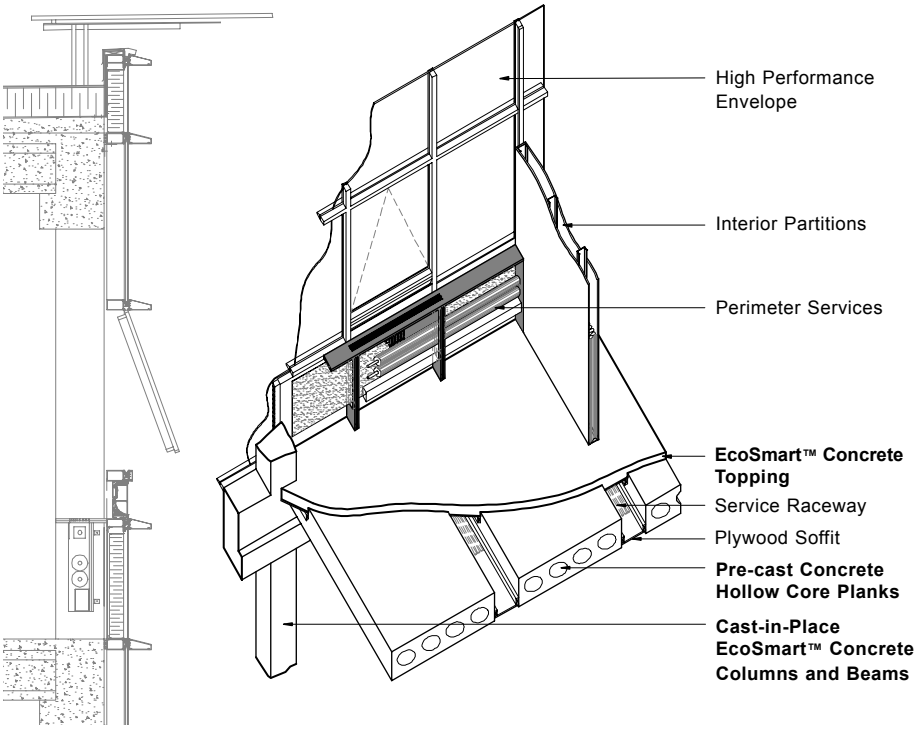
Using EcoSmart™ Concrete:

Liu Centre Case Study

LIU CENTRE FOR THE STUDY OF GLOBAL ISSUES



This document belongs to a series of case study reports commissioned by the Greater Vancouver Regional District for the EcoSmart™ Concrete Project. The EcoSmart™ Concrete Project is funded by the Federal Climate Change Action Fund-TEAM Program. It involves a number of private industry and government stakeholders whose common aim is to reduce the amount of greenhouse gases associated with the use of concrete.

For more information see **www.ecosmart.ca**

June 13, 2001

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INTRODUCTION

This report assesses the use and performance of EcoSmart™ (high volume fly ash) concrete in the *Liu Centre for the Study of Global Issues* - a new research and conference facility at the University of British Columbia. It is intended to complement existing published material* with the addition of project specific data and experiences supplied by the design team, general contractor and material suppliers. The experience of using EcoSmart™ concrete is evaluated according to its contribution to achieving set project goals and its measurable environmental benefits.

HIGHLIGHTS

- **Setting a Precedent** - The Liu Centre was the first building in British Columbia to promote the use of EcoSmart™ concrete as an environmentally responsible construction practice. The success of the project has improved awareness and market acceptance of this technology. It has also generated considerable publicity for the EcoSmart™ Concrete Project, which in a short period of time has seen great advances in the use and application of EcoSmart™ concrete, both locally and further afield.

- **Ease of implementation** - EcoSmart™ concrete was incorporated in the project after tendering phase with no increase in cost to the owner or change to the project schedule. The additional effort and coordination by the design team was minimal.

- **Alignment with Project Goals** - Many of the material benefits of using of EcoSmart™ concrete - which included improved durability, reduced embodied energy, and increased recycled content - dovetailed with the environmental project goals and criteria for material selection.

- **Reduced Environmental Impact** - The EcoSmart™ concrete mix achieved the specified strength and finish qualities using 35% less cement per unit volume. 69.3 tonnes of cement and 62.4 tonnes of CO_2 emissions were avoided by using EcoSmart™ concrete. Put in energy terms, the equivalent energy embodied in 69.3 tonnes of cement could operate the entire Liu Centre facility for 5 months. An additional 19.7 tonne reduction in cement was achieved through an efficient structural design employing pre-cast hollow core slabs.

- **Aesthetic Appeal** - Exposed concrete is the predominant finish in the building. The EcoSmart™ concrete has a warmer grey tone than a conventional mix, attributed to the added fly ash. The colour and surface qualities of the material satisfied the architect's aesthetic expectations.

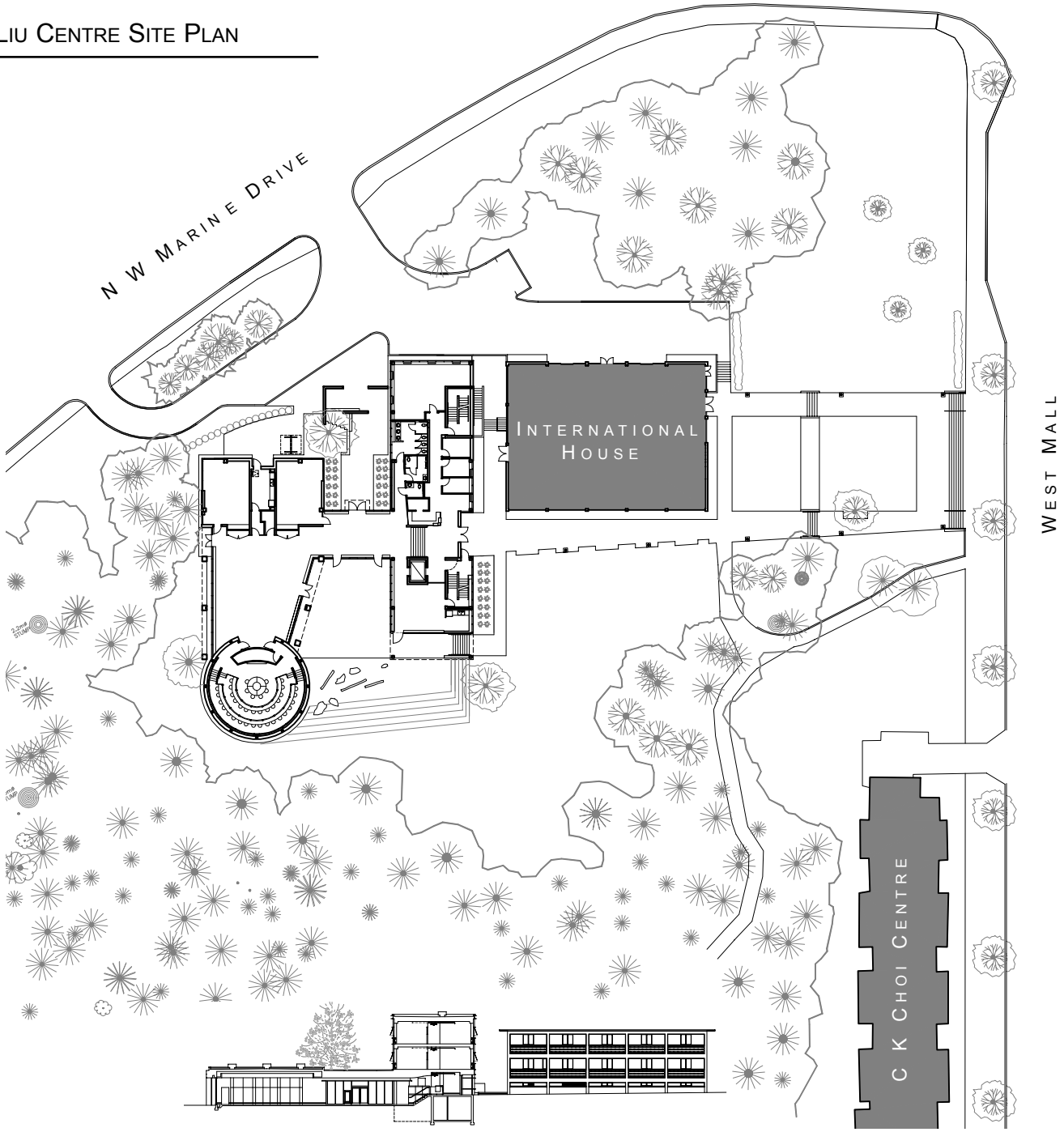
What is EcoSmart™ concrete?

EcoSmart™ concrete is produced by replacing Portland cement in a concrete mix with a maximum amount of a supplementary cementing material (SCM) within the parameters of cost effectiveness, constructability, and performance. Fly ash, a by-product of coal fired power plants, is a common SCM. The primary aim for the development of Eco-smart™ concrete is to significantly reduce the embodied energy of concrete and by doing so reduce CO_2 emissions, which are linked to global climate change. This is accomplished by minimizing the content of Portland cement, the most energy intensive ingredient in the mix.

In a conventional concrete mix, cement makes up about 12% of the weight, yet it accounts for over 90% of the embodied energy. Since concrete is such a common building material, there is great potential that industry wide acceptance of EcoSmart™ concrete could lead to substantial reductions in global CO_2 emissions.

* The use and performance of EcoSmart™ concrete at the Liu Centre has been well documented. Other reports are posted on the official Ecosmart™ Concrete Website. For direct access, enter: http://www.ecosmart.ca/use/case/other/liu_centre.asp.

Liu Centre Site Plan



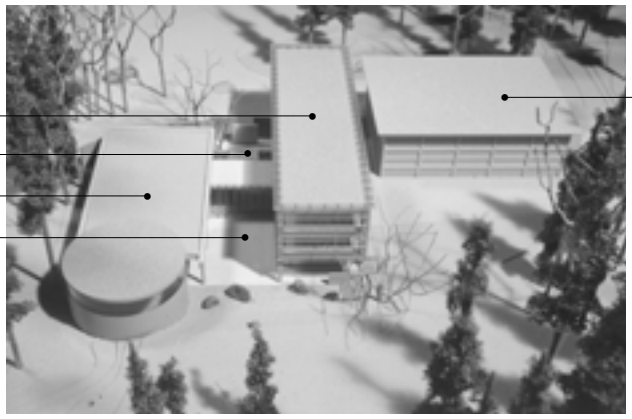
Liu Centre

Research Wing

Entry Courtyard

Seminar Wing

Forest Courtyard



International House

PROJECT INFORMATION

The Facility

The Liu Centre is a new entity at the University of British Columbia. It serves as an important international policy research centre and teaching facility, focusing on the new generation of global issues challenging societies and governments worldwide. Officially opened in September 2000, it is currently under the leadership of past Foreign Affairs Minister Lloyd Axworthy.

The physical building is set within a dramatic wooded site and located between International House and the Nitobe Gardens on the northwest corner of the university campus. The program includes office and conference spaces, which are housed in separate building wings: a three storey Research Wing and a one storey Seminar Wing. The resulting 'H' plan, formed by the two parallel wings connected by a glazed lobby, creates two outdoor courtyards and allows for excellent light penetration and cross ventilation in all spaces.

Sustainable Mandate

At the outset of the project, over forty project stakeholders took part in a 'project alignment' workshop initiated by the client. The goals and objectives recorded at this workshop reflect a commitment to a rigorous 'sustainable' agenda. Performance targets for site, energy and material conservation were set to meet or exceed the C K Choi building, a nearby study center and an internationally recognized benchmark in sustainable design.

Project Data

Occupancy Type	**Office/Assembly**
Number of Storeys	**3**
Building Area	**1750 m^2**
Construction Cost	**$3.1 million**

Project Team

Client	**University of British Columbia** **Campus Planning and Development**
Architect	**Architectura** in collaboration with **Arthur Erickson**
Structural Engineer	**Bush, Bohlman & Partners**
Mechanical Engineer	**Keen Engineering**
Electrical Engineer	**Robert Freundlich & Associates**
Landscape Architect	**Cornelia Hahn Oberlander**
Quantity Surveyor	**James Bush & Associates**
Material Engineer	**Levelton Engineering**
General Contractor	**Haebler Construction**
Ready-Mix Supplier	**Ocean Construction Supplies**
Precast Supplier	**Con-Force Structures**

'Green' Buildings

The Liu Centre belongs to a growing sector of buildings known as 'green' or 'sustainable' buildings, which stress energy efficiency, resource conservation, healthy indoor environments, and protection of the natural environment as goals. These goals, shared by the University and the design team, were used as founding principles in the development of this new facility.

The Liu Centre is a nationally recognized 'green' building. It was selected as one of a eight buildings from across Canada to represent innovation and design excellence at the Green Building Challenge 2000 conference in Maastrict. The use of EcoSmart™ concrete and other sustainable design initiatives have earned the Liu Centre project a number of awards, including:

2001 AIBC Innovation Award

2001 Lieutenant Governor's Medal

2001 CEBC Award of Merit

1999 APEGBC Environmental Design Award

USING ECOSMART™ CONCRETE

General

Concrete is the primary structural material used in the Liu Centre building. The foundations, ground floor slabs, vertical elements and perimeter beams were formed on site, and contain roughly 750 m^3 of ready-mix concrete. The roof of the Seminar Wing is constructed of heavy timber, salvaged from an existing building on site, while the upper floors and roof of the modular Research Wing are covered with hollow core pre-cast planks. The pre-cast members, spanning the entire building width, are spaced to allow service runs at the centerline of rooms and partitions. This innovative and cost effective design, combining pre-cast and cast-in-place elements in a hybrid structure, draws on the particular advantages of each system.

A life cycle cost analysis was used to compare several concrete and heavy timber construction systems for the Liu Centre. In addition to being the most cost-effective option, the selected concrete system also helped achieve many sustainable project objectives, including:

- **durability** - the building structure is designed for an intended life span of 100 years.

- **high thermal mass** - the excellent thermal storage capacity of the exposed concrete structure is an integral component of the natural ventilation and cooling system. It assists in moderating daily indoor temperature fluctuations.

- **minimizing finishes** - the concrete structure is used extensively as an exposed finish. This double function greatly reduced the quantity of applied finishes required. The smooth pre-cast ceilings and sealed concrete floors contrast the rougher, sandblasted cast-in-place elements.

- **high indoor air quality** - the exposed concrete finish resulted in less applied finishes and adhesives being used, reducing the amount of potential volatile organic compounds (VOCs) and other harmful product emissions in the building.

- **structural efficiency** - a structural system employing a cast-in-place concrete frame in combination with pre-cast hollow core planks makes efficient use of concrete material, and provides a durable, fire resistance assembly.

- **design flexibility** - the perimeter beam structure, which picks up all the span loads, permitted flexibility during construction: columns and their footings could be relocated to avoid pruning major roots of large, neighbouring trees. The perimeter structure also allows maximum flexibility of interior partitioning.

EcoSmart™ Concrete added to these qualities with improved long-term durability, reduced embodied energy, greater recycled content, and a more visually pleasing finish at a comparable price.

Process of Implementation

The decision to explore the possibilities of EcoSmart™ concrete in the Liu Centre was primarily based on the environmental benefits associated with using the material - benefits consistent with the project mandate of demonstrating leadership in sustainable design.

Initially, there was some confusion as to the nature of the environmental benefits of using greater amounts of fly ash in the mix. The phrasing of the concrete specifications, which requested bidders to provide an alternative price for a concrete mix 'using a maximum feasible amount of fly ash,' put more emphasis on re-using a waste product (fly ash) than on reducing the quantity of a high embodied energy material (cement).

It was an article in a landscape architecture journal that originally introduced the possibilities of fly ash to the design team. The UBC Sustainability Office also provided some direction. However, with little material to draw from prior to completion of the contract documents, high volume fly ash concrete would appear in the specifications as just a general statement of intent, putting the ball in the bidder's court to see what they might come up with. During the project tendering phase, *Architectura* was put in contact with Dr. Maholtra at *CANMET*, who was able to supply high volume fly ash mix designs based on their extensive lab trials and research on the subject. Two mix designs for EcoSmart™ concrete were incorporated in the specifications as part of an addendum, but at the close of tendering, not one of the six preselected bidders provided an alternative price for the use of the *CANMET* mixes.

The Liu Centre project was eventually awarded to *Haebler Construction* (general contractor) with *Ocean Construction Supplies* (ready-mix supplier). An introductory meeting was arranged to pursue the possibility of using EcoSmart™ concrete with all the key players, including representatives from *Architectura*; *Bush, Bohlman & Partners* (structural engineer); *Levelton Engineering* (material engineer); *Haebler*; and *Ocean*. *Haebler*, reputed for their high quality concrete work, was receptive to trying EcoSmart™ concrete; however, they had concerns that a reduction in cement content could adversely affect the quality of the architectural finish. These concerns were not unfounded, considering the general lack of field experience with EcoSmart™ concrete and the potential risk of not achieving the specified finish on the largely exposed concrete structure of the Liu Centre. This level of uncertainty is quite a contrast from the current situation, where EcoSmart™ concrete is becoming more commonly specified and better understood by the construction industry.

Both *Levelton* and *Ocean* had previous experience using concrete with high fly ash content and were confident that the EcoSmart™ concrete mixes designed by *CANMET* would perform satisfactorily. The decision was made to go ahead. The *CANMET* designs, developed in Ontario, were fine tuned for the local context.

The Liu Centre represented an opportunity for *CANMET* and the project team to apply an innovative and energy efficient technology in a high profile 'green' building. Notwithstanding this interest, the owner was unwilling to permit any modifications to either the schedule or budget for incorporating EcoSmart™ concrete in the project. To offset any potential additional costs associated with the use of the material, *CANMET* was able to secure a grant of $10,000 from the Climate Change Action Fund-TEAM Program.

Sample of EcoSmart™ Concrete Strength Performance

1 day	10 mPa
4 day	20 mPa
7 day	24 mPa
14 day	30 mPa
28 day	34 mPa
56 day	40 mPa

(see Appendix A - Test Reports)

Using lesser quantities of fly ash in concrete is standard industry practice (locally, a 20% fly ash / cement ratio is typical). The goal for the Liu Centre was to use a 50% ratio or more. In retrospect, targeting a 50% fly ash / cement ratio (which can always be achieved by adding a sufficient quantity of fly ash) was perhaps less useful than targeting reductions in total cement content (which relates directly to reductions in CO_2 emissions).

Liu Centre EcoSmart™ Concrete Mix

At the Liu Centre, a single concrete mix design with a 50% fly ash / cement ratio was selected for most applications and exposure classes: the only exceptions being concrete topping and exterior slab on grade. Originally, the 50% EcoSmart™ mix was intended for below-grade concrete only. Another mix, with a higher cement content, was designed for all the above-grade concrete. Based on the excellent performance of the EcoSmart™ mix in the below-grade application, it was maintained for the entire structure. The mix responded to *Haebler*'s concerns about achieving a high quality finish, while maintaining the total quantity of cementitious content (fly ash + cement) under 400 kg/m^3.

STRENGTH	25 mPa @ 28 day (40 mPa @ 56 day)
CEMENT, T10	195 kg/m^3
FLY ASH	195 kg/m^3
CONC. SAND 14mm x 5mm 20mm x 10mm	760 kg/m^3 360 kg/m^3 720 kg/m^3
WATER	130 L
SLUMP	110 ± 20 mm
ADMIXTURE - WRDA 64	STD
AIR CONTENT	3 ± 1%
MAX. W/CM	0.40

Establishing a Baseline for Comparison

In order to demonstrate the environmental benefits of using EcoSmart™ concrete in a particular application, it is necessary to select a baseline mix from which it may be compared. To make a fair comparison, this baseline must be a conventional concrete mix that matches the design objectives, performance criteria, local context and price of the EcoSmart™ concrete mix. This baseline is therefore project and locale specific. There is little value in comparing with a mix design from another project that has different baseline criteria or with a hypothetical mix that does not reflect conventional industry practice.

No conventional mix designs were prepared for the Liu Centre that could act as a baseline, so one was established after the fact. Determining a suitable baseline mix that matches all the criteria above is a tricky prospect and not without some trade offs. John Rutherford at *Ocean* recommended using a 35 mPa Architectural mix as a baseline, which best matches the selected EcoSmart™ concrete mix in cost, strength and end finish characteristics. *Haebler* confirmed that they would have used a 30-40 mPa mix to achieve the desired finish, although a 25 mPa mix would have satisfied the specified 28 day strength requirements.

Measuring success

The impetus behind the development of EcoSmart™ concrete is to reduce CO_2 emissions by minimizing cement content. Thus, a good indicator of the environmental performance of an EcoSmart™ concrete mix is to quantify how much less cement was used (measured against an appropriate baseline) or the equivalent reduction in CO_2 emissions.

$$\% \text{ improvement} = \frac{\text{cement content}_{\text{baseline mix}} - \text{cement content}_{\text{EcoSmart mix}}}{\text{cement content}_{\text{baseline mix}}}$$

A percentage figure of cement reduction over the cement content of a baseline mix can demonstrate how efficiently cement is used in a particular mix and, if aggregated, in an entire project. This percentage value can be used to compare gains in different projects, and opens the door to include other innovations such as efficient structural design. A Liu Centre example of reducing cement through structural efficiency is described below in more detail.

The ratio of fly ash to cement content is often misinterpreted as an indicator of the environmental benefits of EcoSmart™ concrete. A percentage figure like '50% fly ash to cement ratio' is meaningless when expressed out of the context of its mix composition and application. Unfortunately, it is commonly used to imply a 50% reduction in cement content or a 50% improvement over conventional practice - both of which are incorrect.

Cement Reductions and Environmental Benefits

Comparing the Liu Centre baseline mix to the EcoSmart™ mix, there is a 105 kg/m^3 difference (300 kg/m^3 - 195 kg/m^3) in the cement content per cubic metre. This amounts to a 35% reduction in cement use and a similar reduction in CO_2 emissions. The total volume of EcoSmart™ concrete poured in the project is 660 m^3, which when multiplied by the 105 kg/m^3 reduction in cement, yields 69 300 kg, or 69.3 tonnes. This represents a significant savings in the amount cement used in the Liu Centre project, despite its relatively small size.

Cement is a very energy intensive material to produce: with each tonne of cement, approximately 5 GJ of energy are expended and 0.9 tonnes of CO_2 ejected in the atmosphere. These values can be used to generate some impressive statistics:

- By using EcoSmart™ concrete at the Liu Centre, 62.4 tonnes less CO_2 were generated.
- The energy reduction achieved by using less cement would be enough to supply the energy demands of the entire Liu Centre facility for a period of 5 months. This is based on an annual operating energy consumption for the Liu Centre at 878 GJ. The embodied energy in 69.3 tonnes of cement is 346.5 GJ (69.3 tonnes x ~5 GJ/tonne). As a by-product of industry, the embodied energy of the fly ash is considered to be zero and transportation is not considered for either material.

Liu Centre Concrete Mixes
Cement Content per m^3

1 EcoSmart™ Concrete

Cement	195 kg
Fly Ash	195 kg
% SCM	50%

2 Pre-cast Concrete

Cement	290 kg
Fly Ash	75 kg
% SCM	21%

3 Concrete Topping

Cement	240 kg
Fly Ash	130 kg
% SCM	35%

4 Exterior Slab on Grade

Cement	260 kg
Fly Ash	130 kg
% SCM	33%

Baseline Mix
Cement Content per m^3

5 35 mPa (Architectural)

Cement	300 kg
Fly Ash	75 kg
% SCM	20%

Other Means of Achieving Cement Reductions

One of the areas where EcoSmart™ concrete faces challenges is in slab applications: slower setting time may potentially delay finishing and removal of shoring. This was not an issue at the Liu Centre where all the suspended slabs were made up of pre-cast hollow core planks.

It is worth demonstrating the extent to which pre-cast hollow core planks have made effective use of concrete material and cement in the Liu Centre. There are 625.6 lineal metres of 200 x 1220 mm pre-cast planks in the building, which together with the 50 mm topping, use a total of 132.1 m^3 of concrete. This amounts to 29% less concrete than a comparable 200mm cast-in-place slab using 185.8 m^3 of concrete.

The cement content of each system, using the baseline mix for the cast-in-place slab, yields 36.0 tonnes of cement for the hollow core pre-cast system versus 55.7 tonnes of cement for the cast-in-place system - a difference of 19.7 tonnes. This includes a topping mix with a high fly ash content (35%), which for its application could be considered EcoSmart™ concrete.

The corresponding reduction in the use of cement in the hollow core pre-cast system is 35%, which demonstrates that an efficient structural design can be used together with EcoSmart™ concrete to achieve even greater cement reductions.

Schedule

There were no delays in construction associated with the use of EcoSmart™ concrete. Concrete pours at the Liu Centre occurred between the summer and late fall of 1999. Air temperatures during pouring were always above freezing; the potential effects of cold weather conditions on setting time were not experienced.

Formwork stripping and the removal of shoring was not delayed by using EcoSmart™ concrete. Concerns of not achieving sufficient early strength gain proved to be unfounded. The EcoSmart™ concrete mix generally rose to 10 mPa within 24 hours and reached its 28 day strength requirements in under 14 days. In fact, the EcoSmart™ concrete used at the Liu Centre, which was based on a *CANMET* mix design, was overdesigned structurally and could have been better optimized for strength.

Finishing

The EcoSmart™ concrete responded well to the architectural demands of the project. The large quantity of cementitious material in the mix (due to the added fly ash) improved the plasticity of the concrete and was responsible for the enhanced quality of the exposed concrete with its smooth, homogenous finish. The warmer colour of the concrete (again due to the added fly ash) was an unanticipated, yet pleasant surprise.

Until sufficient experience is gained by finishers with regards to the unique characteristics of EcoSmart™ concrete, placing of the material will present challenges. Generally, finishers need to wait longer for slabs to set before troweling. This has potential cost implications if the finishers must wait to begin work or are scheduled too late in the day.

Notes on Cost

The EcoSmart™ concrete mix used at the Liu Centre compared in cost to the amount budgeted by *Haebler* in their contract bid. Given that fly ash is currently sold for roughly half the price of cement, a significant material savings would likely be possible in future EcoSmart™ concrete applications where strength could be better optimized. One way to accomplish this is to specify 56 day or 90 day strengths, instead of the standard 28 days. Where an exposed architectural finish is not required, it is possible to achieve an even greater reduction in the overall cementitious content and in cost.

According to *Haebler*, labour and equipment costs were roughly comparable to using a conventional mix.

CONCLUSION

The performance of EcoSmart™ concrete exceeded the expectations of the project team, not only in terms of strength, but also in its ability to achieve a high quality finish without a cost premium. Employing a relatively conservative mix design, this first time use of EcoSmart™ concrete has nonetheless set a benchmark, fully anticipating advancements in future projects to 'raise the bar' in the reduction of cement content.

This report has quantified the substantial environmental benefits associated with the use of EcoSmart™ concrete and demonstrated the ease at which these benefits can be achieved. The overall success of the project has generated considerable interest and has made the Liu Centre a valuable precedent for subsequent uses of this technology. A number of architects and clients have visited the building and gone on to specify the material in their projects. With the knowledge gained at the Liu Centre, *Haebler* has promoted and implemented EcoSmart™ concrete in the new *Artist Live/Work Studios* on 1540 W 2nd Avenue (documented on www.ecosmart.ca). Other members of the Liu Centre project team are also advocating the use of EcoSmart™ concrete in their new projects, a notable example being the next major expansion phase at the *Vancouver International Airport*.

ACKNOWLEDGEMENTS

This report was prepared by Richard Klopp at *Architectura* for the EcoSmart™ Concrete Project. Kori Chan (project architect) and Roland Haebler at *Haebler Construction* generously gave interviews to expand on and clarify information obtained from the project files. Technical assistance was also provided by John Rutherford at *Ocean Construction Supplies* and Deon Lourens at *Con-Force Structures*. Special thanks to Michel DeSpot at the GVRD, Freda Pagani at UBC and the entire project team.

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