for Cranberry Commons Case study (per cubic meter)

	Case Study	Standard	Case Study	Standard
Strength	25 MPA	25 MPA	30 MPA	30 MPA
Cement (kg)	140 kg	211 kg	169 kg	241 kg
Fly ash (kg)	140 kg	53 kg	206 kg	60 kg
Cementitious Material (kg)	280 kg	263 kg	375 kg	301 kg
Volume used (m^3)	318 kg	N/A	635 kg	N/A
Cement reduction (kg)	71 kg	N/A	72 kg	N/A
Cement reduction (total kg)	22 578 kg	N/A	457 250 kg	N/A
% Cement reduction (per m^3)	33%	N/A	30%	N/A

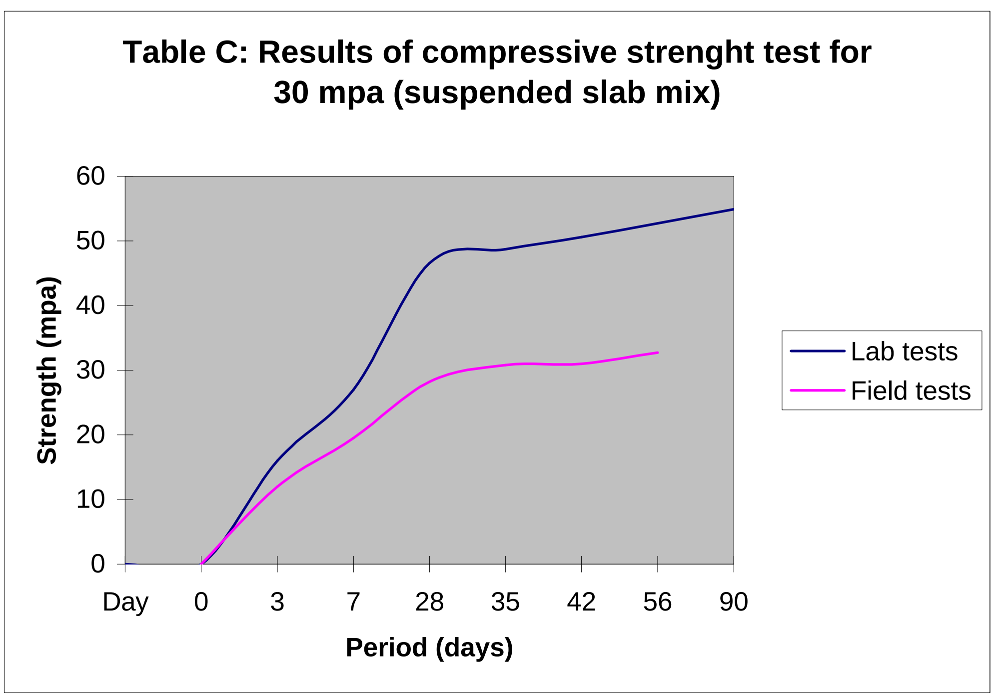
It should be noted that we did not achieve our stated goal of a 50% reduction in cement usage. Our failure to achieve the intended 50% reduction can be attributed to two factors:

1. When we sent our mix objectives to Kask Bros. we stated that it was our goal to use concrete mixes where the cementitious content was 50% flyash. We should have stated that we desired a concrete mix where the cement content was reduced by 50%, which was the intended goal. Kask created mixes where the cementitious content was 50% flyash but the absolute volume of cementitious materials (cement + fly ash) exceeded that of cementitious material in standard mixes and as a result the cement content was not reduced on a 1:1 ratio. (see table above)
2. Kasks mix designer were concerned that further decreases in cement content (with the associated increase in flyash content) might cause set time difficulties. In particular the 7-day strength for the suspended slab mix was a concern.

3.2 **Strength**

The strength requirements (mpa) for the projects' various concrete components were set by Chiu-Sandy-Wunsch, structural engineers. In order to compensate for the expected slower cure times, the specified 28-day strength gain was extended to 56 days.

This extension of the 28-day strength gain was acceptable to the structural engineer because he believed that the structure would not experience actual design live loads until the project was at the landscaping phase. It is interesting to note that, in retrospect, this extension of the 28-day strength was not required. Actual test results (table C) indicated that strengths above 30 mpa were achieved within 28 days. In fact, the test indicated surprising early-age strength that allowed us to maintain our typical stripping times for walls, footings and columns. Although, the forming contractor observed that the concrete was “softer” while stripping the wall, footing and column forms, the concrete achieved a 90-day strength of 52 mpa. This was 70% higher than required by the structural engineering specifications.



3.3 Workability

Parkade wall, footing, curbs and columns

The workability of the concrete was similar to traditional concrete mixes. Typical forms and release agents were used. We found that the Ecosmart^{TM} concrete was "creamier" and therefore easier to pump.

We were able to strip our forms within 24hr of pouring the concrete. Upon stripping the forms, it was noted that the concrete was "softer" than a standard mix of concrete; yet, it did not affect our pour schedule. The slow cure time encountered in the first 24hrs may be accountable to the low temperature under which the footings, walls and columns were poured. The temperature was typically 4 to 8 degrees Celsius. Upon stripping the wall forms, a powdery residue was found on the concrete. It appeared to consist of very small glass-like particles. Laboratory tests by Levelton Engineering Ltd. stated that approximately 50% of the substance consisted of Calcium Oxide or Lime. The remaining 50% consisted of organic material most likely from the releasing agents used.

Slab on grade.

The fly ash within Ecosmart^{TM} concrete retards its curing process and the magnitude and duration of this effect is not well known or well documented. Our experience seems to indicate that the high fly ash content, coupled with the low temperature during the pour, significantly affects the setup time of the concrete. The term "setup" is meant to indicate a particular firmness the concrete needs to achieve before placing crews are able to apply a power towel finish to the concrete.

With typical concrete, the setup time is 2 to 3 hour after it has been placed, but our experience with the Ecosmart concrete was that it needed 7 to 8 hour to setup. This delay between the time placed and setup is significant because it forced the concrete finishers to remain on site for a considerably longer period of time. The concrete finishers worked until 3:00am, when typically they would have been completed at 7:00pm. In the future, it would be necessary to use contractors who are familiar with or will familiarize themselves with Ecosmart concrete and it's set time. It would still be beneficial to pour concrete in the morning while anticipating that the crew could leave for some time and return in the afternoon.

It should be noted that the finishing time was not noticeably longer, but rather, the time spent waiting for the Ecosmart™ concrete to setup was substantially longer. The water content (slump) in the concrete was kept quite low in accordance to Kask Bros. Ready-Mix Ltd. specifications, which made the concrete very stiff and difficult to place. Misting the surface of the concrete with water before placing could alleviate this issue.

Suspended Slab

The experience with the suspended slab was more positive. The single feature that allowed the process to be smoother was the fact that we didn't need a power trowel finish. The finishers were able to hand trowel and by doing so did not have to wait for the concrete to setup. As with the slab on grade, the difficulty for the concrete placers was the requirement by the concrete supplier to keep the water content (slump) low.

This caused the concrete to be stiff and difficult to place. (A wetter concrete is easier to move and place.) Again, this could be remedied by misting with water the surface of the concrete before placing. Of significant importance was that the suspended slab concrete reached its required stripping strength within a week, which is typical of conventional concrete. We were able to strip the suspended slab forms without paying any additional rental fees.

It should be noted that there were some patches of “honeycombing”. Honeycombing refers to an accumulation of aggregate that is visible after removing concrete forms. This occurred in areas where there was high quantities of reinforcing steel and can be attributed to the filtering of the concrete mix. As the concrete mix moved down towards the bottom of the forms, the fines and cement adhered to the reinforcing bars and resulted in the aggregate settling at the bottom of the forms.

3.4 Economics

We found that the price of a standard concrete mix and a high-volume fly ash concrete mix are very comparable. Yet, we found that pouring a high-volume fly ash mix in cooler temperatures requires more added accelerants than a typical concrete mix. Cooler temperatures appears to slow the setting time of the high-volume fly ash concrete mix much more than a typical mix of concrete. Therefore, Gastaldo Concrete stated that for future winter pours, using high-volume fly ash concrete, they will charge more for finishing the concrete because of the longer set time and the difficulty in placing.

It is our expectation that our high-volume fly ash concrete mix that was designed for a 25 mpa would be sufficient for areas requiring 30 mpa because our tests found that the 25 mpa concrete set much stronger than specified. The 25 mpa mix is \$6.00 - \$8.00 /m^3 (7%) less expensive than 30 mpa thus allowing contractors to reduce concrete costs. This would also further reduce the amount of cement and fly ash needed and thus reduce greenhouse gas emissions.

4.0 <u>Conclusion</u>

One of the challenges for the construction industry in the future will be to use new, high-performance materials and technologies, produced at reasonable cost and with the lowest possible environmental impact.

Trades' people (suppliers, placers, finishers) need to be educated about the mix characteristics. We suggest that more documentation on the issues around handling, placing, vibrating and finishing be completed. We were not successful in achieving our stated goal of reducing our cement content by 50% but instead were able to decrease our cement content by 32%, which translates into our project reducing our CO_2 emissions by 63.2 tonnes. It is interesting to note that if we had used our 25mpa mix (which after testing was sufficient in strength to substitute for the 30mpa mix) in all applications we would have achieved a 50% reduction in cement used.