The Use of Higher Volumes of Fly Ash as a Replacement for Cement in Ready-Mixed Concrete

Risk Abatement Study

FINAL REPORT

Submitted to

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Executive Summary

The concept from which this Risk Abatement Study was developed is that increasing quality control (QC) would be sufficient to reduce risk to the ready-mixed concrete producer such that the producer would be comfortable supplying EcoSmart Concrete System (ECS) on a performance basis. This increased QC would presumably be required at the fly ash (FA) producer, ready-mixed concrete producer and contractor levels. The Study found that simply increasing QC would not reduce the risk sufficiently to achieve the objectives. What is needed is more meaningful tests and QC processes that will relate directly to the performance of FA in concrete. These are required at all of the three levels.

Without exception, the industry assigns no significant increase in risk to using FA in concrete at the conventional FA replacement levels of 10 to 30 %.

It was determined that the risk enunciated by the ready-mixed concrete producers is of two forms. It is a *real risk* in that variations in FA quality are greater than those of the cement that the FA is replacing, and this has an increasing impact with increasing percent replacement levels. It is also a *perceived risk* to those unfamiliar with ECS concrete.

The Panel that reviewed this report made a major contribution in terms of defining the risks to all stakeholders. Their input directed further work beyond the scope of this Study. In addition to the proposed EcoSmart Guidelines, the Panel strongly recommended checklists for all parties. Rather than elemental changes to QC procedures, they recommended a total quality management approach similar to what is being implemented in other industries. There is more to QC than simply increasing the number of test reports.

The need for major changes in the CSA A3001 for FA have been identified, the most critical of which are requirements for uniformity and strength potential. Readily available tests have been identified that would better assess major QC properties. In addition, the mill certificates provided by the FA producer need to be more relevant to the users' needs.

The proposed additions to the CSA A23.1 for concrete made with a high volume of supplementary materials (HVSCMs) are a positive step and are strongly supported by the results of this Study.

From a contractor's perspective, ECS does not present any risks that cannot be managed. However, the increased setting time and low early strength pose potential risks.

The Study identifies a major role for the industry associations – the Canadian Ready-Mixed Concrete Association (CRMCA) and the Association of Canadian Industries Recycling Coal Ash (CIRCA) – in implementing the recommendations from this Study. Leadership is required from the FA producers, but developing guidelines for use should come from the ready-mixed concrete industry itself. The Study also identified a major role for EcoSmart in addressing the perceived risks by further case studies and the Guidelines noted above. The availability of Life Cycle Cost calculations for ECS would assist.

The Study was unable to quantify cost differentials for ECS and conventional concrete. It was suggested that it is too early in the development of ECS for market forces to affect costs. Industry's acceptance will come over time as it has for other new technologies such as superplasticizers.

This Study goes far beyond the original scope. It contains much information that will be of value for future pursuit of ECS.

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1.0 Introduction

1.1 EcoSmart™ Concrete Project

EcoSmart is an organization committed to supporting the Government of Canada in efforts to reduce emissions of greenhouse gases (GHGs). Portland cement production in Canada is in the order of 12 megatonnes per year (Mt/year), corresponding to the production of roughly 11 Mt of CO_2. EcoSmart's primary focus is to reduce the amount of CO_2 produced from the production of concrete by replacing a portion of the cement in concrete with supplementary cementing materials (SCMs) while maintaining or improving cost, performance, and constructability. The SCM of interest in this report is fly ash (FA).

The use of fly ash as an SCM is well-developed in Canada. Currently, annual Canadian FA usage in concrete is about 550,000 t {1}. The domestic consumption of cement is about 8.4 Mt, so, nationally, FA usage represents about 6 1/2% of the total cement usage. This 550,000 t is only about 11% of the FA produced {1}. However, the technology is available to use up to 50% replacement of FA for cement in some types of concrete construction. Much of this technology has been developed by the Materials Technology Laboratory of CANMET – Mineral Technology Branch, Natural Resources Canada. The functionality of this technology has been demonstrated in many case histories, including those by EcoSmart {2}. There is, therefore, a latent potential for increasing the current FA replacement levels, and it is the goal of EcoSmart to develop this potential. Concrete with these higher levels of SCMs has become known as "sustainable concrete".

The Canadian ready-mixed concrete industry has stated that they are comfortable with the current level of FA replacement in common use, i.e., 10 to 30%. They also feel that the current CSA Standards readily accommodate these levels.[1] However, they are uncomfortable with the increased risks associated with higher levels of FA replacement. This Study is directed towards assessing those risks and developing procedures to abate them. It is intended that the outcome of this Study will result in recommendations that will reduce the risks, and permit the acceptance of these higher replacement levels as common practice.

In order to achieve the objectives, it is necessary to first define the nature and significance of current quality control (QC) practices. These include QC in the:

- production of the FA itself,
- production of concrete with higher volumes of FA replacement, and
- construction practices associated with use of higher volumes of fly ash in concrete.

The focus of this Study is the higher fly ash replacement levels noted above. For purposes of this report, concrete containing more than 30% FA is referred to as high volume fly ash (HVFA) concrete[2], and the HVFA concrete that meets the EcoSmart's three main principles (see below) is referred to as EcoSmart

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[1] The Standards that will be referred to throughout this Study are CSA A3000, which addresses various aspects of cementitious materials and CSA A 23.1, which "provides the requirements for materials and methods of construction for cast-in-place concrete and concrete precast in the field." At the time of writing of this report, the CSA A3000 Standard was being revised. The information in this report reflects the now-current CSA A3000-03, unless otherwise indicated. Similarly, the CSA A23.1 Standard is currently being revised, and in the course of the Study, the draft of the proposed Standard has been consulted. The notation in this report labels the 2000 version as "current", and the 2005 version as "proposed".

[2] This FA replacement level is consistent with the proposed CSA A23.1 Standard, which uses the more general acronym "HVSCM" – high volume supplementary cementing material – and includes both FA and blast furnace slag.

Concrete System (ECS). However, much of the work herein is also applicable to common levels of FA replacement concretes.

Although this Study deals exclusively with FA, some of its recommendations are also applicable to other SCMs, particularly slag. Further, the scope of this report is for FA that is commercially used as an SCM in concrete. As noted above, there are large amounts of FA in Canada that do not find use as an SCM either because of lack of demand or inferior FA quality.

EcoSmart is actively involved in other studies that have an impact on the work here. These include:

- addressing technical issues that have been raised by industry with regard to ECS {3},
- developing recommendations for revisions to CSA A23.1 {7} and A3001 {8}, and

The reader should be aware of the **three principles** under which EcoSmart advocates the use of FA replacement levels in concrete. Those levels must:

1. be capable of being implemented at no increase in cost,
2. result in constructable concrete, and
3. result in no loss of concrete durability,

while minimizing the GHG emissions associated with the concrete mixture.

EcoSmart does not advocate a fixed level of FA replacement for all concrete elements, in all parts of Canada, under all climatic conditions. Depending on these parameters, the FA replacement levels may range anywhere from 15 to 60% {4}.

1.2 Rationale for the Study

Industry stakeholders, particularly the ready-mixed concrete producers, advised EcoSmart that there is a risk associated with the use of higher volumes of fly ash in concrete. This risk is defined in Figure 1.

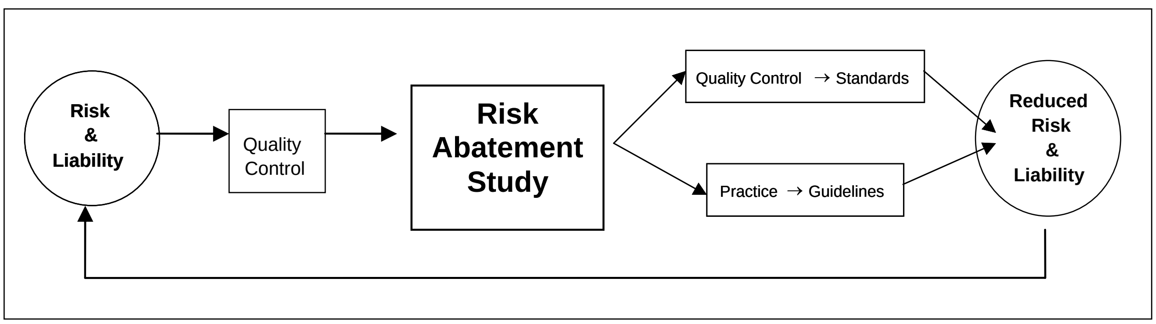

Figure 1: Risk Associated with Use of Higher Volumes of Fly Ash in Concrete

This risk manifests itself in terms of increased liability to the ready-mixed concrete producer who is responsible for the performance and properties of the concrete.

Risk is seen as arising largely from the questionable / inadequate QC of the FA and/or the concrete produced with it. Thus, this Study has been undertaken to develop the requirements for improved QC and construction practices, and to provide recommendations for amending standards and developing guidelines. Development of appropriate standards and guidelines is expected to reduce the risk associated with the use of ECS.

Elements of the rationale include:

1. Current CSA requirements are not as stringent for FA as for Portland cement. These Standards may be outdated and/or inappropriate for evaluating the properties of FA when used at the replacement levels advocated here (i.e., higher than typical "comfort" levels). Additional and/or different testing procedures may be required.
2. Construction standards have not been developed with the ECS levels of cement replacement in mind, and so additional requirements may be needed. For example, it may be necessary to require a minimum total cementing materials content in low strength concrete.
3. Standard specification strength tests are conducted on mortar cubes, which may not properly represent the performance of the FA in concrete. The tests also may not represent the FA's performance with different cements or with air-entraining agents (AEAs) and other admixtures. Further, the Standards do not evaluate, except indirectly, the glass phases of the FA, which are recognized as a major element of the FA's performance.
4. Each material in concrete has its own variable properties. Given that the uniformity of FA is not controlled in CSA A3000, use of it at say 50% of the cementing materials, may result in corresponding increased variations in the properties of the concrete produced from it. These variations would be less important at the current common replacement levels.

1.3 Objectives

The objectives of this Study are:

1. To ensure constant quality and minimal risk associated with construction using ECS by developing the QC of:
   a) fly ash,
   b) HVFA concrete mixture evaluations, and
   c) construction practices.
2. To provide a basis for amending the current Standards and developing practice guidelines.

Ultimately, it is intended that the results of this Study both evolve into submissions to the CSA Committees with regard to necessary changes in the Standards, and are used in the development of guidelines for the effective use of ECS.

The intended audience for this Study includes:

- Standards organizations,
- Advisory Committee for the Minerals and Metals Program of Action Plan 2000 on Climate Change (Supplementary Cementing Materials program area),
- FA producers and FA users, specifically those involved in the production of concrete and cement-based products,
- cement producers,
- contractors, and
- design community (engineers and architects).

2.0 Scope and Methodology

As indicated in Section 1.1, the focus of the Study is on the use of FA in ECS; however, some of the findings apply equally to any concrete containing FA.

The methodology for the Study was defined by EcoSmart and is presented in Appendix A. Essentially, the methodology was to:

- define the nature of the risk as perceived by industry,
- define industry's current practices with regard to QC of HVFA concrete,
- evaluate the current Standards with regard to their effectiveness in controlling quality and how those Standards are applied by industry, and
- recommend solutions as risk abatements.

Accomplishing the above has required:

- Defining the current state of the art in QC of HVFA concrete by the producers of the FA, the users (i.e., the ready-mixed concrete producers), and the construction industry;
- Analyzing the Standards from the perspective of what they control and by what means;
- Tracing the history of development of the Standards;
- Comparing Canadian Standards with those from other countries, both with regard to technical content and philosophy[3];
- Conducting interviews with the industry and stakeholders[4] with regard to both their understanding of the current situation and suggestions for improvement:
  - ready-mixed concrete producers and their industry associations, both provincially and nationally,
  - researchers active in HVFA concrete,
  - individuals active in CSA Standard preparation,
  - concrete contractors, and
  - FA producers and marketers, including their industry association, CIRCA;
- Obtaining feedback from Seminars, particularly those conducted by CANMET and EcoSmart and conducting discussions with international industry members with regard to their QC practices;
- Reviewing the existing HVFA concrete QC guidelines by various technical organizations; and
- Reviewing the available literature on QC of FA.

Subsequently, a draft of this Study's findings was reviewed by a Panel of experts familiar with the use of HVFA concrete. The Panel included the individuals listed in Table 1.

[3] Relevant sections of reviewed Standards are included in Appendix E and Appendix F.
[4] Those interviewed were advised that names would not be identified in this report because some of the information provided was of a commercial nature.

Table 1: Risk Abatement Study Review Panel

Stakeholder Group	**Individual**
EcoSmart Concrete Project	Phil Seabrook, Study Director
Cement & Concrete Producer (Lafarge)	Robert Munro
Cement Producers (Cement Association of Canada – CAC)	Richard McGrath
Fly Ash Producers (Association of Canadian Industries Recycling Coal Ash – CIRCA)	John Flynn
Contractor (Ellis Don)	Lloyd Keller
Canadian Standards Association (University of Toronto)	Doug Hooton
Designer (Read Jones Christoffersen Ltd.)	Ron Mazza
EcoSmart Concrete Project	Maggie Wojtarowicz
Ready-Mixed Concrete Association (Atlantic Provinces Ready-Mixed Concrete Association – APRMCA)	John Connely
Research (Natural Resources Canada – CANMET)	Benoit Fournier
Research (University of New Brunswick)	Mike Thomas

Recommendations of the Panel are summarized in Section 9.0. Where appropriate, the comments have been incorporated into this report.

References used for the Study are presented in the Bibliography in Section 14.0. Included in Section 14.0 is a list of the Standards referenced in this Study.

3.0 Background Information

FA has been in use as a cement replacement in Canadian concrete since the mid 1970s[5]. Interviews conducted during the Study and reference to the literature did not identify any durability problems with FA concretes other than occasional problems with scaling of flatwork in freezing and thawing exposures, particularly those exposures exacerbated by the use of deicing salts. Where those problems occurred, they were often associated with inadequate curing and the lower quality of concrete such as is used in residential construction.

However, the replacement levels of FA used in these previous concretes have typically been in the 10 to 20% range. The concrete being considered in the Study would normally have much higher replacement levels, in the 30 to 50 % range (in ECS, the levels are determined by the EcoSmart criteria in Section 1.1).

The Author knows from personal involvement in the preparation of the previous CSA A23.1 Standard that the Committee of those days did not address possible additional requirements that might arise from the use of today's higher FA replacement levels. Despite this, the Standard has been used, to the extent that it is applicable, in the construction of numerous successful EcoSmart case study projects. Therefore, it is not inappropriate but possibly incomplete Standards that are in question.

Throughout the Study, many stakeholders have stated that they are comfortable with the application of the Standards to the common replacement levels of FA. Those replacement levels vary with the practices of a particular geographical area, but maximums of 20 to 30% were suggested for this comfort level. For them, risk management = comfort.

[5] The first use was by Ontario Hydro in 1950 in the Otto Holden Dam, followed by numerous other dams in Ontario. These typically used 20 to 30% FA.

For the ready-mixed concrete producer, lack of FA uniformity increases the possibility of producing concrete that is occasionally non-compliant with specifications (i.e., typically non-compliant with regard to strength or air content), and therefore, there is a corresponding increased risk of liability. This is the crux of the Study.

FA is used as a supplementary cementing material. The traditional Portland cement is a product manufactured under stringent QC requirements, and it is those resulting levels of performance and uniformity that the ready-mixed concrete producer are accustomed to having in their cementing materials. FA is a waste by-product that results from the production of a primary product, electricity, and therefore, is not subject to the same levels of control.

4.0 Information from Stakeholders

4.1 Contractors

4.1.1 General

Interviews were conducted with general contractors who specialize in concrete construction, and with finishers / tradesmen.

Contractors focus mainly on schedule and cost. From a quality perspective, they see the responsibility lying with the design team, and that their duty is to comply with the contract specifications. From a risk perspective, their concern is that which is noted in all publications about HVFA concrete, and is inherent in the system. Their main concerns include:

1. Increased setting times necessitate longer hours for the finishing crews. With higher volumes of some fly ashes in cooler temperatures, this can result in the finishing crew having to stay overnight and complete their work the next day {2, 3, 4}.
2. Slower early strength gain necessitates either longer duration for suspended slab shoring or delays in formwork stripping {3, 5}. The risk here is that the in situ concrete strength will not be adequately assessed, and the forms will be stripped before it is safe.

Some contractors also noted the cost associated with increased curing time although this did not appear to be a major risk factor. Curing was considered the responsibility of the Owner to specify the appropriate requirements. It is possible that additional curing is not identified as a major factor because, in practice, proper curing is so inconvenient that much of the specified curing is not performed.

Contractors seem to appreciate that the level of these risks varies with the type of FA, being much higher with Type F than Type C[6]. Further, the risk is proportional to the FA replacement levels. All contractors stated that they do not identify risk (or cost) at the common 20% FA replacement levels.

4.1.2 Placing and Finishing

Some placers noted that the improved pumpability of ECS {3} reduced risks from pump blockage.

Finishers noted that the absence of bleed water in ECS makes the timing of trowel-finishing more difficult, and some training / experience is necessary. The Author's project experience shows that

[6] "Fly ash is categorized as Type F or Type C. Type F is produced when either anthracite, bituminous, or sub-bituminous coal is burned. Type C normally comes from lignite or sub-bituminous coal." (http://www.rinkermaterials.com/hydroconduit/infobriefs/i1005.htm, accessed September 13, 2004). The primary xdifference in physical properties between Types F and C is that Type C has a significantly higher CaO content.

finishers can handle ECS once they understand the differences. This strongly supports EcoSmart's approach in which finishers get an opportunity to work with the concrete in the early stages of a project, typically in the footings.

The following was noted by a concrete contractor[7] with considerable experience with ECS, typically at levels of 50% Type F FA {2}:

- The risk is largely with the owner who specifies ECS or the ready-mixed concrete producer who supplies it (on a performance basis). Initially, mixture proportions are adopted that are conservative, and then these are progressively modified as results indicating higher-than-specified strengths are received.
- No extra QC is required from his perspective, but the ready-mixed concrete producer intensifies its QC.
- There is a potential problem in using high flowing concrete (ECS with superplasticizers), because it results in leakage at tieholes and form joints.
- The costs of ECS are probably slightly higher than conventional concrete because of the extra finishing time required, and the fact that ready-mixed concrete producers do not pass on the savings in reduced cementing materials costs. Presumably, there is a trade-off between extra QC and risk, and decreased materials costs.
- In his operation, separate crews are used for placing and finishing slabs. The finishing crew typically arrives an hour after the completion of placing but when using ECS, this is extended to typically 2 hours.
- The appearance of ECS is superior to that of conventional concrete, both with regard to colour and freedom from bugholes.
- It has not been difficult to have HVFA concrete supplied on a performance basis by ready-mixed concrete producers.
- He also noted that FA is a component of concrete, and concrete is a component of the building, so there is a need to make ECS work as part of the total building system. This is discussed further in Section 11.0.

Finisher reactions varied. One finisher said that the differences between the concrete's finishing properties are greater among concrete producers than between ECS and conventional mixtures. He also noted that higher volumes of FA are not desirable for extruded curb mixtures because plastic shrinkage cracks could result from the lack of bleed water.

Another finisher advised that ECS was "sticky" (this is because of the higher paste volume at a given cementing materials content) and looked "dead" (this is because of the lack of bleed water).

It is known that HVFA mixtures in exterior flatwork have a tendency to "skin-over", particularly if there are drying conditions, such as high winds. This phenomenon is well known for concrete containing silica fume and can cause a crust to form on the surface, resulting in either plastic tear cracks from the trowels and/or a wavy surface planeness.

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[7] This contractor specializes in exposed architectural concrete and was one of the first to use EcoSmart concrete. He does not generally do high-rise or other concrete work requiring high cycle formwork, and stated that EcoSmart concrete would not be suitable for that type of construction. Most of his concrete formwork, placing, and finishing is done by subcontractors.

4.1.3 QC Practices and Experience with HVFA Concrete

It is recognized that Standards {7} do not have any mandatory additional QC requirements for HVFA concrete. However, some additional monitoring is required as noted below.

Contractors experienced with Type C FA indicated that it has a propensity to produce efflorescence.

One of Canada's larger contractors, who has experience with ECS, offered the following comments:

- They have used up to 50% FA replacement, mostly in mass concrete such as raft slabs, and have experienced no problems.
- For large or critical projects, it is necessary to "tighten up on the CSA Standards – CSA is too loose". They perform their own QC on the FA in addition to reviewing the supplier's mill certificates. Internal testing consists of loss on ignition (LOI), fineness (45 µm), and color (they have found that colour variations are indicative of uniformity – see also Section 4.3.2). They also perform a simple "float-out" test in which the foreign material floating to the surface of FA placed in water is observed. Internally, they look for <2% variation in test properties.
- They require that the supplier's mill certificates accompany the FA shipment. In their ECS projects, the concrete producer has paid special attention to QC. They refer to the New York State requirements for FA qualification (see Section 5.2 and Appendix E).
- They look for net mixing water reductions to assure that the ECS mixture proportions are working. They expect a 6 to 8% reduction for Type C, and higher for Type F compared to conventional concrete.
- With regard to low ambient air temperature, they require that the mix does not drop below 15^{o}C because their experience is that, if a mix is allowed to chill, subsequent heat will not be as effective in achieving strength gain. This requires temperature monitoring.
- They approach trial mixes for specifications by using various cements with the available FA. Results show that the same FA performs much better with some cements than with others; apparently higher tricalcium aluminate (C_3A) and alkali cements work better.
- The lack of bleed water is a problem for finishing of ECS, and it requires experience and monitoring. The key is observing the water sheen. Fog mists or evaporation retarding agents may need to be used to prevent plastic shrinkage.

In general, this contractor suggested that there is no problem using ECS provided that you are prepared to monitor its performance. The same type of monitoring is required for ECS as with conventional concrete, but to a greater extent. There is, however, a learning curve with the finishing.

One larger contractor provided a copy of their internal QC requirements that they demand of their concrete producer (see Appendix E). In this case, the concrete producer is required to obtain certification of SCM quality from the SCM supplier.

It has been noted above that ECS does not produce a significant amount of bleed water. However, in a recent project in which a shrinkage-reducing admixture was added to ECS, considerable bleeding occurred. It was subsequently determined that such admixtures have a tendency to increase bleeding in ECS {4}. This points out the need to check the compatibility of the concreting materials.

4.1.4 Costs of QC

The matter of possible increased costs of additional QC of ECS was raised with the contractors. Without defining the specific nature of those increases, it was difficult to assign numbers.

It is recognized that FA is generally one-half to two-thirds the cost of cement, and since it can be substituted kg for kg in mixture proportions, at least up to some level of replacement (perhaps up to 25% FA), the cost of the concrete itself is less[8]. In Western Canada, this difference might be in the order of $5 to $8/m^3. Offsetting this are the additional monitoring, curing, finishing, and formwork removal times noted above.

EcoSmart's experience with tendering alternates for the supply of ECS versus conventional concrete is that there is neither cost premiums nor savings {4}.

4.2 Ready-Mixed Concrete Producers

4.2.1 Position of the Ready-Mixed Concrete Industry

The ready-mixed concrete industry originally indicated that there are risks associated with the use of ECS (see Section 1.2). The following information was obtained from interviews with the national and provincial Ready-Mixed Concrete Associations, and individual ready-mixed concrete producers. Appendix B provides an outline of the types of questions / issues that were discussed with the Associations.

The Canadian Ready-Mixed Concrete Association (CRMCA) is actively involved with EcoSmart in dialogue on the use of ECS. They have stated that "*…our position is that promoting SCM contents outside the current industry standards comes with significant liability issues…*". This statement is the underlying reason for EcoSmart undertaking this Study (see Sections 1.1 and 1.2). They have also stated that "*The concrete industry in Canada has positioned environmental awareness at the top of their agenda*."

To further illustrate the industry's concerns, an excerpt from the Atlantic Provinces Ready-Mixed Concrete Association (APRMCA) newsletter is presented in Appendix B.

The ready-mixed concrete industry has indicated that the qualities they want in a FA are uniformity and high reactivity (which equates to high strength potential).

4.2.2 Nature of the Risk

The ready-mixed concrete industry has been unable to provide specific data or technical information on the nature of the risk. From the industry's perspective:

Risk = Liability

It is apparent from the Study interviews that liability is a prominent issue in the minds of the ready-mixed concrete industry.

EcoSmart is not aware of the specific problems that lead to concerns from CRMCA. In addition, this Study determined that the more sophisticated members of the ready-mixed concrete industry are using replacement levels higher than the 20-30% common levels (see Section 1.3) on a routine basis. There are

[8] The strength efficiency of FA, when replacing cement, varies with the particular FA and local practice. In one area, 60 kg of cement are replaced with 80 kg of FA.

many successful projects with these higher replacements {2}[9]. However, because it is the industry's perception that there is a risk, it will be addressed as such.

The general nature of the risk is presented in Section 1.2. Additional aspects include:

1. There is a risk that designers / owners will adopt national specifications requiring high replacement levels that do not recognize the availability or quality / performance of local FA. This is against the EcoSmart approach (see Section 1.1), but unfortunately has already occurred in isolated instances.

2. Given that the variability of FA can be greater than that of cement, and that FA is replacing a large percentage of the cement, there is an obvious risk of greater variations in properties of the resulting mixture. Normally, the property of interest is strength. The industry in Ontario contrasts the risk of the use of fly ash with the use of slag, the production of which is better controlled than that of FA.

   The EcoSmart case studies {2} have not shown increased variability. In one of the Author's recent large infrastructure projects that used ECS with FA replacements generally about 1 ½ times the common levels, the uniformity of the concrete, as judged by the standard deviation of the strength results, was in the range expected for conventional concrete {4}. Following is a typical set of values for one of that project's ECS mixture proportions:

   - Average 56 day compressive strength – 47.6 MPa
   - Cementing materials efficiency @ 56 days – 14.0 MPa / 100 kg
   - Standard deviation – 4.8 MPa
   - Coefficient of variation – 10.0%

   There are a number of other mixture proportions on this project with similar values. These would be considered both excellent uniformity and cementing materials strength efficiency. One concrete producer noted that he had not experienced any difference in strength uniformity between 0% and 40% FA concrete.

3. One Ready-Mixed Concrete Association stated that FA is "uncontrolled", and therefore, its performance is unpredictable. As indicated above, the ready-mixed concrete industry wants a FA with the same predictability as cement.

4. It was noted that while the cement producers provide technical support to ready-mixed concrete producers (particularly the smaller or less technically sophisticated ones), there is generally no similar technical support from the FA producers.

5. There is concern about the ability of the smaller ready-mixed concrete producers to implement the extra QC required to accommodate ECS.

The CSA Standard for concrete {7} defines the minimum levels of quality for concrete, and assigns responsibilities for the concrete's performance. Ultimately, of course, it is intended to protect the public. Under the current performance option (see CSA A23.1-00, Clause 16.1, Alternate 1 of Table 13), the ready-mixed concrete producer is responsible for the quality of the concrete at the discharge from the delivery truck. This is well understood and accepted by the industry. If, say 40% minimum FA replacement for cement is specified, then it is the ready-mixed concrete producer's responsibility to design and produce a concrete mix meeting the 40% minimum plus the other criteria such as W/CM,

[9] One reviewer of a draft of this report noted that, while good strength uniformity was obtained in the EcoSmart case studies, presumably due to the availability of uniform FA, occasionally there are uniformity variations in the FA that may compromise the strength of HVFA concrete. There are limited test methods that result in recognition of these occasions.

slump, air content, and strength. If the FA does not perform as expected, there can be a non-compliance resulting in possible liability. Unfortunately, the contractor's concreting system can also negatively affect the quality of the concrete, but in the postmortem analyses, history teaches us that the ready-mixed concrete producer is often held responsible; hence, the concern over liability.

One concrete producer offered the comment that in general, concrete producers should not participate in the supply of HVFA concrete (or presumably ECS) if they are not comfortable with this type of concrete.

It was stated that the use of FA in blended cement eliminates the concern about FA being a waste by-product. In blended cement production, the same QC is applied as for normal cement, so it becomes a manufactured product. Additional FA could still be batched separately for special projects. One ready-mixed concrete producer noted that this approach reduces overall flexibility in ECS mixture proportioning.

The risk of problems increases as the quality of concrete decreases (e.g., residential). However, one concrete producer offered that risk would be lowered if this concrete were produced to the Standards, specifically to the maximum W/CM of 0.70, which is now required for residential concrete in CSA A438 {9}. He noted that there is a greater risk associated with uncontrolled mixing water contents than from variations in FA uniformity. Related to this, another concrete producer stated that the risk increases with low strength concrete mixes (i.e., residential concrete) because of the generally lower level of QC, the demand for higher workability, and the lack of recognition of the need for curing and protection.

Another element of the risk, although not the responsibility of the concrete producer, is the need for extended curing of ECS, and the realization that curing requirements are often violated in construction. Producers feel that they inherit some of this risk, because contractors have a tendency to download responsibilities.

- One large concrete producer advised that they support FA use without any special requirements up to a replacement level of 25% (the comparable number for slag would be 35%). Replacement over 25% would be considered high risk requiring special QC plus a "shared responsibility" between the ready-mixed concrete producer and the owner/contractor.

This concrete producer said that "…90% of the calls that they receive about FA concrete relate to air problems…". In spite of this, their use of FA is increasing, and they are moving their replacement levels upward.

The same concrete producer also noted that their testing has shown that "…all fly ashes are not created equal…" and that they perform differently with different cements.

4.2.3 Quality Control of HVFA Concrete by Ready-Mixed Concrete Producers

4.2.3.1 QC of the FA

All concrete producers that were interviewed as part of this Study receive mill certificates for their FA. These are typically distributed as tests on a monthly composite sample. It was recognized that the FA is often in concrete before certificates are received. Producers generally do not do anything with the certificate data other than to "…look at it from the perspective of uniformity with the typical (previous) values." Data is not integrated into their QC.

Some of the larger concrete producers have developed internal test procedures for evaluating / monitoring the performance of the FA in their concrete (see Section 4.2.3.2).

Of all the ready-mixed concrete producers known to the Author, none do any QC or independent testing on the FA itself. The concrete producers simply accept the QC that is done by the FA supplier. For some smaller concrete producers, the concept is "…cement-is-cement, fly ash-is-fly ash…", and performance is assumed.

4.2.3.2 QC of the Concrete Produced with FA and other SCMs

It was noted that the Standard {7} has no special requirements for QC of high volume supplementary cementing materials (HVSCM) concrete. The proposed revisions to the Standard define safeguards for the durability of HVSCM concrete that have to be accommodated in the mixture proportioning, but are silent on any additional field QC testing (see the proposed CSA A23.1, Clause 8.8).

Concrete producers indicated that they do not perform any special QC testing when supplying HVFA concrete. However, they normally intensify the frequency of their sampling and testing, because such projects are typically high profile with rigid specification compliance. Related to this is the need to perform additional air content tests because of the propensity of FA to cause fluctuations in entrained air (see Section 4.2.2). Overall, concrete producers increase the amount of field-testing when using HVFA concrete because it is more sensitive to change in plastic properties.

Concern was expressed by a number of those interviewed that the risk is higher for those smaller ready-mixed concrete producers who do not have comprehensive QC, and rely on FA suppliers for both a portion of the QC and technical support. It was noted that the cement companies and the CAC supply considerable technical support and troubleshooting advice. Similar support is not readily available from the FA suppliers.

Two concrete producers independently described their own internal test programs in which they compared the compressive strength of identical production mixes: one with 25% FA replacement and one with cement only (no FA). In both cases virtually identical strengths were obtained, and there was no indication of a reduction in the uniformity (i.e., standard deviation) of the mixes with FA. Data from these tests is unfortunately not available for publication, but some was shown to the Author, and it did not indicate significantly larger variations between mixes with and without FA as might be expected from the assumed risk in Section 4.2.2.

In a discussion about this matter with industry leaders in sustainability P.K. Mehta and M. Malhotra[10], it was stated that ready-mixed concrete producers should not supply HVFA concrete if they do not have in place a comprehensive QC program, both with regard to the FA used and the concrete produced from it. Unfortunately, this would disqualify many of the small ready-mixed concrete producers from producing HVFA concrete or ECS.

4.2.4 Other Issues Raised by the Ready-Mixed Concrete Industry

The CRMCA and others strongly stated that EcoSmart would better serve the industry, and EcoSmart's objectives of reducing GHGs, if they focus on expanding the use of FA within the current / common replacement levels, given that on a Canada-wide basis, FA use is 6.5% that of cement {1}. In a separate conversation, CRMCA suggested that the concrete sustainability issue should be moderated. One Ready-Mixed Concrete Association quoted the range of 18 to 30% as the existing envelope of common replacement levels.

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[10] P.K. Mehta is Professor Emeritus, University of California, Berkeley, and M. Malhotra is Research Scientist Emeritus, Natural Resources Canada, CANMET.

With regard to concrete supply requirements in CSA A23.1, the proposed draft of revisions introduce what the industry calls *total performance concrete* (see Clause 4.4). The CRMCA has suggested that this would mean that a specifier should not require anything but testable parameters if they require the ready-mixed concrete producer to be responsible for the quality of the concrete. CRMCA extends this to mean that, should the specifier require a minimum SCM content, then the ready-mixed concrete producer is no longer responsible for the quality of the concrete. Others do not share this interpretation, noting that the owner (see Clause 4.1.2.1 and Table 5) has the right to specify sustainability requirements. However, if the Clause 4.1.2.1 is accepted as CRMCA interprets it, the revisions would transfer all the responsibility to the specifier / contractor / owner.

The implication of this proposed revision for ECS usage is that there is no clear or accepted definition of what should be contained in a performance specification for ECS.

Some concrete industry members suggest that EcoSmart conduct a Life Cycle Analysis of the costs, and GHG and energy impacts (including transportation) of ECS versus conventional concrete.

Related to the positions on the nature of the risk in Section 4.2.2, one concrete producer was most concerned about the EcoSmart position that the "highest practical amount of FA should be used." He stated that he had to add a "fudge factor" (presumably an increase in standard deviation – see also Section 10.2) to mixture proportions with higher volumes of fly ash, while none was required with the "normal" replacement levels.

It was noted that some governments in Canada still prohibit FA, or limit the replacement to small percentages, 10% in one case. Further, some prohibit FA in concrete placed after September, presumably because of the need for additional curing and/or protection prior to freezing.

One group stated that they are comfortable at 25% replacement levels "in the right application…". This approach is consistent with EcoSmart's recommendations in Section 1.1.

For perspective, one concrete producer noted that strength comes from the cement, FA is just "…along for the ride…" and you should not "…send the concrete out if you are not comfortable…". Such a comment indicates a lack of knowledge of FA properties among some members of the concrete industry, and thus, the need for further education.

An interesting risk mitigation not mentioned by the ready-mixed concrete industry relates to mitigation of the alkali-silica reaction (ASR). For example, the proposed CSA A23.1, Section B4.8, reads, "…90% of BC aggregates tested have exceeded the recommended limit (0.15%) when tested in the accelerated mortar bar test. When tested in the concrete prism test, the proportion of BC aggregates that exceed the CSA recommended limit of 0.04% at one year is approximately 45%." An accepted mitigation measure is the use of FA, the minimum amounts ranging from 20% to 35% depending on the severity of the reactivity and the composition of the FA (figures quoted are for Type CI FA – see also Table 6 of {10}).

During an EcoSmart seminar, the following comments were raised by industry:

- ECS cannot be supplied for the turnover times (i.e., formwork cycling) that industry wants.
- The challenge is curing – needs will vary across Canada according to the local relative humidity.
- Slag is much easier to control than FA.
- There are still a number of specifications (in Alberta) that prohibit FA – this arises from scaling problems of past years.

- If there are problems with the concrete, the ready-mixed concrete producer is on the front line.
- The Engineer's liability lingers longest.

4.3 Fly Ash Producers

4.3.1 Position of the FA Production Industry with regard to Fly Ash as an SCM

A schematic of a typical power plant is shown in Appendix C. The location of fly ash producers in Canada is also presented in Appendix C.

FA producers who operate the power plants honestly stated that the quality of the FA was not one of their priorities, and that their business is producing power. They recognize the responsibility to dispose of their waste products in an environmentally acceptable way, and therefore see the value in selling FA as an SCM. Although historically they have little interest in the FA properties, some now have an increasing awareness that it can be an asset, and there are potential upsides to using FA disposal as an element of the plant's sustainability program.

One representative of CIRCA stated that "due diligence will always be absolutely necessary if sustainable development initiatives call for optimizing the use of an SCM such as FA."

There is also the matter of financial perspective. FA costs about $8/t at the power plant, to process, handle, store, and ship. The fact that a ready-mixed concrete producer can then pay in the order of $75/t for FA indicates that the costs of transporting FA from its point of origin to concrete producers can be substantial.

It must be appreciated that most power plants in Canada distribute their FA through marketers. They adopt the position that they do not know the SCM/concrete world, and are happy to ship this waste product to someone who does. These others have the contractual responsibility for developing, marketing, and QC associated with the FA.

Given that there are variations in coal composition, either within a particular deposit or from the multi sources that are often fired at one plant, the focus of a power plant is to maximize the energy potential of those variations. This will result in variations in the properties of the dust that is collected in the stack. FA producers stated that they can trace the properties of their FA to the coal source.

The industry also recognizes the difference in FA quality and/or uniformity between base load plants and those required to produce power for peak loads. FA from the latter is traditionally more variable.

4.3.2 QC by the Fly Ash Producers

Daily QC at the plant, if any, is basic. For example, one FA producer reported not doing any. The testing is usually confined to periodic determination of LOI and 45 µm only[11]. The other tests required by the Standard are performed off site, commonly by the marketer. At least the minimum tests required by CSA A3001-03 {8} are performed at some point. Often tests additional to those required by the Standard, or Standard tests at an additional frequency, are also performed.

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[11] LOI = Loss on Ignition, which approximates the carbon content of samples, expressed as the percentage loss in weight of a sample ignited to constant weight at a specified temperature, usually 900 to 1000^{o}C. 45 µm = sieve size used in determining the fineness of samples, where the percentage of residue retained on the sieve screen is calculated and compared against the maximum allowable value in the Standard.

Most plants have internal criteria for acceptance that are much more stringent than those in the CSA A3001-03 Standard. When FA tests do not meet these more stringent criteria, the FA is diverted to waste, or some other use, and diversion continues until the production again meets the criteria. Similarly, most plants have testing frequencies that exceed the CSA A3001-03 Standard.

One plant reported sampling and testing (i.e., LOI and 45 µm) every 3 hours. Their internal standards showed:

- LOI – target 0.2 to 0.4%; maximum allowed = 0.55%, and
- 45 µm – target 9 to 15%; maximum allowed = 19%.

Plants chemically analyze their feed coal, including the determination of volatile organics. They claim that from this they can predict most of the properties of the FA. Therefore, they suggest that their QC is handled through process control, given that the best quality FA will result from the most effective burning. Some plants use colour reference charts to qualitatively determine the carbon content of samples.

Plants generally do not utilize all of the FA available. And most power generators have other plants that are not currently providing FA to the concrete market, but that could do so with beneficiation of the ash. Technology is readily available to beneficiate. Normally, this involves removal of excess carbon and/or classification to remove coarse (non-reactive) fractions.

A number of FA producers suggested the use of the Foam Index and XRF tests[12]. Some FA producers are already using these tests internally. Some FA producers also do glass phase analyses.

FA producers were questioned about the uniformity that could be expected in production. No data was offered or was located in the review of literature. There was reference to uniformity problems in the Japanese publications (see Section 5.4), but again, no data was given. The contention in Section 3.0 is that QC of FA is much less than that of cement. Logic would support this, and anecdotal information was provided, but no hard data.

4.3.3 Costs of QC

Power plants generally do not cost the FA QC separately, presumably because it is small compared to the other aspects of the process. One FA producer suggested that the cost of conducting the complete ASTM C618 (see Table 2 for comparison to CSA A3000-03) was in the order of $0.15/t.

The QC program at one large plant was estimated at $0.90/t. This does not include the supplementary tests by the marketer.

Marketers readily acknowledged that the Pozzolanic Activity Index results do not correlate with the strength of FA in concrete. A number of them advised that they are internally using other test methods to monitor their FA quality, i.e., the Foam Index and XRF. In discussions about alternate test procedures, they noted that there is no clear understanding of what FA properties should be measured.

In considering the cost to benefit ratio of FA QC testing, the following approach was suggested:

- determine the relevance of the particular test,

[12] Foam Index Text has been used to predict the air-entraining characteristics of samples and to determine the amount of AEA that needs to be added to concrete mixtures. XRF Test involves x-ray analysis of chemical reactivity of samples.

- determine what frequency is necessary to cover fluctuations in FA production, and
- determine the cost.

Table 2: Comparison of International Standards for Fly Ash

PROPERTY	COUNTRY					
	Canada **CSA A3001-03**	**US** **ASTM C618-00**	**Japan (Type II)** **JIS A 2601 /** **JSCE 2000**	**India (Grade 1)** **IS 3812-1999**	**EU** **BS EN 450:1995**	**Australia** **(Medium Gd)** **AS 3582.1-1998**
Chemical						
Loss on Ignition, % max Type F Type CI and CH	 8.0 M 6.0 M	6.0 M Up to 12.0 with performance	5.0 M	12.0 M	5.0 M	5.0 M
Sulphur trioxide, % max	5.0 M	5.0 M		2.75 M	3.0 M	3.0 M
CaO, %	Varies with type	Varies with type		-	1.0 M	
Moisture content, % max	3.0 O	3.0 M	1.0 M			1.0 M
$S_1O_2 + Al_2O_3 + Fe_2O_3$, % min	-	70.0 M		70.0 M		
Available alkali re ASR % max	-	1.5 O		1.5 M		NL O
S_1O_2, % min	-	-	45 M	35.0 M		
MgO, % max	-	-				
Chloride, % max	-				0.1 M	NL O
Physical						
Fineness, 45 μm max %	34 M	34 M	40 M	-	40 M	35 M
Blaine m²/kg			250 M	320 M		
Soundness max %	0.8 M	0.8 M		0.8 M	50/50 FA/PC, 10 mm Exp. M	
PA Index 7 days % control	-	75 M		-	-	
28 days % control	75 O	75 M	80 M	80 M	75 M	NL O
91 days % control	-		90 M		85 M	
Reactivity with alkalis (re ASR)	Yes O					
Uniformity of AEA	Yes O	Yes O				
Sulphate resistance	Yes	Yes O				
Water requirement, % control	-	105 M				NL O
PA Lime, MPa Min	-	-	-	4.0 M	-	
Drying shrinkage % max	-			0.15 M		
Density kg/m^3	-		>1,950 M		+/- 150 average M	NL O
Flow ratio, % min	-		95 M			
Other						
Uniformity	No requirement				(Probabilistic approach)	
Density +/- % average		5 M			+/- 10% Average	
45 μm +/- % average		5 M				+/- 5% from sample
Cement for testing		Use project	Blend any 3 local		Standard available	
Sampling	-	-	Rationale plan	-	Autocontrol with sampling plan, frequency time based	Statistical
Alternative test methods recognized	No	No	Yes	No	Yes	Yes
Certification	Typical data or certificate	Purchaser must designate	Supplier submits, form presented	Supplier submits, may provide copy to purchaser, 3rd party test recognized	Not specified	Report form provided, compliance specified

Legend: O = Optional M = Mandatory NL = No limit

4.3.4 The Risk Element

Following is a definition of risk from a FA marketer who has experience dating back to the 1970s. Power plants occasionally go down for a period due to mechanical or maintenance problems. There is always a fluctuation in FA quality during start-up. This is monitored only by LOI and 45 µm in most plants, but these tests are not sufficient to predict the performance of the FA in concrete. Some recent examples were provided, but are not available for publication. Again, it was suggested that these variations are not critical at average replacements, but would be at the higher levels of replacement. There currently is no predictive test to determine the effectiveness (i.e., basically, strength and air-entrainment stability) of FA. So a marketer could have a problem and not know it.

Most FA is shipped before completion of all of the CSA tests. But even if those tests were completed, the effectiveness is not necessarily predicted. The only strength test, Pozzolanic Activity Index (see CSA A3001-03, Table A.3), does not correlate well with strength in concrete. And it is run at a fixed FA replacement of 25%, which does not cover the range of replacements in ECS.

One marketer suggested that the use of ECS should not be advanced beyond "engineered" projects until proper predictive tests are available. He used the analogy of cement in which extensive physical and chemical testing is done at a high frequency, and from that, predictive performance is available.

4.3.5 Other Issues Raised by FA Producers

The Author was advised that the FA supplier to a large EcoSmart case study project that required 50% replacement issued a letter to the concrete producer stating that they would not be responsible for the concrete's quality.

One FA supplier has data, which is not available for publication but was shown to the Author that showed some water-reducing admixtures do not work well with some FAs. These admixtures are designed for effectiveness with cement, and not necessarily with FA. Compatibility tests are required for HVFA concrete.

Plants are cognizant of environmental issues. However, they indicated that they do not feel that there are any imminent threats to FA use from environmental regulations. Mercury emissions are a potential concern (as they have been in the US), but most of Canadian coal is low in mercury. There was also a comment about vanadium. It was stated that no Canadian commercial ash is rated as "hazardous" under the federal Transportation of Dangerous Goods Regulations rules. However, if the rules being proposed for the US are transferred to Canada, Canadian FAs will not be suitable as an SCM without beneficiation.

One estimate of the cost of installation of beneficiation equipment was $6 million. Another FA producer estimated the operating cost for beneficiation at $10/t.

The matter of shipping FA before the tests were completed was discussed with the FA producers and marketers. The time to report a full set of CSA A3001-03 (mandatory and optional) tests would take about 1 ½ months from the time of sampling. From the FA producer's perspective, it is a matter of storage silo availability. The marketers believe that they do sufficient QC to assure reasonable quality and some hold the FA for a few days so that data in addition to the basic LOI and 45 µm are available. Adding to the storage problem is the fact that the bulk of power plant demand, and thus, FA production, is in the winter, while the FA demand is in the summer.

Two FA producers advised that there would not be major changes in the power plant approach unless there was legislation requiring no dumping (as there is in Japan). The issues then become storage, transport, and investments in beneficiation.

4.4 Designers / Owners

Designers / owners advised that they rely on concrete specialists for guidance when using ECS. This results in requiring FA replacement levels appropriate for the criteria in Section 1.1.

They believe that specifying that FA "…shall meet the requirements of CSA A3000…" is sufficient to guarantee quality. Few request copies of mill certificates. Even if they request and review the mill certificates, the QC on the project would not necessarily increase. The reasons for this are that the mill certificate may not necessarily correspond to the batch of fly ash used on a given project, the information on the mill certificates does not necessarily provide the critical FA parameters to ensure its performance in concrete, and by the time the mill certificates are received the FA may already be in the concrete.

However, some authorities, particularly those in areas where the source of the FA is not known (because of a number of potential FA suppliers in an area), have detailed QC requirements. One example is shown in Appendix E and discussed in Section 4.1.3.

With regard to QC, designers have not specified increased testing for ECS. The requirements of CSA A23.1-00, Clause 17.1, therefore, apply**. If** a designer was to specify doubling the frequency of the tests, the extra cost might be in the order of $1/m^3 (based on typical commercial testing rates and average volumes of concrete placement). However, increased testing, both with regard to frequency and the properties tested, have been done on most of the HVFA projects, including the EcoSmart case studies {2}. In general, it is difficult to assign a specific cost to these requirements.

It is recognized that there has been a reduction in the traditional quality of the Atlantic Canada fly ashes due to the introduction of pet coke fuel {3}. Currently, FA is imported from the eastern US. An Atlantic Canada concrete specialist advised that he is no longer prepared to specify ECS, because the quality of fly ash is not assured. His inquiries of the potential FA suppliers indicated that they could not provide historical data on performance of their FA in concrete used in aggressive exposures.

5.0 Information from Sources Outside Canada

5.1 General

The Review Panel cautioned that it may be difficult to apply international experience directly to the Canadian situation. Because of the differences in coal types, direct comparisons may be misleading.

5.2 United States

Appendix E contains the outline of an approach adopted by New York State. Apparently they have gravitated to that approach because many of their potential FA supplies are from peak load plants. New York requires comprehensive submissions by the FA supplier in order to be approved for supply to their Department of Transportation projects. As shown in Appendix E, these go far beyond the basic requirements of ASTM C618, although they do integrate these requirements. They require a sampling plan, a definition of the internal acceptance criteria (i.e., LOI and 45 µm), a methodology of diverting non-compliant FA, a 12-month history of performance, and the submission of mill certificates.

A literature search on the keywords "fly ash" and "quality control" produced few results relevant to this Study. Those located were primarily large projects, and typically with the US Army Corps of Engineers who introduced FA in North America through their dam projects. In those cases, internal and project-specific QC procedures were set up.

5.3 Europe

Europe uses blended cements extensively; 50 to 60% of these have FA as part or all of the SCM replacement. They recognize 4 different types of Portland-fly ash cement.

The maximum substitution of FA for cement, if added as an SCM at the batch plant, is 33%[13].

FA can be used in two forms: accompanied by a certificate from a 3rd party laboratory that does the sampling and testing, or tested to compliance by the user (ready-mixed concrete producer). The problem experienced by FA producing power plants is that they import coal from various sources, which results in corresponding variations in the FA. They also use agricultural waste as a fuel supplement with similar variations.

Discussions with Norwegian consultants who are active in developing the Service Life Models for their concretes indicated that it is not practical to get 100-year service life without the use of SCMs, and that there are few instances where straight Portland cement is used in infrastructure projects.

Europe is moving to performance specifications, but currently they are still largely prescriptive, including limits on minimum cementing materials contents and the maximum amount of SCM that can be added. Interestingly, if one were to add additional FA to a blended cement, one would not be allowed to count it as part of the minimum cementing materials content.

5.4 Japan

Much of the literature search results for the keywords "fly ash" and "quality control" point to Japanese references, the majority of which were not available in English. Therefore, contact was made with a Japanese authority, Prof. Kenji Sakata of the Okayama University, for assistance with translations and additional expertise of FA use in Japan. It was noted that there are considerable variations in the properties and qualities of Japanese fly ashes.

It should be appreciated that landfilling of FA as waste is not permitted in Japan, so there is great incentive to make effective use of FA as an SCM.

According to Prof. Sakata:

- The Japanese are using mixtures with 80 to 90% FA; the FA then also becomes the fine aggregate. In these cases, a flowable slurry is produced.[14]
- A QC program was set up using flow and tapping density correlated with the water demand. These tests were effective in estimating the concrete mixture proportions. The FA QC also included LOI, methylene-blue absorption, specific surface (by BET), and tapping density[15] (and thus, bulk density) as a method of predicting air-entraining admixture (AEA) dosages. Low-temperature plasma and surface-active aqueous solution treatments were considered. A recommendation for specific surface < 6.0 m^2/g was made. Variations in quality of ash were stated to be the result of the unburnt carbon.

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[13] Thirty-three per cent is the maximum amount that can be included in the calculation of W/CM; if more is added, it is considered inert aggregate.

[14] A similar approach has recently been used for BC Hydro's electrical duct grouting, where thermal conductivity has to be minimized.

[15] In determining the tapping density, a volume of FA is placed in a standard cylinder and the outside is tapped a prescribed amount to consolidate the FA. The bulk density is then measured.

- The Japanese Industrial Standard (JIS) tests are not considered timely for determinations of FA variation. Determinations of the bulk specific gravity of the FA are sufficient to predict the unit water content required for a specified slump, and the required AEA dosage for the concrete.
- The use of 28-day strength acceptance is appropriate for FA replacements between 15 and 30%; the test should be at 91 days when the FA is over 45%. Optimum strength has been obtained at 30% replacement.
- XRF can be substituted for the conventional wet chemistry tests.
- The dispersion of test results for all properties was greater for HVFA than conventional concrete. The long-term strength and durability of HVFA concrete was better.

The above points out that the properties determined by JIS are not sufficient to do QC on FA, and that other supplementary tests are required. Focus is on the analyses of carbon. Further, the time required for the JIS tests is not compatible with the needs of construction.

The Japanese Society of Civil Engineers (JSCE) has produced an excellent guide to the use of FA in construction {14}. It is largely a commentary on the JIS for FA. The section on QC is reproduced in Appendix E. It notes the need to comply with the Standard (see Table 2), including reliance on certificates from the FA supplier. It also suggests that consideration be given to expanded requirements such as:

- assurance that the FA is properly dispersed in the mix (may need longer mixing time),
- determination of the Pozzolanic Activity with cement be made at the FA replacement percentage proposed for the project,
- measurement of key properties (i.e., surface area and LOI are noted) to be made at shorter intervals than in the JIS,
- establishment of special uniformity requirements, and
- pre-qualification testing, including admixture compatibility.

6.0 Standards

6.1 Basis of the Canadian Standards

6.1.1 Fly Ash

The Canadian Standards Association addresses the use of FA in concrete in CSA A3001-03 through A3005-03 (where the last 2 digits represent the year of publication), together referred to as CSA A3000 – Cementitious Materials Compendium. A3001-03 is applicable to various properties of cementitious materials, namely quality requirements, while sampling and testing requirements are covered in CSA A3004-03. Comparison of CSA A3001-98 with the new CSA A3001-03 (see Appendix F for a detailed comparison) show that there are no differences in the fundamental requirements (see CSA A3001-03, Tables 5, 6, and A.3). However, there have been a few changes as follows:

- substantially increased recognition of, and requirements for blended cements,
- substantial reductions in the required testing frequencies (see Table 3),
- additional notes to assist in interpreting or conducting test procedures,
- modifications to the method of assessing the ability of the FA to mitigate ASR, and

- revisions to the nature of the mill certificate. It will now be acceptable (see CSA A3004-A1-03, Clause 5.5.1) to either provide typical test data, or provide a certificate stating that the FA meets the requirements of the applicable Standard specified at the time of purchase.

There is recognition of the importance of glass content as an indication of strength potential for slag, but there is no similar requirement for FA[16].

Tests for the effect of the FA on drying shrinkage and water demand, which appeared in previous editions of the CSA A3000 and A23.5 Standard, have been deleted. These, however, are critical requirements for assessing the effectiveness of higher volumes of FA in a concrete mixture, and should be reintroduced in the CSA A3000 Standard.

Typical FA mill certificates are presented in Appendix C. It is noted that none of these certificates contain the source information that is required in CSA A3004-A1-03, Clause 5.5.

The testing requirements are separated into mandatory and optional (see CSA A3001-03, Tables 5, 6, and A.3). The only mandatory tests are:

- chemical – CaO, SO_3, LOI, and
- physical – fineness (45 µm) and autoclave expansion.

In order to assess quality of the two parameters critical to the ready-mixed concrete producer (i.e., the strength and air content), Optional Requirements have to be specified.

The only test that assesses strength potential is the Pozzolanic Strength Activity Index. Mixtures for this are prepared with a fixed 20% FA replacement of cement, which may not be representative of the performance of concrete with higher volumes of cement replacement.

There are no uniformity requirements in the revised standard, except for the Optional Requirement for AEA dosage in CSA A3001-03, Table A.3. The approach to uniformity of air content is that the required amount of AEA to produce an air content of 18% by volume of mortar shall not vary more than 20% from the average established from the 10 preceding tests. This is focused on the carbon content of the FA, because this has a major influence on the required AEA dosage and the uniformity of the air content. In the previous version, there were uniformity requirements for the 45 µm fineness and the density; these have been dropped from the 2003 version.

CSA A3004-A1-03, Table 1 requires that the testing frequency be substantially increased when there is less than 6 months of FA production records.

As noted in Table 3, there are no changes in the required physical and chemical properties of FA between the 1998 and 2003 versions of A3001. However, relevant here is the marked reduction in the required test frequency for 2003. Further, both versions have the permissive option that "[e]ither the manufacturer or the purchaser has the right to waive the noted frequency of testing and to specify an alternative for indicating compliance with the requirements of the noted specifications." (See CSA A3004-A1-03, Table 1 Note.) This relaxation in requirements is obviously contrary to this Study's assumed solution of increasing the amount of QC as a risk abatement strategy. In the Author's review, no examples of the "waiving" were obtained.

[16] There is no simple test for glass content of FA.

Members of the A3004 Committee advised that the test frequencies were reduced, because most FA producers had developed knowledge of the performance of their product, and that the previous frequencies were unnecessary.

A review was conducted of the 1982 and 1986 versions of the then-current CSA A23.5 Standard for FA (see Appendix F). There are few changes between the requirements in those Standards and the parallel ones in the 1998 and 2003 editions.

6.1.2 Portland Cement

Similar to the CSA A3001-03 for FA, the 2003 version of the Standard contains updated requirements for Portland cement. Appendix C contains a typical cement mill certificate from a producer.

This Standard does contain a uniformity requirement for strength (see CSA A3001-03, Clause 4.6.3) based on the standard deviation of 30 consecutive strength samples.

With regard to testing frequency, it is noted that in CSA A3004-A1-03, Table 1 (as for fly ash) "…either the manufacturer or purchaser has the right to waive the noted frequency of testing, and to specify an alternative for indicating compliance to the noted specification…", which is highly permissive.

6.1.3 Comparison of Required QC on Cement and Fly Ash

Appendix F contains a detailed comparison of the successive editions of the Standard for Portland cement and FA requirements. Table 3 is a summary.

In terms of the frequency of testing, it was stated by the ready-mixed concrete producers and others, that the Standard was much more demanding for cement than FA. Table 3 shows that the specified minimum frequencies are similar – higher frequencies are required for some properties in either Standard. Generally, the test frequency is once per every 1000 t to 4000 t. However, it is known that cement producers do considerably more frequent testing, and test other properties as part of their internal QC.

With regard to sampling, CSA A3004-A1-03 has the same requirements for Portland cement and FA.

Table 3: CSA A3001-03 and A3004-A1-03 Testing Requirements for General Use (GU) Cement and Type F Fly Ash

Property	**Portland Cement (GU)**		**Fly Ash (Type F)**		
	Required	**Frequency**	**Required**	**Frequency**	
Chemical		**(2003)**		**(1998)**	**(2003)**
LOI, % max	3.0	Lot or 1/2000 t	8.0 (Type F)	Lot or 500 t	Daily or 400 t
Insoluble Residue, % max	1.5	Lot or 1/2000 t	-	-	-
SO_3, % max			5.0	Lot or 1000 t	Monthly or 3000 t
C_3A >8%	3.5	Lot or 1/1000 t			
C_3A <8%	3.0	Lot or 1/1000 t			
MgO, % max	5.0	Lot or 1/2000 t	-	-	-
CaO, %	-	-	< 8.0	Lot or 500 t	Monthly or 3000 t
Physical					
Fineness, 45 µm, % retained max.	28	Lot or 1/2000 t	34	Lot or 100 t	Daily or 400 t
Soundness, % exp. max	1.0	Lot or 1/1000 t	0.8	Lot or 1000 t	Monthly or 3000 t
Setting Time, minutes					
Minimum	45	Lot or 1/1000 t	-	-	-
Maximum	375	Lot or 1/1000 t	-	-	-
Compressive Strength, MPa					
3 days	14.5	1/2000 t	-	-	-
7 days	20.0	1/2000 t	-	-	-
28 days	26.5	1/2000 t	-	-	-
Uniformity, CV, %	8.0	-			
*Uniformity, AEA, max. % variation			20	Lot or 1000 t	Monthly or 3000 t
*PA Index, 28 days, min. % of control			75	Lot or 1000 t	Monthly or 3000 t
*Control of expansion due to ASR, 14 days, max. % expansion			0.10	3 months	3 months
*Sulphate resistance in blended cement, max. % expansion at 6 months					
Type MS		Lot or 1/4000 t	0.10	3 months	3 months
Type HS		Lot or 1/4000 t	0.05	3 months	3 months
*Moisture Content, max. %			3.0	N/S	N/S
Density			N/S	Lot or 500 t	Monthly or 3000 t
*Heat of Hydration, 7-day max., kJ/kg					
Type MH	300	Lot or 1/4000 t	300	3 months	3 months
Type LH	275	Lot or 1/4000 t	275	3 months	3 months

* Optional Test
N/S Not Specified

6.1.4 Use of Fly Ash in Concrete

The current Standard governing "the requirements for materials and methods of construction for cast-in-place concrete and concrete precast in the field" is CSA A23.1-00 {7}. This Standard does not make special provisions for concrete containing FA, either at lower or higher replacements. For QC testing (see CSA A23.1-00, Clause 17), requirements are the same for concrete with and without FA. However, the Standard does have this requirement:

- CSA A23.1-00, Clause 15.1.5 states:
  > "When combinations of Portland cement and supplementary cementing materials are used, they shall have been proven, to the satisfaction of the owner, to produce concrete resistant to the exposure conditions outlined…"

It is important to consider the related requirements in the proposed CSA A23.1, Clause 8.8. In the proposed version, there is:

- recognition of the need for special requirements for concrete containing "…SCM above that typically used for normal construction"; it goes on to define "above" as > 30% FA,
- a conservative approach to durability in which a decreased W/CM (i.e., reduce by 0.05) is required for a particular exposure, and there are maximum W/CM limits with regard to potential carbonation exposure,
- increased curing requirements; the increase varies with the replacement level of FA, and
- the requirement for trial mixes to demonstrate appropriate concrete quality.

With regard to the need for increased early strength monitoring, CSA A23.1-00, Clause 17.6 outlines options for various types of tests, however, none specific for concrete containing FA. The early strength monitoring technology is well-developed and readily available commercially.

As discussed in Sections 4.2.3 and 4.4, it is difficult to apply a cost to the extra QC requirements in the proposed CSA A23.1, Clause 8.8. For the decreased W/CM, there would not be an increased cost of the concrete itself, because the HVFA concrete would have at least 10 L/m^3 less water, and this would compensate for the 0.05 reduction indicated above. The contractors contacted were not able to provide unit costs for the extra curing. Alternative bids have shown no premium; contractors advised that there was a premium but it was too small to be worth the special pricing.

6.1.5 Fly Ash Standards in Other Countries

Table 2 presents a comparison of the requirements for FA in various international Standards. The actual test procedures for a particular parameter may not be the same in all countries, but the purpose of Table 2 is to show whether there is or is not a requirement. The key distinctive features of the other Standards compared to CSA A3001 are:

- The EU Standards have a statistical approach to the acceptance of all parameters. It minimizes the number of properties tested, but increases the control on each.
- Some Standards put the responsibility on the owner (as does CSA A3001 to a degree) to specify the FA properties important for their purpose. This is particularly true for Australia. In the supply of FA for general use in ready-mixed concrete, this presents logistical problems because the FA in a silo cannot be segregated for a particular project.
- Some Standards do not recognize the Optional Requirement approach.
- Most Standards have uniformity requirements.

- Most Standards have a formal system for mill certificates.

Australia {15} has a unique approach to methods of demonstrating compliance (see Appendix E). It recognizes, at the mutual agreement of the owner and the FA supplier:

- statistical sampling to an approved plan by the FA supplier,
- FA producer's mill certificates,
- acceptance of the FA supplier's QC system, and/or
- other methods by mutual agreement.

Numerical values for the various properties are similar (see Table 2). Testing frequencies that are not stated in Table 2 are also similar.

It is apparent from Table 2 that the CSA A3001 requirements are amongst the least stringent in any country. From the ready-mixed concrete producer's perspective, the key properties of strength efficiency and uniformity are not well served.

7.0 Gap Between Current Standards and Those Required for HVFA Concrete and ECS

7.1 General

It was stated by a number of parties interviewed, including those concerned with the risk, that the existing Standards are adequate for conventional concrete, which, for purposes here is defined as that containing up to about 25% FA replacement.

It is recognized that the CSA Committees are cognizant of the need for additions / modifications to the Standards to address HVFA concrete, and that there are a number of proposals, including those outlined in this report, that are under consideration.

A fundamental decision must be made as to where responsibility lies. Table 2 shows examples of the onus being on the owner or user to specify any special FA properties necessary for their purposes. The FA or concrete producer must document that compliance. There are logistical problems here for the ready-mixed concrete producer, because they have only one FA silo and one product must fit all.

7.2 CSA A3001 for Cement

This Study did not specifically address QC of cement except as a comparison to FA. However, it was determined that QC by the cement producers is highly sophisticated, and is conducted at frequencies and parameters far in excess of the minimums in CSA A3001.

7.3 CSA A3001 for FA

The Standard does not have an impact on the day-to-day use of FA. It presents minimum values which are commonly exceeded by the FA producers, and (most of) their QC is based on much refined internal standards. If a plant were to produce a FA just meeting the minimums in CSA A3001, it would not be commercially acceptable. In interviews during this Study, no one raised issues with the Standard, because it is not a factor in the day-to-day use of FA in concrete.

CSA A3001 for FA is the least stringent of any of the international Standards examined. However, in defense of the Standard, those involved in its preparation (including those on the Panel – see Section 9.0) stated that they had removed tests that could not be correlated with the quality of the FA as used. An example was the removal of the test for alkali content and Pozzolanic Activity with lime.[17]

The basis of FA quality as supplied is certification by the FA producer. This is consistent with the international trend to performance Standards. There is no provision for 3rd party verification (although the owner can test if desired). Recommendations provided in Section 10.0 are based on this approach.

The test properties do not directly or effectively provide the information needed by the ready-mixed concrete producer, namely strength and uniformity (see Section 4.2). Therefore, there is a need to:

- provide uniformity requirements;
- define mill certificate requirements more clearly and address the problem of shipping FA before the tests are completed
- define test procedures that are meaningful for concrete strength, uniformity, and performance (durability aspects are adequately covered in the Standard).

The matter of test frequency was examined. There is no indication here that increasing that frequency would abate the risk.

7.4 CSA A23.1

Assuming that the provisions of the proposed CSA A23.1, Clause 8.8 (as well as those in proposed Clause 4.1.1.1.5) are implemented, the matter of appropriate mixture proportioning and curing is addressed. It is the Author's opinion that these are appropriately conservative.

There is the issue of the possible need for increased QC testing. It is premised on the assumption that the HVSCM concrete will have a higher degree of variation. The Author has found no data to support this premise, but industry believes it to be true (see Section 4.2.3.1).

The procedures for monitoring early age strength are presented in CSA A23.2. Requirements for uniformity of air content are covered in CSA 23.1. These existing Standards are adequate with respect to conventional and HVFA concrete.

8.0 Position of the Stakeholders with regard to Risk

The following summarizes the findings with regard to risk as perceived by the stakeholders.

8.1 FA Producers

The FA producers are not directly involved in the process of supplying FA, and have made a corporate decision to subcontract this to marketers. It is of course possible that some independent ready-mixed concrete producer would purchase FA directly from a power plant (this may exist in Saskatchewan), but the Author found no evidence of this occurring.

FA producers believe that monitoring the coal chemistry and sources, plus a small amount of basic QC testing, permits them to provide an acceptable quality and uniformity of FA (see Section 4.3.2).

[17] The Panel agreed that CSA A3001 had fewer properties tested, but stated that many of the properties tested by other countries were not meaningful on terms of FA quality, or alternately the particular test was not reproducible.

Their main interest is the sensitivity to disposing of a waste product in an environmentally responsible way. Some told the Author that they intend to get more directly involved with QC of FA for use as an SCM, but this has not occurred to date.

Therefore, the FA producers do not play a major part in the risk abatement. However, the Author has been made aware of a recent case where the quality of the FA shifted, resulting in drops in strengths of concrete from their traditional level. The FA still readily complied with the Standard. This change was not picked up by the normal QC tests by the FA producer, but was detected by the marketer in testing with their concrete. This points out a shortcoming of the QC and/or the tests conducted and/or the Standard.

The degree to which risk is controlled today is largely the result of the QC by the marketers. However, the FA producers do have risk as a supplier of a product, and could be leaders in the risk abatement process.

8.2 Designers

Designer's interest is largely driven by the Green Building or LEED™ interest of owners. They do not identify any particular risk but typically retain engineering specialists to assist in implementing the use of ECS on a project. Designers appreciate the potential for improved long-term properties and service life of the concrete.

The only risk element identified by designers is the need for extended curing. This is not a problem if the provisions of the proposed CSA A23.1, Clause 8.8 are implemented, but curing is notoriously ignored by contractors. One solution is to make curing a pay item in contracts.

Unfortunately, curing is also a risk to the ready-mixed concrete producer. This is because assessing in situ quality through testing of cores cannot differentiate the source of a quality deficiency (either the concrete as supplied or the curing process).

The Panel noted that there is also a risk to reinforced concrete in exposures conducive to carbonation. There has been premature deterioration of concrete in other parts of the world. The proposed CSA A23.1 addresses this.

8.3 Contractors

No significant risk elements were identified from the contractor's perspective. Differences between ECS and conventional concrete can be monitored and managed. There are risks of cost overruns if the contractor and the trades are not prepared for these differences. Orientation and training of the tradespeople is required {2}.

The interviews with contractors reported in Section 4.1.1 were with larger contractors who had successfully used ECS in projects. These contractors would be classed as relatively sophisticated in managing their concreting operations. Some members of the Panel disagreed with the above risk profile stating that:

- there is risk associated with uncertainty surrounding delayed strength gain, and
- the risk is magnified by cold temperatures – such temperatures are common throughout a significant part of the year in all regions of Canada.

8.4 Ready-Mixed Concrete Producers

The Study identified risks that are both real and perceived.

Perceived risks come from lack of familiarity with HVFA concrete and ECS, and these are understandable as a natural concern over the unknown. In areas where ECS has been used, there is not the same concern. In BC, where most of the EcoSmart case studies {2} have been conducted, there is not the same concern. In fact, 40% or higher FA replacement mixes are available as standard designs from some ready-mixed concrete producers.

There is a relevant analogy to the introduction of both superplasticizers and High Performance Concrete about 15 years ago. Initially, the ready-mixed concrete industry would not provide these on a performance basis, but today they are available in that form from virtually all ready-mixed concrete producers.

The industry correctly acknowledges that the risk is higher with the smaller concrete producers and for those without comprehensive QC programs. Ideally, CRMCA would like a system that could be used by all of its members.

The real risk is a change in the properties and/or uniformity of the FA that would not be detected by the existing QC methods of the FA supplier (see Section 8.1). Unfortunately, the ready-mixed concrete industry was not in a position to define the specifics of what they need in terms of the quality of the FA other than uniformity, strength potential, and stable air entrainment. From that definition, an appropriate QC program could be developed. It appears that such information has not been assembled; CIRCA indicated that it will be addressing this need.

The industry believes that the proposed changes to the methods of ordering concrete (see the proposed CSA A23.1, Table 5) will significantly reduce their liability. A discussion of those changes is beyond the scope of this Study, but if the industry is correct, then the problem is apparently largely solved. Presumably, the logic behind this perception is that the new requirements for concrete supply will force the ready-mixed concrete producers to improve their internal QC (including certification of operations), and allow them to reduce the amount of FA replacement to levels that are comfortable from a risk perspective. Such an approach is not in the interests of advancing the sustainability of concrete, but may partially address the risk element.

8.5 Cement Producers

The only cement producer position relevant is with regard to the production of blended cement. The cementing material then becomes a "controlled" product in the eyes of the ready-mixed concrete producers.

There are already blended cements available in Eastern Canada, with cement replacement by SCM in the order of 27%.

9.0 Results of Panel Review

Members of the Panel are identified in Table 1.

The result of the Panel's deliberations is presented in Appendix G, along with a summary by the Author. The process was enlightening. Responsible and constructive suggestions were made. Where appropriate, the Panel's suggestions are incorporated into the text. In a few cases, they differ from the Author's findings.

Many of the suggestions are beyond the scope of this report. However, they will be an excellent reference for future EcoSmart work.

Perhaps the most significant conclusion from the Panel's work is that risk in using ECS is much broader than that which EcoSmart envisioned when the Terms of Reference for this Study were developed. Leading from this is the fact, accepted by the Author, that simply increasing the amount of the current QC testing will not provide the desired risk abatement.

The Panel felt strongly that the draft report that they reviewed did not properly assess the constructability risks, despite the contractor's position in Section 4.1. It is acknowledged that the contractor position in Section 4.1 is based on relatively sophisticated contractors who have been through, and have mastered, the ECS learning process. It is, however, necessary to appreciate that there are constructability issues in addition to the materials issues that are the focus of this Study.

The Panel noted that the process of assessing the activation energy of a particular SCM needs to be standardized.

9.1 Quality Management

The Panel had a strong recommendation on the need for an umbrella quality management system (QMS) for the QC of FA (and other SCMs). This discussion was led by the FA producer. It is consistent with the total system recommendation by the contractor (see Section 4.1.3) and with the overall direction of industry to "objective-based" Standards.

The QMS would replace the current prescriptive specification approach in the Standards. The envisioned QMS process would include the following elements:

- a requirement that the designer use only performance-based specifications,
- the FA producer would be obligated to communicate changes in coal chemistry to the users (i.e., ready-mixed concrete producer), and be in a position to certify that the FA meets the Standard, including any uniformity requirements,
- the required prequalification data (see New York State Requirements for FA Qualification example in Appendix E),
- mill certificates more meaningful from the user's perspective,
- the ready-mixed concrete producer would have an effective QC program that would include testing of the FA in actual concrete mixes,
- the contractor would have a management system appropriate for the particular type of HVSCM concrete,
- overall clear definitions of responsibility.

10.0 Recommendations

10.1 From EcoSmart

Given that perceived risk for constructability with ECS is a matter of familiarity, EcoSmart should expand its case studies to other parts of Canada. This should be done using the successful model that to date has been predominantly BC-based. Ready-mixed concrete producers could be involved in this process, as they have been involved in BC. The Panel strongly supported this recommendation.

Included here should be increased awareness among specifiers so that unrealistic or high risk FA replacement levels are not specified in areas of Canada, or under conditions, where they are not appropriate. In this regard, the tenets of EcoSmart in Section 1.1 must be integrated.

The Guidelines that EcoSmart proposes to produce from this and other studies would be beneficial in this regard. Such Guidelines would address the:

- methods of risk control for contractors (see Section 8.3), and
- QC practices that should be undertaken by a ready-mixed concrete producer[18].

The Panel envisioned that these Guidelines would include checklists for each of the above stakeholders.

It is evident that awareness may be more important than Standards.[19]

10.2 Standards

10.2.1 CSA A23.1

It should be recognized that, over the years, CSA A23.1 has introduced new technologies to the Canadian concrete industry by using a series of notes and guidelines in the Standard. Mandatory requirements are initially introduced in a conservative form, then, as they develop in the industry, they are refined and made more cost effective. Continuing this approach is strongly recommended here.

Risk can be abated by:

1. Requiring mandatory 56- (or possibly 91-) day strength acceptance for the 1 or 2 Classes of HVSCM concrete in the proposed CSA A23.1, Clause 8.8 (this is already recognized for other types of concrete in the current CSA A23.1, Clause 17.6.4.3.2).
2. Increasing the frequency of testing in CSA A23.1-00, Clause 17. Doubling the frequency is an option. The Panel did not support this approach claiming that tests more representative of the critical properties rather than more of the same tests are required. Unfortunately these more representative tests are not readily available for routine QC today.
3. Increasing the Factor of Safety in ECS mixture proportioning. The requirements in CSA A23.1-00, Clause 17.6.7.1 are:

$$f_{cr} = f_c' + 1.4\,s$$ [20]

where f_c' = the specified strength

[18] Protocols for QC that show the interrelationship and responsibility separation between the stakeholders, and outline the meaningful data required.

[19] Information here suggests that such QC would include, but not be limited to:

- qualification of materials, including their compatibility,
- correlation with mill certificates for the SCM,
- a pre-work meeting to discuss QC and constructability issues,
- conducting trial placements with a range of cementing materials factors,
- mix designs with an initial conservative cementing materials content for the specified strength, and
- increased initial QC site testing.

[20] The equation becomes $f_{cr} = f_c' + (2.4\,s - 3.5)$ if s exceeds 3.5 MPa.

f_{cr} = the required average strength to achieve the f_c'
s = the standard deviation
1.4 is a factor that assures no more than 1:10 test values < f_c'

In this system, the ready-mixed concrete producer's uniformity of strength production is determined by "*s*". The better the control, the lower can be the over-design factor. It would be easy to assign a higher Factor of Safety to the classes of HVSCM concrete in the proposed CSA A23.1, Clause 8.8, say 1:15 (1 in 15 tests low). The statistics are readily available and well recognized by ready-mixed concrete producers. However, it is noted that "*s*" is a measure of uniformity, and if the uniformity of HVSCM concrete is lower than regular concrete, then there is automatic compensation built into the above formula. Nevertheless, the use of an increased low-test acceptance factor would reduce the risk for the concrete producer, and therefore, would be desirable at least during the early stages of implementation of ECS at a particular plant.

Implementation of this recommendation would result in a small increase in the total cementing materials content of the resulting concrete.

10.2.2 CSA A3001 for FA

This Standard needs a review from two perspectives – firstly, to determine if the required tests are meaningful in controlling the quality of FA, and secondly, to determine if the situation is improved by increasing the frequency of tests. But first, the Committee must decide on the general approach. Table 2 provides some options from other countries.

The Author favours the Australian approach wherein there are specified limits for a few key properties, and then test procedures for others that the purchaser may want to include. There would then be uniformity requirements for the key properties. This would require major education of the designers, because simply specifying "…fly ash shall meet CSA A3000…" will not suffice. One benefit of this system is that the designer can focus on particular requirements for their project or concrete exposure such as ASR mitigation, shrinkage, or sulphate resistance.

Consideration should also be given to increasing the test frequency for those key properties only. It was noted by one reviewer that a common approach should be taken for all concrete.

As an extension to the Australian approach, consideration should be given to requiring at some frequency (perhaps annually), a complete set of tests of all parameters (mandatory and optional). In this case, important tests for HVFA concrete such as drying shrinkage and water demand should be included. This qualification report should be available to the designer on request. The test values of the key properties then form the basis of assigned uniformity values.

At a minimum, the Standard should consider the following:

1. Include uniformity requirements for key properties. One obvious choice is fineness. The mechanics for establishing uniformity limits are available in ASTM C1451.
2. Provide detailed guidelines / requirements for the mill certificates. Address the responsibility if the FA is used before the certificate is available.
3. Add alkali limits. There are procedures in use for this test (see Table 2). However, the challenge will be to assign limits, particularly considering that it is the combination of high alkalis and sulphates that is critical.
4. Provide alternate and/or more meaningful tests for:

- fineness[21], and
- carbon content.

Such tests are in use elsewhere, including some plants in Canada, and are not highly sophisticated, so they could be readily introduced to the current test matrix.

5. Where appropriate in the preparation of test mixes, require the replacement of cement with FA to match the requirements of the project.
6. Establish detailed requirements for the qualification of FA. The new Appendix D of CSA A3001-03, or modifications thereof, should be a base.

It is evident that there is currently is no test for the strength potential of the FA that can be correlated with concrete strength. An actual test in concrete (as is being used by some marketers –see also Section 4.2.3) should be introduced.

EcoSmart has already made a submission to CSA A3001 (see copy in Appendix B) presenting some preliminary thoughts on revisions to the Standards and related concepts. It is expected that the results of this Study will permit the submission of further details.

10.3 Ready-Mixed Concrete Producers

Ready-Mixed Concrete Associations should discourage their members from supplying HVFA concrete or ECS if they do not have comprehensive QC of both the FA itself and the concrete that they produce with it. This is a commercial decision and is the most fundamental part of risk abatement.

Ready-mixed concrete producers should be aware that the risk is higher in high W/CM concrete, such as residential concrete which represents about 40% of the total concrete produced {1}.

As indicated in Section 10.1, there is an important role for the Ready-Mixed Concrete Associations in the education process. Given that much of the world is successfully using large SCM replacements of cement in concrete, it would be constructive if the Ready-Mixed Concrete Associations in Canada were proactive in implementing sustainable concrete in this country. They have indicated their interest in doing so.

10.4 Fly Ash Producers

Although not demonstrated to date, the FA producers could be proactive in establishing effective QC procedures. They have the ability internally to provide a more comprehensive assessment of their FA quality and uniformity. They could also sponsor related research on new or improved test methods.

10.5 Contractors

This Study has determined that there is no risk to the contractors that cannot be managed with today's technology. For the more sophisticated contractors, the process has already been developed. Others would benefit from the Guidelines that EcoSmart will be producing.

10.6 Designers

It is necessary to educate designers so that they specify reasonable requirements for sustainable concrete. Currently there are a number of designers who have this ability but many who do not. This can be rectified by guide specifications in the EcoSmart Guidelines.

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[21] Malhotra and Mehta {6} state that "Typically, the pozzolanic activity of a fly ash is proportional to the amount of particles under 10um, whereas particles larger than 45 µm show a little or no pozzolanic property."

10.7 Stakeholders Generally – Quality Management

Those interviewed and those on the Review Panel made a strong case for the development of a new approach to QC of ECS (see Section 9.0). Such an approach would be a total quality management system, presumably patterned on ISO 9001. In the ISO system, all stakeholders have a voice and have input in the process. If properly developed, this QMS would supplant the current prescriptive specification approach.

It is recommended that the stakeholder industry get together to develop the QMS. The venue for such a development would logically be CSA, who have considerable knowledge of the mechanics of quality management. CSA would require a commitment from industry to both fund the development of the QMS (it may come out initially as a "guideline"), and to subsequently implement it. A certification process is possible.

Leadership, and the bulk of the funding, would logically come from the FA producers, perhaps through CIRCA. This would be a demonstration by the producers that they are truly committed to the quality management of their product.

11.0 Discussion

Following is a discussion of the approach that was used to develop the above recommendations.

- There needs to be more education of the industry on the management of the differences between ECS and conventional concrete. Both EcoSmart and the industry can contribute to raising this awareness. Part of this process is already planned. The ready-mixed concrete producers, as an industry, should decide if they want to be part of the problem or the solution. Some members are already major contributors to the solution.
- For the QC of ECS, the approach should be an expansion of concept in the proposed CSA A23.1, Clause 8.8, in which special and conservative requirements for the concrete are introduced. These will simply be extensions of the current requirements and will not be difficult to implement.
- The needs of the ready-mixed concrete producers are fundamentally uniformity and high strength potential from the FA, as discussed in Section 4.2. Uniformity can be achieved by introducing appropriate requirements in the Standard. In the Author's opinion, this is a critical component. Similar requirements exist elsewhere. What this Study has failed to do is identify an existing test procedure – the "silver bullet" – that would effectively monitor strength potential. There is still a risk that FA could be produced meeting Standards, including the revisions to Standards suggested here, and would not provide adequate strength potential. Such a test will have to be developed, but fortunately a base already exists in the internal QC by some of the marketers.

This Study identifies a number of changes that will be necessary to abate the risk to the ready-mixed concrete producer. The question that has to be asked is whether they will be sufficient to bring that risk to a manageable level? These changes will not be sufficient if the industry does not support their implementation. Changes to CSA A23.1 are a positive step in that direction.

The key to developing the quality management system described in Section 10.7 is leadership by the FA producers. This requires that they both recognize the value of their product to sustainability and the impact of variations on the ready-mixed concrete industry's product.

Readers should appreciate that ECS discussed here is not a new technology. It has been an element of many projects, including the EcoSmart case studies {2}. For the most part, these projects were "engineered" as described in Section 4.2.1. Similar practices should be applied to the development of ECS in the market. With variations these practices should include:

- Hold pre-work meetings with all stakeholders to encourage co-operation and explain differences in the concrete. Assure that responsibilities are understood.
- Prepare mixture proportions that take advantage of the positive features of ECS.
- Do pre-qualification trial mixes as required by the proposed CSA A23.1. Assure compatibility of the proposed materials.
- Do "orientation" pours with the initial project concrete – involve the placing and finishing crews.
- Increase testing for the initial work. Communicate results to the ready-mixed concrete producer.
- Cure the concrete.
- Recognize the contributions of the stakeholders at the end of the work.

Eventually, the market will mature as has happened with other new concrete technologies, such as superplasticizers and High Performance Concrete.

Thought was given to recommending either that ECS should not be used in low strength concrete or that a minimum total cementing materials content for ECS should be required irrespective of the design strength. These are options, but the recommendations of "…don't use without proper QC…" is advanced as an alternate approach in this Study.

It is interesting to note that the use of SCMs, including FA, in blended cement produced at a cement plant solves the concern of industry that "…cement is manufactured, FA is not…" by applying cement production QC to the product.

It is the position of the Author that ECS should not be considered for use with poor and non-compliant concreting practices. Rather, ECS should be developed to improve the standard of concrete construction.

12.0 Costs

Industry was understandably reluctant to provide cost information because they are of a commercial nature. Some costs available to the Author are recorded in the text. For examples, see Section 4.1.4.

Implementation of the recommendations made in this study will obviously increase the cost of QC of both the FA itself and the concrete produced from it. However, to compensate for at least some of that, the market for FA will increase, and the risk will decrease. These increases are not expected to be large, and if they reduce risk, as is expected, perhaps there will be cost savings.

The Review Panel cautioned that it is the total cost to all stakeholders that must be assessed. A Contractor on the Panel counseled that it is too early in the evolution of, and comfort with ECS to provide costs. When ECS becomes mainstream, market-based pricing will become competitive.

13.0 Acknowledgements

A large number of individuals and firms contributed to this Study – those interviewed and those who provided sources of information. Industry representatives contacted were open and responsible with the requested information. At the unintentional risk of downplaying these contributions, the Author wishes to acknowledge the specific contribution of:

- Professor Kenji Sakata and his colleagues in Japan who provided the required information from that source,
- The Review Panel (see Table 1) who provided enlightened and responsible comments and steered the direction of the findings in this report to a higher and broader level than originally anticipated by EcoSmart, and
- Maggie Wojtarowicz, M.A.Sc., E.I.T., of EcoSmart, for the diligent review and editing of the text.

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14.2 Standards Referenced

7. CSA A23.1. *"Concrete Materials and Methods of Concrete Construction"*, 2000 and 2003 (draft).
8. CSA A3000. *"Cementitious Materials Compendium"*, 1982, 1986(R1992), 1998, and 2003. Includes subsections A3001 *"Cementitious Materials for Use in Concrete"* and A3004 *"Physical Test Methods for Cementitious Materials for Use in Concrete and Masonry"*.
9. CSA A438. *"Concrete Construction for Housing and Small Buildings"*, 2000.
10. CSA A23.3-27A. *"Standard Practice to Identify Degree of Alkali-Reactivity of Aggregates and to Identify Measures to Avoid Deleterious Expansion in Concrete"*, 2000.

11. ASTM C618. *“Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Concrete”*, 2000.

12. ASTM C917. *“Standard Test Method for Evaluation of Cement Strength Uniformity From a Single Source”*, 1998.

13. ASTM C1451. *“Standard Practice for Determining Uniformity of Ingredients of Concrete From a Single Source”*, 1999.

14. JSCE No. 36. *“Recommendation for Construction of Concrete Containing fly Ash as a Mineral Admixture”*, December 2000.

15. AS 3582.1. *“Supplementary Cementitious Materials for Use with Portland and Blended Cement, Part 1: Fly Ash”*, 1998.

16. IS 3812. *"Specification for Fly Ash for Use as Pozzolans and Admixtures"*, 1999.

17. BS EN 450. *"Fly Ash for Concrete – Definitions, Requirements and Quality Control”*, 1995.

Appendix A: Methodology of Risk Abatement Study

Excerpt from:

Review of Fly Ash Quality Requirements
and Control of EcoSmart™ Concrete Quality
– Risk Abatement

Report Outline – Draft

4. Methodology

4.1 General

- Identify the source of concerns that lead to this study
- Analyze the current standards, their application, and construction practices
- Identify shortcomings of current standards and practices in ensuring the highest quality of fly ash concrete
- Recommend solutions to overcoming these shortcomings
- Utilize the following resources (information and people's experiences) and process (consultation and collaboration) (see also Organisational Chart):

4.2 Detailed

- Review the traditional usage levels of FA and current leading edge usage levels as targeted by EcoSmart. Compare FA usage levels for which Standards exist with traditional and current usage levels.
- Investigate technical facts of the 1986 Ontario Basements Case in the context of standards and construction practices "of the day". Review Case files and literature, and interview experts. Compare the Ontario Case with other cases in this timeframe and with recent cases.
- Review the context of current Standards for Portland cement, FA, concrete, and construction practices. Determine to what level of cement replacement by SCM the current controls are appropriate.
- Define current FA QC as required by Standards, and as practiced by the FA suppliers. Compare the approach to QC for FA with those for cement. Include an assessment of the frequency of QC testing for both FA and cement.
- Define the uniformity of Portland cement and FA as currently supplied to the market.
- Define to what level typical Portland cement and FA properties currently exceed Standards. Compare industry standards to required Standards.
- Define current QC of concrete and construction practices, as required by Standards and as practiced by industry.
- Indicate the relevance and appropriateness of the various QC procedures to the production of quality concrete, and in particular, of quality EcoSmart concrete. Consider the influence of Standards and of the quality of cementing materials and construction practices. Determine if the current Standards are sufficiently stringent.
- Determine if there is a gap between what the users (typically ready-mixed concrete suppliers but also precast, dry-bag and other users) would like and what is available in terms of QC data from the supplier.
- Define the critical quality parameters necessary to assure uniformity of performance of concrete containing FA in the field. Extend this to include EcoSmart concrete.

- Define which construction practices are influenced the most by the quality of fly ash and concrete.
- Review the cost of current QC measures, and compare with the cost of insufficient QC measures. Estimate the cost of additional QC measures required to mitigate risk and potential liability.
- Recommend what additional testing and/or standards are required to advance the user's confidence in the quality of FA and reduce risks and liability.
- Consult with Standards organizations (CSA, ASTM, ACI, etc.) to determine the process and need for changing current standards.

4.3 Process

4.3.1 Research and Data Collection

4.3.1.1 Lafarge Files

- Examine technical data in the Lafarge files regarding the 1986 Ontario Basements Case
- Consider quality control procedures, quality of fly ash used, quality of construction methods

4.3.1.2 CANMET

- Examine procedures used at CANMET

4.3.1.3 Literature

4.3.2 Consultation with Experts

- Consult Portland cement/fly ash/cement/concrete industry to determine the procedures quality control currently follows for both fly ash (compared with Portland cement) and concrete production

4.3.2.1 Consultation with Standards Organizations

- Consult CSA, ASTM, ACI, etc. to determine the process of changing standards such that the recommendations made in the study are in sink with the standards development process, and that these recommendations to amend standards will be implemented
- Consult the standards organizations to determine the history and rationale of the development of the current standards

4.3.3 Progress Meetings

- Incorporate input from various stakeholders, including EcoSmart Steering Committee, cement/concrete industry, fly ash producers, standards organizations, and the design community (engineers and architects), that will be discussed during regularly scheduled progress meetings

Appendix B: EcoSmart Interface with Industry

B-1. CSA A23.1 – Public Review Comment on Draft Standard
B-2. CSA A3001 – Recommendations for 2003 Edition
B-3. Interview Questions to Industry Associations
B-4. Excerpt from APRMCA Newsletter

EcoSmart™ Concrete Project
A Concrete Contribution to the Environment™

504 – 999 Canada Place, Vancouver, BC, Canada V6C 3E1 Tel: (604) 775-6217 Fax: (604) 666-8123 Email: information@ecosmart.ca

Ms. Cecilia Vega
Canadian Standards Association
5060 Spectrum Way, Suite 100
Mississauga, Ontario, L4W 5N6
Submitted by Email: cecilia.vega@csa.ca

January 7, 2004

Dear Ms. Vega:

RE: EcoSmart Public Review Comment on the Draft Standard A23.1

EcoSmart is pleased to submit the following comments to the Canadian Standards Association regarding the current Draft Standard A23.1.

In line with EcoSmart's objective to minimize the greenhouse gas (GHG) signature of concrete by optimising the replacement of Portland cement with supplementary cementing materials (SCM), we would like to express our support for the CSA in developing a Standard on concrete made with a high-volume of supplementary cementing materials (HVSCM) in Clause 8.8. The following comments are based on the experience gained by EcoSmart through numerous case studies, applied research studies, and collaboration with industry to resolve some of the potential problems with using HVSCM concrete.

Clause 8.8.1.3 – Exposure to Deicing Salts and Freezing and Thawing

The proposed Clause 8.8.1.3 does not limit the SCM content that is acceptable for Exposure Classes C-XL, C1 and C2 (Table 1), as recommended by NRCan/CANMET, or as discussed in Annex XXX. NRCan/CANMET recommends limiting the use of fly ash to 25% for flatwork concrete exposed to deicing salts and freezing and thawing. Annex XXX indicates that a review of published results points to 30% fly ash level being an acceptable limit for scaling resistance. However, since Annexes are not mandatory parts of the Standard, the discussion in Annex XXX does not actually limit the FA content in the Standard for these Exposure Classes. EcoSmart is not aware of a limit for slag use under these conditions, although is aware that there may be similar scaling resistance issues. Therefore, we propose adding the following to Clause 8.8.1.3:

"…*and if the concrete is a flatwork that is also exposed to chlorides (i.e., Classes C-XL, C1, and C2 in Table 1), the fly ash content shall be limited to 25% in the interest of reducing the risk of scaling*."

Furthermore, the reduction of the maximum water to cementing materials ratio of the concrete by 0.05 for HVSCM-1 is presumably related to higher susceptibility to scaling and greater sensitivity to proper curing of HVSCM concrete mixes. With de-icing salt scaling, for example, being potentially a problem at fly ash replacement levels above 25-30%, we suggest that the W/CM reduction be extended to HVSCM-2.

Clause 8.8.1.4 – Requirements for Reinforced Concrete

The latter half of Clause 8.8.1.4 should read:

"…*shall* not be greater than 0.40 for HVSCM-1 concrete and not greater than 0.45 for HVSCM-*2* concrete."

Table 5 – Alternative Methods for Specifying Concrete

EcoSmart supports simplifying the Standard, and clarifying the roles and responsibilities for specifying, supplying, placing, finishing, and curing the concrete (Table 5), thus, working towards mitigating the risk of producing poor quality concrete. We suggest a couple of improvements to assist the implementation of the proposed changes.

While industry certification programs are one way to increase the quality control on concrete, none of the existing industry certification programs as listed in the Note to Table 5 are designed to ensure adequate supplier knowledge of less conventional concretes, such as High Performance Concrete – Clause 8.2, Self Consolidating Concrete – Clause 8.6, and Concrete Made with a High Volume of Supplementary Cementing Materials – Clause 8.8. With the proposed changes to the Performance Method of specifying concrete, particularly with respect to the type of information that the supplier shall provide (e.g., certification of compliance with performance criteria specified), the supplier certification programs must be adequately designed to cover the less conventional concretes. Therefore, we propose that the Note to Table 5 specifically request this type of certification, with the following (or similar) wording:

"*When requesting High Performance Concrete – Clause 8.2, Self Consolidating Concrete – Clause 8.6, or Concrete Made with a High Volume of Supplementary Cementing Materials – Clause 8.8, the Owner may accept concrete industry certification programs that are specifically designed to ensure adequate knowledge of the supplier to design, produce and deliver these types of concrete.*"

Table 5 and Annex XX – What is Performance?

We suggest that the Standard needs to include a definition of environmental/sustainability performance of concrete, particularly as it relates to the production of concrete (i.e., choice of materials, design of concrete mixtures, and construction practices). How does the Standard capture the performance criteria of reduced GHG emissions, for example? The one "measurable term" (p. 178) for GHG emissions reduction is the cement content of a concrete mixture, however, the performance-based alternative to specifying concrete does not allow the Owner to specify and independently verify this. Annex XX, which serves as a guide for facilitating the performance approach, does not define a measurable term for the performance of concrete in terms of GHG emissions – an increasingly important performance characteristic of concrete to the Owner. To verify that this performance criteria is met, the concrete supplier would have to either provide the concrete mix designs, that include the cement content, or in some other way be able to verify the GHG signature of the concrete. The latter would require a GHG labelling program for concrete.

With the rapid induction of the LEED™ system in Canada for rating the environmental performance of buildings, and with an increasing number of building projects requiring LEED certification, there is also a growing need for verification of the GHG signature and the recycled content of concrete. Without a provision for documentation of these quantities, there is a danger that the concrete industry may lose some of its market share to the steel industry, which readily provides this information for steel. We propose inserting the following definition as item (f) under Hardened State section on page 179 (note: it is being proposed that this item be inserted as item (f) in keeping with the order of performance parameters listed in item (c) of Table 5, of the criteria that the Owner shall specify using the Performance Method):

"*(f) Sustainability aspect in terms of the greenhouse gas (GHG) signature, recycled material content of concrete, and longevity (i.e., limitations, such as the minimum and/or maximum, on the embodied GHG emissions, recycled material content, and service life); this includes choice of materials, design of concrete mixtures, and construction practices.*"

Annex XX – Roles and Responsibilities

In the section on Concrete Supplier, we suggest adding the following:

"*Nothing in this Standard exempts the concrete supplier from proving the mix designs and information on concrete ingredients, if this information is required by the Owner or the Design Authority as verification that the performance requirements have been met.*"

Annex XX – Selecting an Alternative

We suggest that non-certified, ISO-like programs are not effective in achieving the required quality of concrete, because certification and regular auditing by a certified third party is an integral part of the system. If an ISO approach is used, then ISO certification should be required.

Annex XXX – Explanation of Clause 8.7.1 – General (NOTE: Clause numbering to be corrected.)

We suggests including a reference to the field implementation work done with HVSCM concrete via the EcoSmart Project, and propose adding the following wording to the first paragraph, following the Malhotra and Mehta reference:

"*The EcoSmart Project, supported by the Federal Government of Canada, has produced more than a dozen case studies where HVSCM concrete has been used on actual construction projects. [EcoSmart Project, www.ecosmart.ca.]*"

Also in this paragraph, the reference to LEED™ in the statement "However, there has recently been increased economic and environmental incentives (e.g. LEED™) to use these materials, especially fly ash…at higher levels…" is not entirely true, since the current LEED™ system actually does not give any incentive to use SCM at any level. Presently, a proposal developed by EcoSmart to include such an incentive is in the process of being accepted by the Canada and the US Green Building Councils, and the reference to LEED™ in this statement should not be included until the EcoSmart proposal is actually accepted and incorporated into LEED™.

Annex XXX – Explanation of Clause 8.7.5 Trial Mixes

Item (c) under the "HVSCM mixtures, if optimized, will:" phrase needs to be qualified, in that the total CM content needs to be increased ONLY if high early strength is required, or if equivalent strength is required at 28 days. If the early strength is not an issue, and the strength acceptance age is increased to 56 or 90 days, then total CM content can remain the same, or can be lowered. We propose the following alternate wording for item (c):

"(c) A higher total mass of cementing materials than the comparable plain Hydraulic cement mixture for a particular strength *up to the strength acceptance age of 28 days. For strength acceptance age longer than 28 days, for example, 56 or 90 days, HVSCM mixtures may have a total mass of cementing materials equivalent or lower than the comparable plain Hydraulic cement mixture for a particular strength.*"

In the last paragraph of the Trial Mixes Section, we propose revising the statement "In general mixes should be proportional to achieve the original setting times and early strengths required" to:

"*In general, mixes should be proportioned to achieve the setting times and strengths required for a particular application, i.e., applications may require high early strength, or may require high ultimate strengths without necessarily requiring high early strengths.*"

Also in the last paragraph of this section, the issue of required high early strengths may be addressed in several ways where HVSCM is being used. We propose revising the statement "For mixes where a early strength is required, HVSCM may not be appropriate" to:

"*When properly proportioned and cured, HVSCM concrete can be made to achieve sufficient early strengths. For instance, a lower W/CM with appropriate curing, or specifying a higher ultimate strength (e.g., 40 MPa instead of 35 MPa) may result in sufficient early strengths.*"

Annex XXX – Explanation of Clause 8.7.6 (Curing Requirements)

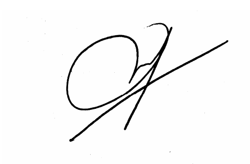
We suggest adding the following after the first paragraph:

"*One tool that the Owner may find useful, which has been successfully used by others, is to require that the curing process be a separate cost item in the contract, in order to assure that the Contractor is aware of the critical nature of the curing. This tool applies equally well to all concrete of the critical exposure Classes C, F, A and S.*"

EcoSmart would appreciate a response to how the CSA plans to address the issues raised above. We would be pleased to provide additional information, if required.

Thank you for considering our input.

Sincerely,



Michel de Spot, P.Eng.
EcoSmart Chair

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Benoit Fournier
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Chair, CSA A3000 Sub-Committee on SCM
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November 7, 2003

Dear Benoit:

Re: Direction of CSA A3001.3 With Regard to Requirements for Fly Ash as an SCM

You are aware that EcoSmart has been reviewing the requirements of the new A3001.3 with regard to its impact on, and relevance to the use of higher volumes of fly ash replacement for cement in concrete. In view of the upcoming A3000 planning meeting, EcoSmart wishes to share the following thoughts with your Committee with the intent of determining your interest in the items below and possibly receiving from A3000 direction on how you wish to proceed on some or all of those items.

The EcoSmart activity here arises from our Risk Abatement Study (RAS) – see below. This Study is not complete, but there is sufficient information on some items such that we can share these comments and suggestions with the Committee. This is intended as an opportunity to both open dialogue between EcoSmart and A3000 and identify those requirements for fly ash in the Standard that require further consideration, rather than as an in-depth submission.

The EcoSmart Steering Committee has reviewed the above outline. One Member asked for greater emphasis on determination of the glass phases in the fly ash. He also points out that "The industry still cannot measure the variables leading to an understanding of strength gain characteristics. We know for example, when comparing fly ashes with similar chemistry and Pozzolanic Activity Index, there may be significantly different performances at high cement replacement percentages, when measuring 56 day strength in concrete." The RAS will need to address these along with the other industry concerns raised to EcoSmart thus far.

Phil Seabrook, Director of RAS, expects to be in Toronto on Nov. 14 and would be prepared to participate in discussions if you considered that appropriate.

The EcoSmart RAS

This Study was developed from a submission to EcoSmart from the fly ash user community, particularly the ready-mixed concrete producers, that the use of the higher amounts of cement replacements with fly ash results in increased risk to the producer. They were comfortable that the existing CSA Standards were appropriate for the conventional replacement levels in the order of 25%, but were of the opinion that they would not be adequate for the replacement levels advocated by EcoSmart. In addition, the nature of the resulting risk could not be well defined.

The Terms of Reference for the Study is attached.

The portion of the Study related to the A3000 Standard has taken the form of:
- a review of the new A3001;
- consideration of the approach in Standards from other countries; and
- interviews with fly ash producers, marketers, and ready-mixed concrete producers and users.

It is expected that the results of the Study will produce, amongst other things, recommendations for changes to quality control procedures to reduce the risk. These procedures will apply to:
- fly ash as a product;
- ready-mixed concrete; and
- construction practices.

The industry feels that the "specifier" should also be added to the list although not in the form of QC. Some of this has already been addressed in the draft clauses of 27.7 in A23.1. For purposes here, the first bullet above is of primary interest.

Review of A3000.1

If one were to specify (as is commonly done) that "…fly ash shall meet CSA A3001…", one would be assured that it would have been tested for:
- chemically – LOI and SO_3;
- physically – 45um and autoclave expansion;

at the frequencies in A3004.A1. One could also specify the Optional tests, although that is seldom done.

Is required that the fly ash supplier "...shall ensure that the product complies…"; however, the process for that is not defined. One could request a test certificate, which the supplier has to provide within 8 weeks, and we believe that many users receive these certificates. Interestingly, some certificates that have been made available to us do not comply with the Standard with regard to product identification – see 5.5 and 5.8 of A3004-A1.

From a quality perspective, the above tests have little to do with the performance of the fly ash in concrete as required by the user as discussed below. Some protection with regard to durability is afforded. Obviously the Optional requirements are necessary to get meaningful data on the product's potential performance in concrete. Fortunately, most fly ash producers do some of the Optional tests.

If the SO_3 exceeds 5.0%, the sulphate expansion test is required, but that is conducted at only a 20% fly ash replacement level.

The only requirement for uniformity is the Optional Uniformity of Air Entraining Admixture test.

Annex D presents an excellent outline of the process to qualify alternative cementing materials. The obvious question is: why would this not be applied also to new fly ash sources (such as those without 5 years of field performance)?

Preliminary Study Findings

1] Nature of the risk

The ready-mixed concrete producers have had difficulty defining details of the risk that they perceive, except to say that their liability for the quality of the concrete is increased with the higher replacement levels. However, it was determined that there was a legitimate concern that specifiers would ask for high fly ash replacements in areas of Canada in which the quality of the fly ash available was not appropriate.

The statement is made by some that, while cement is a manufactured product, fly ash is a by-product. Related to that is a major difference in quality requirements between cement and fly ash. The use of blended cement obviously solves this concern.

There is a statistical increase in the variation of a particular mix corresponding to the variation of an additional material (high volumes of fly ash here). In cases where the fly ash has larger LOI values, there is a risk of negative impact on air entrainment if the LOI fluctuates.

Finally there is the possibility of fly ash being supplied that just meets the minimum requirements of a particular property in A3001, while the common practice performance of that property is much higher. Reductions in the performance of the user's traditional mixture proportions could then result. The major property of concern here is strength, which is (indirectly) assessed by the PAI.

2] Review of Standards for Fly Ash from Other Countries

2.1 India

The Indian Standard requires extensive chemical testing – (Fe_2O_3 +SiO_2+ Al_2O_3), MgO, SO_3, and SiO_2 separately, as well as LOI. They also have a test for alkali for use in cases where ASR is a risk. Physical testing includes Blaine fineness, PA lime and cement, drying shrinkage and autoclave expansion.

The product is "certified" by the manufacturer. Although it is not defined in their Standard, we are advised that the government requires a prequalification program, a 6-month uniformity evaluation, and Certificate of Compliance with the Standard from an independent tester (the Government) to accompany each shipment.

2.2 Australia

Australia has dropped the need for the autoclave expansion test because their fly ash has no periclase – this illustrates the process of adapting a Standard to the realities of the material. They also recognize the need to use a base form of cement in the tests that require cement. There are no uniformity requirements. Test frequencies are more time-based than based on the rate of production.

They have a process for permitting alternative test methods.

Australia permits 3 types of fly ash, fine, medium and coarse; the "medium" is closest to A3001 requirements.

The properties that are "reportable" are the usual LOI + 45um+ SO_3, and:

- alkali content;
- relative density;
- water demand;

- relative strength; and
- chloride ion content.

Certification of quality can be made in two modes – a 3rd party Certificate, or internal testing by the producer operating under an audited and registered QM program. A Standard form of test certificate is provided.

2.3 European Union

The EN 197-2, "Conformity Evaluation" is a complex QM process defining the roles of the manufacturer and the third party certification. There is an option to sell fly ash as a certified product (by 3rd party), or non-certified in which the ready-mixed concrete operator is required to conduct qualification tests.

They presently have a maximum 33% fly ash if used as an added material; if used in blended cement, you cannot count it as "K" factor (durability). A maximum 10% CaO is specified.

2.4 Japan

Japan recognizes 4 Types of fly ash; of these, only Type I and II would be of interest here. Their Standard, JSA 6201, requires the testing of:

- SiO_2;
- LOI;
- fineness by 45um <u>or</u> Blaine – uniformity limits are provided for fineness;
- flow;
- relative density; and
- PA with cement.

Reporting of results is via a certificate from the Manufacturer, which accompanies the shipment. All test properties are to be included in the certificate.

2.5 United States

As your Committee knows, ASTM C618 is similar to A3001, but there are these interesting differences:

- the invitation to add the Optional requirements is emphasized in the text;
- mandatory chemical requirements include the $\{SiO_2 + Al_2O_3 + Fe_2O_3\}$; there is no optional test for sulphate if SO_3 >5%;
- mandatory physical requirements, including PA with cement and uniformity controls based on the density and fineness parameters;
- Optional physical requirements include an LOI X 45um factor, alkali content for ASR exposure, and sulphate resistance where appropriate;
- recognition, at least in the autoclave expansion test, that the % replacement of fly ash for cement, in the particular concrete, being considered must be addressed in the test specimens.

It is EcoSmart's judgement that C618 is more focussed on the use of the fly ash in concrete than A3001. What is not clear in C618 is how the specific exposure determinations, for example sulphate, are controlled in the purchase of fly ash by the ready-mixed concrete user from the producer.

We are advised that the limit on alkali that was previously present in C618 was removed because the test was found to be meaningless.

3] Test Methods In Use

Ecosmart has identified the following tests that are being used elsewhere. We acknowledge that some are more research oriented and are not suitable for quality control or a Standard.

Test	Function	Comments
Methyleneblue Absorption	Analysis for carbon	Appears to sort activated carbon from other forms.
Blaine Fineness	Measures surface area of particles	Equipment readily available and in common use for fly ash by some. Much better than the single point 45um.
Glass Phases	Assesses reactive component of the ash	Only suitable for base classification.
Foam Index	Subjective measurement of amount of air-entraining agent needed	No standard available but used by some fly ash producers.
Concrete Mix Test	In use by some users who have developed their own standards	Addresses a fundamental requirement – see above.
Packing density	Indirect measure of fineness	
BTE	Total surface of ash particles	Expensive equipment.
XRD	Complete chemical spectrum including trace elements	In use by some fly ash producers. May be hard to define significance, if any, of the trace elements. Some of this may become necessary for environmental compliance.
Water Demand	Assesses the efficiency of the fly ash in terms of improving rheology of a (mortar) mix	Essential requirement for HVFA concrete. Without the reduction, you do not have efficient HVFA concrete.

4] Items for A3000's Consideration

4.1 Uniformity

It appears obvious that a control on uniformity is required. The problem is deciding what properties can be realistically assessed in this way and how that information would be of value to the ready-mixed concrete user. Cement strength uniformity is assessed in 4.6.3 of A3001, and ASTM C1415 provides an approach. Fineness and carbon content (not necessarily LOI) are possible choices but that leaves the critical matter of strength potential.

4.2 Chemical Properties

A more meaningful test for carbon is required – some options are in 4] above. XRD appears to be an obvious choice. Many users are switching to "autocontrol" as a chemical test option. See more in 5.6.

4.3 Timing of Tests

It is recognized that fly ash is often in concrete before some of the tests are completed. EcoSmart is aware of cases where the only post-delivery tests completed are LOI and 45um. This does not appear to protect the user. In countries where a certificate is required, this would not happen.

4.4 Tests in Concrete

There is a need to develop a meaningful strength test in concrete as indicated in 4] above. Technology and experience are available to create such a test. A “standard” cement is required.

4.5 % Fly Ash in Test Sample Preparation

Where appropriate, the % replacement should match the level of intended use. Admittedly, there are logistics problems here.

4.6 Carbon Content

Consideration should be given to a test to replace or supplement LOI that would identify those carbon forms that are significant in terms of use in concrete generally, and air entrainment specifically.

4.7 Alkali Content

It is clear that there needs to be a control on the total alkali content. Unfortunately, this is complicated by the fact that it is the sum (not necessarily the arithmetic sum) of the alkali + sulphate content that is important. We have not been able to define the required limits for this parameter except in a very general way. Additional research is needed.

4.8 Reporting

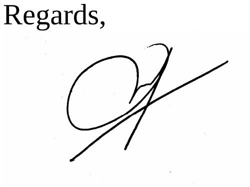
Consideration would have to be given to expanded reporting requirements by the fly ash producer. There is also the matter of timing / availability of the test results given that much of the fly ash used is in the forms before the test results are available. The question arising is: what properties need to be tested to be assured of no major negative impacts of the fly ash on concrete quality?

Possibly, a prequalification durability test could be defined in cases where the SO_3 + soluble alkali is greater than some level.

Thank you for considering EcoSmart’s suggestions. We recognize that there is a need to define the problem that one is attempting to solve before making changes for change’s sake.

We look forward to your direction.

Regards,



Michel de Spot, P.Eng.
Chair, EcoSmart™ Concrete Project

CC: Phil Seabrook, P.Eng., Phiz Engineering Ltd.

Attachments

EcoSmart™ Concrete Project
A Concrete Contribution to the Environment™

504 – 999 Canada Place, Vancouver, BC, Canada V6C 3E1 Tel: (604) 775-6217 Fax: (604) 666-8123 Email: information@ecosmart.ca

September 10, 2003

RE: Study of Risk Abatement in the Use of High Volumes of Fly Ash (HVFA) as Cement Replacements in Ready-Mix Concrete

Dear _____________:

You will be aware of EcoSmart's study into risk abatement for HVFA concrete. This study arose from a submission to EcoSmart™ by the concrete industry, particularly the ready-mixed sector, which identified increased risks associated with higher volumes of fly ash replacement. Further, industry advised that the existing CSA Standards, while appropriate for the current conventional replacements of +/- 20%, might not be suitable for HVFA.

In basic terms, the objective of our study is to:
- Identify the nature of those risks;
- Develop methods to abate the risks.

It is EcoSmart's intent to both make representation to CSA for changes to the Standards and to publish guidelines on effective practices for the use of this HVFA concrete. We hope to do so in concert with industry's desires as much as possible.

You are probably aware that CSA is considering a new Section to outline increased quality control procedures for higher volume SCM replacements. EcoSmart supports the direction of that draft but is concerned that it will not be sufficient for complete risk abatement.

The purpose of this communication is to solicit input from your Association. We will also contact other Associations and individual ready-mixed producers for input.

Risk can be abated by quality control. We see three components to that control:
1. By the fly ash producer;
2. By the user, in this case the ready-mixed supplier; and
3. At the construction site.

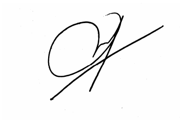
Our focus in this discussion will be on the second point, but we would appreciate any comments on the other components.

Attached is a list of topics that we wish to discuss. We appreciate that you will not have input on all of these and that some will not be relevant to your situation. Phil Seabrook is directing this study, and will call you in a few days to determine how you might provide input. You may choose to reply verbally or in a written form, or to assign this task to an individual Member who is knowledgeable about HVFA concrete. Please note, it is EcoSmart's practice not to identify the source of information provided other than to say "…. industry advises…".

On a separate but related matter, we would appreciate being advised as to what requirements there are for residential concrete in your area. You will be aware that CSA proposes to draw residential concrete back into A23.1 and we are considering how that will impact the use of SCMs in that concrete.

Thank you for your co-operation.

Regards,



Michel de Spot, P.Eng.
Chair, EcoSmart™ Concrete Project

Attachment:

EcoSmart RAS Study – Concrete Supply Aspects
Topics for Discussion with Producers

Fly Ash as a Product Supplied

- What QC information does the R/M get from the FA supplier? Do they get technical support?
- What do they do with that information? How is it integrated into their QC?
- What additional information would be useful?
- How do they address FA uniformity?
- Compare the QC on cements with that of FA.

Concrete Mix Designs for HVFA and Related Risk Matters

- What are the mix design adjustments required when HVFA is requested? Do they substitute kg/kg, and if so, up to what % replacement?
- Up to what level of FA replacement is the industry comfortable with the normal QC system? What would be required to increase these comfort levels?
- What additional risks accompany the production of HVFA? How might these be prevented or at least reduced?

QC at the R/M Plant

- What additional testing or other aspects of QC are done if the concrete is HVFA?

Review the Proposed Approach for A23.1

- What is the industry's reaction?
- What additional measures or requirements would be appropriate from the perspective of QC of the FA itself, both during R/M production and in the field?
- What problems, if any, will there be in complying with the Standard?
- If CSA goes to the complete performance Standard, what impact will this have on the use of HVFA concrete?

Reaction from Contractors

- What do the R/M producers hear from the placing and finishing trades when they supply HVFA?

Excerpt from APRMCA Newsletter

SCMs – what do you know about them?

Connely's Dura-Notes

By John Connely,
APRMCA Marketing Director

The environment continues to be in the forefront for Canada's ready mixed concrete industry. It seems this space in recent issues of the Ready Mix News was consumed in one way or another by the topic, and rightfully so. Few topics are as important to your personal and financial well-being as the environment. It figures into your daily lifestyle, the state of your business and its future, and the country's economic status.... and so on!

It's right that the environment remains a high priority. After all, we are the ones who messed it up, so shouldn't we now be responsible for the clean up? Or at least find methods to cope with our nasty state of affairs?

The Canadian Ready Mixed Concrete Association (CRMCA) is seeking to grab the attention of groups and organizations proposing or now working towards much higher supplementary cementing materials (SCM) replacement of cement in concrete than typically practical or constructible under current industry standards.

There are several key proponents for a greater use of SCMs in Canada. There's the Government of Canada via the department of Public Works and Government Services (PWGSC), which owns, operates and builds institutional facilities; and Natural Resources Canada through its mineral and metals branch and associated agencies; notably the International Centre for Sustainable Development of Cement and Concrete.

Additionally, organizations such as the EcoSmart™ Concrete Project out of Vancouver, B.C., which is funded primarily by government with some industry financial support, have as their purpose the creation and utilization of technology to support increased use of SCMs in concrete to reduce greenhouse gas (GHG). EcoSmart isn't a proprietary brand or a specific product formulation. EcoSmart is, "a government-industry partnership pledged to reduce the greenhouse gas signature of concrete by maximizing the replacement of portland cement in the concrete mix with supplementary cementing materials while maintaining or improving cost, performance and constructability."

If you're not entirely certain what is meant by the term supplementary cementing materials, "they are materials that when used with portland cement contribute to the properties of the hardened concrete through hydraulic or pozzolanic activity or both. Typical examples are fly ash, ground granulated blast furnace slag (GGBFS) and silica fume." (Source: Current Situation on the Production and Use of Supplementary Cementitious Materials (SCMs) in Concrete Construction in Canada — N. Bouzoubaâ, B. Fournier). High-volume supplementary cementing materials (HVSCM) concrete is concrete containing levels of SCM significantly above typical use levels for normal construction.

There's now a comfort level among ready mixed concrete producers, developed over the past 20 or so years, for SCM replacements in the range of 15 to 30 per cent. The concern now is regarding the concept for medium-volume (MVSCM – up to 30 to 45 per cent), and high-volume (HVSCM — 45 to 60 per cent) supplementary cementing materials being utilized in the cause of GHG reduction. A new CSA standard is just in the process of being developed, but in the absence of specifications based on accepted standards and practical experience, the fear is that confusion will lead to product or project failures and huge liabilities.

There are more than 1,000 ready mixed concrete facilities in Canada producing on the order of 25 million cubic metres of concrete annually. These operations are all small power houses of economic activity, important to the communities where they're located, and essential to the viability of local construction markets. The main market breakdown for ready mixed concrete are: residential (32.1 per cent), commercial-industrial-institutional (49.7 per cent), infrastructure (7.6 per cent), and other-special (10.6 per cent). Typical SCM replacements are 10 to 25 per cent for fly ash, 15 to 40 per cent for slag, and five to 12 per cent for silica fume (Source: Current Situation on the Production and Use of Supplementary Cementitious Materials (SCMs) in Concrete Construction in Canada — N. Bouzoubaâ, B. Fournier).

There are good reasons to use supplementary cementing materials, but it's preferable to optimize rather than maximize SCM replacement of cement powder. SCMs in the cement and concrete industries can be divided into three categories: engineering, economic and ecological benefits (Source: Malhotra and Mehta, 1996). The engineering benefits are to improve the workability and reduce water demand of the mix; to enhance ultimate strength, impermeability and durability; and to improve resistance to thermal cracking.

The economic perspective is based on portland cement being an expensive component of a concrete mixture, as it's a highly energy-intensive material to manufacture. Most SCMs are industrial by-products with little or no direct energy-related costs whose economic advantage may be reduced due to the transportation costs when sourced far from their point of use. Three of the four types of SCMs used are produced in Canada, namely fly ash, slag and silica fume, and all are in common use by the construction industry.

Ecological benefits are due to a savings in GHG emissions. Every tonne of portland cement produced causes the release of approximately the same amount of carbon dioxide into the environment. Therefore, for every quantity of portland cement replaced by SCMs, there's a saving of CO_2 by almost the same quantity. CRMCA members contend Canada would be much better served by encouraging greater usage of SCMs at today's commonly accepted "comfort zone" of 15 to 30 per cent in larger market areas, especially residential, rather than promoting HVSCM applications with many more limitations.

The CRMCA applauds the work being done for the promotion of SCM use in concrete. However, the apparent lack of attention by the proponents for the folks who ultimately manufacture and deliver the product, within the parameters of virtually any specification created, must change. Suppliers must be kept in the loop, but this doesn't seem to be the case.

There is a perceived, if not real, sense among members of CRMCA that its member associations were left out of the equation for the most part. The planning and implementation of this new SCM technology and appropriate standards can only achieve success when all the key partners are involved. In the end it's "our product" that's being modified. Consequently, the associated day-to-day problems and liabilities will inevitability land in the laps of ready mixed producers.

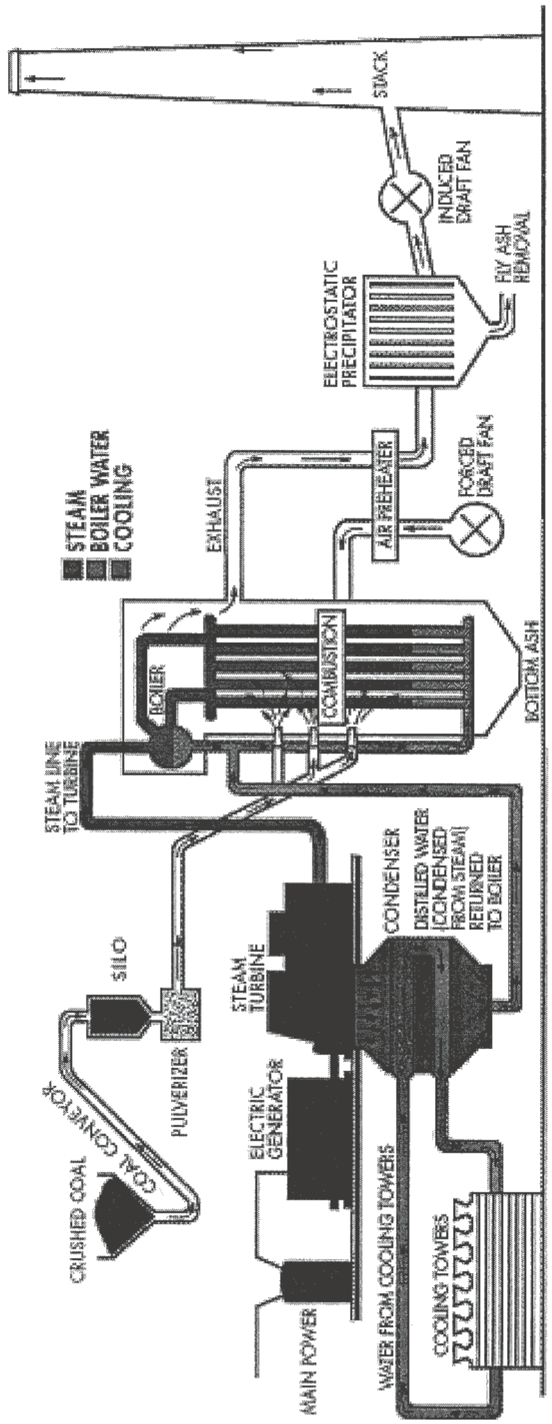
We need to be clear that we're very much in favour of new and improved technology. We have a keen interest in playing a role in bettering our environment through the use of SCMs. We think our input can be significant.

Most important, we welcome the opportunity to work with the many potential partners in our industry, to build better for the benefit of everyone. However, we expect to be consulted and listened to in the first instance, not after the fact. We aren't intransigent and inflexible, but rather we're experienced and reasonable. Our experience can be invaluable to the many players who may have less than full appreciation for the daily realities of the construction business.

Appendix C: Fly Ash Production in Canada

E-1. Schematic of a Typical Power Plant
E-2. Location of Potentially Useable Sources of SCMs for Use in Canada
E-3. Fly Ash Mill Certificates
E-4. Portland Cement Mill Certificate

Schematic of a Typical Power Plant



Location of Potentially Useable Sources of SCMs for Use in Canada

{Adopted from Bouzoubaâ, N. and Fournier, B. *"Current Situation of Supplementary Cementitious Materials (SCMs) in Canada"*, CANMET Report MTL 2003-4 (TR), Natural Resources Canada, Ottawa, April 2003.}

Fly Ash Mill Certificates

LAFARGE NORTH AMERICA

TYPE CI-CSA-A23.5

FLY ASH

Laboratory Test Report

Certification

The fly ash represented by this analysis complies with the current requirements of CSA A23.5 for Type CI Supplementary Cementing Material.
Material obtained for testing are silo and shipping samples.

Physical Analysis

	Limit	Actual
Fineness: Retained on 325:	34% max.	14.3%
Autoclave Expansion/Contraction:	0.8% max.	0.04%
Specific Gravity:		2.54
Chemical Analysis		
Loss on Ignition:	6.0% max.	0.33%
Calcium Oxide (CaO):	8-20%	14%
Sulphate Ion (SO3):	5.0% max.	1.7%

Reference Cement per CSA A23.5

	Limit	Actual
Compressive Strength - 28 day (MPa):	35 min.	42.7
Total Alkalis as Na2Oeq:	0.6-0.9%	0.72

CSA A23.5 Test Results

	Limit	Actual
Pozzolanic Activity Index: 28 day:	75% min.	103%
Compressive Strength (MPa): 28 Day:		44.1

The procedures in CSA A23.2-00 27A should be followed when using Supplementary Cementing Materials with potentially alkali reactive aggregate.

Signed: [signature]

Cementitious Quality Supervisor

Source: Northern
Month: July
Year: 2003

LAFARGE CANADA INC.
CEMENT GROUP/STONEY CREEK PLANT
360 Jones Road, Stoney Creek, Ontario L8E 5N2
Telephone: (905) 643-4101 Fax: (905) 643-2099

COMMERCIAL TESTING LABORATORIES

A DIVISION OF CTL/THOMPSON, INC.

CHEMICAL AND PHYSICAL ANALYSES OF FLY ASH

TICKET NUMBER: 2004 497 **Job Number:** 2004 **REPORT DATE:** 03/24/97

REPORT TO: Pozzolanic International
7525 S.E. 24th St.
Suite 630
Mercer Island , WA 98040

PLANT OF ORIGIN. Centralia
SAMPLE ID: 01-97 CAN
DOCKETS:

DATE SAMPLED: 01/24/97
DATE RECEIVED: 01/24/97

CHEMICAL COMPOSITION(%):

			CAN/CSA-A23.5-M86(1987) SPECIFICATIONS TYPE F
Silicon Dioxide	48.03		
Aluminum Oxide	28.08		
Iron Oxide	6.72		
Total		80.83	
Sulfur Trioxide		0.58	5.0 Max
Calcium Oxide		7.19	
Moisture Content		0.10	3.0 Max
Loss on Ignition		0.12	12.0 Max

PHYSICAL TEST RESULTS:

Fineness		
Retained on 45 um sieve, (%)	15.66	34 Max
Strength Activity Index		
With Portland Cement (%)		
Accelerated (7 days @ 65 C)	100.3	68 Min
ASTM C-311 (28 days @ 38 C)	88.	75 Min
Water Requirement, % of Control	93.4	
Soundness		
Autoclave Expansion (%)	-0.02	0.8 Max
Density (g/cc)	2.3	
Increase of Drying Shrinkage (%)		

COMMENTS:

COMMERCIAL TESTING LABORATORIES

By Orville R. Werner II, P.E.

COLORADO REGISTERED ORVILLE R. WERNER II 14540 PROFESSIONAL ENGINEER

32 UPAN STREET DENVER, COLORADO 80223 303 / 825-3207

This test report relates only to the items tested and shall not be reproduced, except in full, without written approval of Commercial Testing Laboratories.

COMMERCIAL TESTING LABORATORIES

A DIVISION OF CTL / THOMPSON, INC.

Chemical and Physical Analysis of Fly Ash

Developed For: *I.S.G. Resources*
950 Andover Park East
Tukwila, WA 98188

Ticket: *2574*	Plant of Origin: *Centralia US*	Sample Date Range: *11/25/2002*
Job: *9344*	Sample ID: *085-02*	to:
Report Date: *02/10/2003*	Docket: *8004012-8004082 -*	Date Received: *12/02/2002*

Chemical Composition (%)

			CSA-A23.5-98 Specifications Class F	CSA-A23.5-98 Specifications Class C1
Total Silica, Aluminum, Iron:	*80.6*			
Silicon Dioxide:		*50.7*		
Aluminum Oxide:		*21.9*		
Iron Oxide:		*8.0*		
Sulfur Trioxide:	*0.3*		5.0 Max	5.0 Max
Calcium Oxide:	*9.0*		8.0 Max	8.0 - 20.0
Moisture Content:	*0.1*		3.0 Max	3.0 Max
Loss on Ignition:	*0.2*		8.0 Max	6.0 Max

Physical Test Results

		CSA-A23.5-98 Specifications Class F	CSA-A23.5-98 Specifications Class C1
Fineness, Retained on #325 Sieve (%):	*27.6*	34 Max	34 Max
Strength Activity Index (%) ASTM C-311 (28 Days @ 23 C):	*89.7*	75 Min	75 Min
Water Requirement, % of Control:	*93.8*		
Soundness, Autoclave Expansion (%):	*-0.04*	0.8 Max	0.8 Max
Density:	*2.30*		

Comments:

Commercial Testing Laboratories

Orville R. Werner II, P.E.

COLORADO REGISTERED PROFESSIONAL ENGINEER ORVILLE R. WERNER II 14540 2/10/2003

22 LIPAN STREET DENVER, COLORADO 80223 303 / 825-0777

E-5. Portland Cement Mill Certificate

TILBURY

Tilbury Cement Limited
7777 Ross Road
Delta, British Columbia
Tel: (604) 946-0411
Fax: (604) 946-2420

Mailing Address:
P.O. Box 950
Delta, British Columbia
V4K 3S8

**AVERAGE CHEMICAL AND PHYSICAL CHARACTERISTICS
OF CSA TYPE 10 NORMAL PORTLAND CEMENT
PRODUCED AT TILBURY CEMENT, DELTA, B.C.**

Certificate No.:	L10-2	L10-3	L10-4	L10-5	L10-6
Dates Produced:	1997/03/02 1997/03/08	1997/03/09 1997/03/15	1997/03/16 1997/03/22	1997/03/24 1997/03/29	1997/03/30 1997/04/05
SiO2 (%)	20.4	20.4	20.6	20.5	20.4
Al2O3 (%)	4.8	4.7	4.8	4.7	4.7
Fe2O3 (%)	3.4	3.5	3.5	3.4	3.4
CaO (%)	64.6	64.6	64.4	64.7	64.6
MgO (%)	.8	.7	.8	.7	.8
SO3 (%)	2.88	2.81	2.82	2.83	2.82
Na2O (%)	0.29	0.27	0.28	0.27	0.24
K2O (%)	0.30	0.27	0.29	0.27	0.26
TiO2 (%)	0.23	0.24	0.24	0.23	0.24
C3S (%)	63	63	61	62	63
C2S (%)	11	11	13	12	11
C3A (%)	6.8	6.7	6.8	6.9	6.7
C4AF (%)	10.4	10.5	10.5	10.2	10.4
Total Alkalis (%)	0.48	0.45	0.47	0.45	0.41
Loss on Ignition (%)	2.32	2.31	2.28	2.37	2.39
Insoluble Residue (%)	.13	.23	.21	.08	.19
Free Calcium Oxide (%)	0.33	0.36	0.25	0.18	0.35
Blaine (m2/Kg)	411	409	[illegible]	398	400
+45 μ sieve (+325) (%)	2.7	2.2	2.2	2.3	2.2
Vicat Setting Time					
Initial (min)	115	122	127	140	130
Final (min)	222	230	236	251	239
Air Content of Mortar (%)	7.1	6.5	5.9	5.6	5.7
Soundness (%)	-0.03	-0.02	-0.03	-0.02	-0.05
Compressive Strength					
3 Days (MPa)	29.8	28.7	29.9	28.1	27.9
7 Days (MPa)	35.8	36.0	36.1	36.7	35.0
28 Days (MPa)	44.3	44.3	45.4	43.9	44.2

This will certify that the above described cement meets CSA Specificiations A5 for Type 10 Normal Portland Cement.

Plant Chemist Tom Gibson [signature] 6-May-1997

WORKING TOGETHER TO BUILD OUR COMMUNITIES

A CBR Company

LEHIGH
HEIDELBERGCEMENT Group

Lehigh Northwest Cement Limited
7777 Ross Road
Delta, British Columbia, V4G 1B8
P.O. Box 950, V4K 3S6
Tel: 604.946.0411
Fax: 604.946.9215

MILL TEST REPORT

Cement Type: **CSA Type 10**
Low Alkali Portland Cement

Plant: **Delta, BC**

Certificate #: D1-300

Production Period:	May 01 2003 May 31 2003	Test Result	CSA A5 Specification
SiO2 (%)	*CSA A456.1*	20.6	-
Al2O3 (%)	*CSA A456.1*	4.67	-
Fe2O3 (%)	*CSA A456.1*	3.71	-
CaO (%)	*CSA A456.1*	64.4	-
MgO (%)	*CSA A456.1*	0.72	*max. 5.0*
SO3 (%)	*CSA A456.1*	2.84	*max. 3.0*
Na2O (%)	*CSA A456.1*	0.30	-
K2O (%)	*CSA A456.1*	0.29	-
TiO2 (%)	*CSA A456.1*	0.25	-
C3S (%)	*ASTM C150*	61	-
C2S (%)	*ASTM C150*	13	-
C3A (%)	*CSA A456.1*	6.1	-
C4AF (%)	*ASTM C150*	11.3	-
Total Alkalis (%)	*CSA A456.1*	0.49	*max. 0.60*
Loss on Ignition (%)	*CSA A456.1*	2.41	*max. 3.0*
Insoluble Residue (%)	*CSA A456.1*	0.26	*max. 1.5*
Free Calcium Oxide (%)	*CSA A456.1*	0.32	-
Blaine Fineness (m2/kg)	*ASTM C204*	397	-
+325 mesh	*CSA A456.2-A3*	2.1	*max. 28*
Vicat Setting Time			
Initial (minutes)	*CSA A456.2-B2*	100	*min. 45 max. 360*
Final (minutes)	*CSA A456.2-B2*	204	-
Air Content (%)	*CSA A456.2-C4*	7.39	-
Autoclave Expansion (%)	*CSA A456.2-B5*	-0.04	*max. 1.0*
Compressive Strength		MPa / psi	
3 Day	*CSA A456.2-C2*	27.7 / 4018	*min. 14.5*
7 Day	*CSA A456.2-C2*	34.0 / 4937	*min. 20.0*
28 Day (previous month)	*CSA A456.2-C2*	41.0 / 5948	*min. 26.5*

This will certify that the above described cement meets CSA Specification A5 for Type 10 Low Alkali Portland Cement.

Eileen M. Jang — Eileen Jang — June 6, 2003

Appendix D: Relevant Sections of the Proposed CSA A23.1 Standard

The following are excerpts from the ***PUBLIC REVIEW DRAFT 2003*** on CSA A23.1 Standard.

Clause 4.1.1.1.5
"4.1.1 Durability Requirements

4.1.1.1.5
When combinations of hydraulic Hydraulic cement and supplementary cementing materials are used, they shall have been proven, to the satisfaction of the owner, to produce concrete resistant to the exposure conditions outlined in Clauses 4.1.1.2 to 4.1.1.5."

Clause 4.1.2.1
"4.1.2. Alternatives for Specifying Concrete

4.1.2.1
The owner shall select the specifying alternative given in Table 5

Note: *When specifying concrete, the following items, should be considered:*
a) Class of Exposure (W/CM, Air, permeability index) Table 2
b) Minimum Specified Strength at age
c) Intended application
d) Aggregate Properties (size, Special Grading, alkali aggregate reaction) Clause 4.2.3
e) Architectural (colour, finish, appearance) Clause 8.3
f) Sustainable Development (use of SCM)
g) Volume Stability
h) Quality Control Plan
i) Pre-qualification (trial batch, historical data, material conformance)
j) Other"

Clause 4.4
"4.4. Quality Control

4.4.1 General
Responsibilities for concrete quality are contained in Table [5]. Additional guidance is contained in Annex XX.

4.4.1.1 Owner's Responsibilities

4.4.1.1.1
Evaluation of concrete quality to ensure performance to the requirements of this Standard shall be the responsibility of the owner. Unlimited access to the work for purposes of inspection and selection of samples shall be available to the owner at all times.

4.4.1.1.2
The owner shall be responsible for reviewing all test reports to ensure that the requirements of this Standard have been met."

Excerpts from PUBLIC REVIEW DRAFT

Clause 8.8
"8.8 Concrete Made with a High-Volume of Supplementary Cementing Materials (HVSCM)

8.8.1 General

8.8.1.1
High-volume supplementary cementing materials concrete contains a level of SCM above that typically used for normal construction. Annex XXX contains additional information on HVSCM concretes. For the purposes of this standard concrete, two categories of HVSCM, 1 and 2, are defined as follows:

HVSCM-1: $FA/40 + S/45 > 1$
HVSCM-2: $FA/30 + S/35 > 1$

where:

FA = fly ash (Type F, CI or CH) content of the concrete (% mass of total cementing materials)
S = slag content of the concrete (% mass of total cementing materials)

A concrete which meets the definition HVSCM-1 and –2 is deemed to be HVSCM-1

8.8.1.2 Materials
Supplementary cementing materials used in HVSCM shall meet the requirements of CSA A 3001.

8.8.1.3 Requirements for C, F, S, R and A Classes of Exposure
The maximum water-to-cementing materials ratio of the concrete should meet the limits in Table 2, except when the concrete is exposed to freezing and thawing in which case the values in Table 2 shall be reduced by 0.05 for HVSCM-1.
Note: For example, for concrete with C-1 exposure, the maximum water-to-cementing materials ratio in Table 2 is 0.40; for HVSCM-1 concrete this maximum value should be reduced to 0.35.

The minimum 28d compressive strength requirements given in Table 2 shall be specified at 56 days for HVSCM-1 concrete.

8.8.1.4 Requirements for Reinforced Concrete
For reinforced concrete elements exposed to moisture and air, with depths of cover less than 50 mm, the water-to-cementing material ratio should not be greater than 0.40 for HVSCM-1 concrete and not greater than 0.45 for HVSCM-1 concrete.
Note: This requirement is intended to minimize the risk of corrosion of embedded steel due to carbonation of the concrete cover.

8.8.1.5 Trial Mixes
Laboratory trial mixes, followed by full-size batch tests, shall be made to demonstrate that the materials, mix formula, and production techniques chosen will produce concrete meeting the requirements for the job. The following properties, as applicable to the work, shall be evaluated in the trial: workability, air content, finishability, setting time, temperature development, hardened air-void parameters, strength and durability. If recent and adequate test data exist, the owner may waive this requirement.
Note: If materials or placing conditions change significantly, further trials may be necessary.

8.8.1.6 Curing Requirements
The curing and protection requirements of Curing Regime 3 shall be implemented for HVSCM-1 and Curing Regime 2 of Table 20 shall be implemented for HVSCM-2.

8.8.1.6.1 Basic Curing
Concrete surfaces shall be cured for either 7 d at a minimum temperature of 10ºC or for the time necessary to attain 40% of the specified compressive strength of the concrete.
Notes:
(1) Concrete strength can be assessed by testing field-cured cylinders or by using nondestructive testing methods as described in Clause 4.4.
(2) Following the cessation of moist curing, the development of strength continues for a short time, provided that temperature conditions are favourable. Some strength development will also be reactivated if moist curing is resumed.

8.8.1.6.2 Curing for Durability
Concrete for exposure classifications F-1, C-XL, C-1, C-2, S-1, and S-2,, concrete exposed to abrasion, and concrete exposed to air pollution in heavy industrial areas as defined in Clause 4.1.1, shall be cured for 10 d at a minimum temperature of 10ºC and for the time necessary to attain 70% of the specified compressive strength of the concrete.
Note: *At the end of the curing period for concrete of F-1, C-XL, C-1, C-2, S-1 and S-2 classes of exposure, a period of at least one month of air drying should elapse before the application of de-icing chemicals to the concrete.*

8.8.1.6.3 Curing Plan
The contractor shall submit to the owner for approval a plan for curing of the HVSCM concrete, including:

- *the type of curing material to be used;*
- *how the surface will be kept moist and the quality control requirements for keeping the surface moist;*
- *the time of initiation and duration of curing;*
- *provisions to address potential problems such as high winds, and hot and cold weather; and*
- *the limitations of access, if any, to the surfaces being cured."*

Table 5

Table 5
Alternative Methods for Specifying Concrete
(See Clauses 4.1.2.1, 4.1.2.3, 4.2.3.2.2, 5.2.4.3.2, and 8.1.4.)

Alternative	**The Owner shall specify**	**The contractor shall**	**The supplier shall**
(1) **Performance:** When the owner requires the concrete supplier to assume responsibility for performance of the concrete as delivered and the contractor to assume responsibility for the concrete in-place.	(a) required structural criteria including Strength at age (b) required durability criteria including Class of Exposure (c) additional criteria for durability, volume stability, architectural, sustainability and any additional Owner performance, pre-qualification or verification criteria (d) quality management requirements, (See Annex xx*) (e) whether the concrete supplier shall meet Certification requirements of concrete industry certification programs.(see Note)	(a) work with the supplier to establish the concrete mix properties to meet performance criteria for plastic and hardened concrete, considering Contractor's criteria for construction and placement and Owner's performance criteria (b) submit documentation demonstrating the Owner's prequalification performance requirements have been met, (c) prepare and implement a Quality Control Plan to ensure that the Owner's performance criteria will be met, submit documentation demonstrating the Owner's performance requirements have been met,	(a) certify that the plant, equipment and all materials to be used in the concrete comply with the requirements of this Standard (b) certify that the mix design satisfies the requirements of Clause 4.3. (c) certify that production and delivery of concrete will meet the requirements of Clause 5.2 (d) certify that the concrete complies with the performance criteria specified (e) prepare and implement a Quality Control Plan to ensure that the contractors performance requirements will be met if required (f) certify that the concrete supplier meets industry Certification requirements, if specified (see Note)
(2) **Prescription:** When the Owner assumes responsibility for the concrete.	(a) mix proportions including the quantities of any or all materials (admixtures, aggregates, cementing materials and water) by mass per cubic metre of concrete; (b) the range of air content; (c) the slump range (d) use of a Concrete Quality Plan, if required (e) other requirements	(a) plan the construction methods based on Owners' mix proportions and parameters (b) obtain approval from the Owner for any deviation from the specified mix design or parameters (c) identify to the Owner any anticipated problems or deficiencies with the mix parameters related to construction	(a) that the plant, equipment, and all materials to be used in the concrete comply with the requirements of this Standard (b) that the concrete complies with the prescriptive criteria as supplied by the contractor (c) Identifies to the contractor any anticipated problems or deficiencies with the mix parameters related to construction

Note*: The Owner may accept concrete industry certification programs such as provincial or regional ready mixed concrete association facility certification programs. (e.g Atlantic Provinces Ready Mixed Concrete Association, BNQ Program – Quebec, Ready Mixed Concrete Association of Ontario Approved Quality Plan, Audit and Facility Certification program, , Manitoba Ready Mixed Concrete Association, Saskatchewan Ready Mixed Concrete Association, Alberta Ready Mixed Concrete Association, British Columbia Ready Mixed Concrete Association). These programs, dealing with materials, material handling, batching, mixing equipment etc. certify the ability of the supplier to produce concrete as prescribed by each program.*

Appendix E: International and Company Internal QC Requirements

E-1. New York State Requirements for FA Qualification
E-2. Large Contractor's Internal Quality Control Requirements
E-3. JSCE No. 36 – 2000, Chapter 8 – Quality Control and Inspection
E-4. AS 3582.1-1998, Appendix A

New York State Requirements for FA Qualification

U.S. ASH COMPANY
2555 WEADOCK HWY. • P.O. BOX 60
ESSEXVILLE, MI 48732 • (517) 892-3521

FAX (517) 892-9868

January 12, 1998

New York State
Department of Transportation
Building 7A, Room 200
1220 Washington Ave.
Albany, NY 12232

Re: Application for Approved List Status

Dear Mr. Clements;

U.S. Ash Co. would like to present the following information for your review and evaluation, so that we can ultimately obtain your approval to list the Class F fly ash produced at Centerior Energy's Eastlake Generating Station Unit 5 on NYSDOT's Approved List.

<u>FACILITY REPORT</u>

COMPANY	U.S. Ash Co. P.O. Box 60 Essexville, MI 48732
POWER COMPANY	Cleveland Electric Illuminating 55 Public Square Cleveland, OH 44101
STATION NAME	Eastlake Generating Station Unit 5 10 Erie Rd. Eastlake, OH 44095

Eastlake Generating Station has a total capacity of 1257 Megawatts . U.S. Ash Co. is proposing that the fly ash produced from Unit 5 be considered for NYSDOT approval. Unit 5 is a 600 megawatt boiler. The fly ash produced from Unit 5 is separated from the flue gas in electrostatic precipitators and transferred into four five hundred (500) ton silos beneath the precipitators. Fly ash in these silos is then tested for L.O.I. and fineness. If acceptable per the Quality Control Plan, it is either loaded directly into rail cars, or transferred to a 1000 ton sales silo for truck loading. If fly ash is found to be unacceptable, it is conditioned with water and loaded into dump trucks for disposal at an off site landfill. All fly ash provided for New York customers will first be trucked to U.S. Ash's 5000 ton terminal located in Buffalo, New York and then distributed to the customer.

QUALITY CONTROL

The parameters established by U.S. Ash Co. for acceptable Class F fly ash are as follows:

L.O.I.	Maximum	3.0%
Fineness	Maximum	34.0%

All procedures and equipment conform to the current revisions of the following applicable ASTM Standards:

ASTM C-114
ASTM C-118
ASTM C-311
ASTM C-430
ASTM C-618 (except maximum L.O.I. of 3.0 %)

The Quality control plan will be carried out by U.S. Ash Co. representatives at both the Eastlake Station and the Buffalo Terminal.

EASTLAKE

U.S. Ash personnel will have the following hours at the Eastlake Station:

March 15 thru December 15	6:00 am to 6:00 pm
December 16 thru March 14	7:00 am to 4:00 pm

The personnel will test the fly ash as it is collected in the 4-500 ton silos below the precipitators to determine if it meets our requirements. If the fly ash meets our requirements it will be transferred via pneumatic conveying to the 1000 ton sales silo. If the fly ash does not meet our requirements the fly ash will be disposed of. The following procedure will be used on a daily basis to determine the quality of the fly ash:

The first duty for our personnel will be to take samples of the fly ash from the four 500 ton silos. The samples will be taken from sample ports located directly above the pneumatic transfer system that conveys the fly ash to the 1000 ton sales silo. They will then contact the plant operator regarding the plant operating conditions. They will then return to our on-site lab to determine the LOI and fineness of the samples. The results are logged and the following decisions are made based upon the LOI and fineness of the samples:

LOI LESS THAN 2.5% AND FINENESS LESS THAN 34%

U.S. Ash representatives will initiate the conveying of the fly ash from the 4 500 ton silos to the 1000 ton sales silo. Further sampling of the fly ash in the 4 500 ton silos will be done every five hours.

LOI GREATER THAN 2.5% AND LESS THAN 3.0% AND FINENESS LESS THAN 34%

U.S. Ash representative will initiate the conveying of the fly ash from the 4 500 ton silos to the 1000 ton sales silo. Further sampling of the fly ash in the 4 500 ton silos will be done every three hours.

LOI GREATER THAN 3.0% OR FINENESS GREATER THAN 34%

U.S. Ash representative will contact the plant operator to inform him that the fly ash in the 4 500 tons silos is to be disposed of via trucks to the off site landfill. The silos will be emptied and the testing frequency will be increased to once every hour.

At this point only U.S. Ash accepted fly ash meeting NYSDOT material requirements of 711-10 is in the 1000 ton storage silo. From here the fly ash will be transported to our facility in Buffalo, NY. Samples from each truck will be taken with a minimum of every third load checked for LOI. Once we have transported 5000 tons to our Buffalo terminal the silos will be sealed and await testing by NYSDOT personnel as it is shipped to our New York customers. Samples from each truck loaded at our Buffalo facility will be tested at our Buffalo facility to insure that the fly ash meets our specifications of a maximum LOI of 3.0% and a maximum fineness of 34%. A composite sample comprised of all truck samples will be tested for a complete physical and chemical analysis as specified in the most recent revision of ASTM C311 and C618.

In addition to the above listed testing programs, periodic cross checking of samples will be conducted at other U.S. Ash facilities where we maintain quality control personnel. This testing will include comparative LOI and fineness testing, as well as periodic specific gravity testing.

ADDITIONAL APPLICATION INFORMATION

The U.S. Ash contact person at the Eastlake site will be Mark Ryan at 1-216-951-1031.

Eastlake Unit 5 produces only Class F fly ash and the Buffalo Terminal will only handle Eastlake Unit 5 fly ash.

Attached you will find:

1. A twelve month history of fly ash test results representing Eastlake Unit 5 fly ash.

2. A schematic showing Eastlake unit 5, electrostatic precipitators, silos and truck loading facility.

3. Approval certifying Eastlake Unit 5 is acceptable in the states of Michigan, Ohio, Pennsylvania and West Virginia.

We will have daily contact with Eastlake personal to insure that any changes in operating procedures will not effect our quality of fly ash. The following will be monitored by U.S. Ash personnel:

1. Unit Start Up. In most startup situations oil is used as an assist in igniting the boiler. For the first 24 hours after any start up all of the fly ash will be disposed of. After that U.S. Ash personnel will conduct sampling on an hourly basis to insure that the fly ash is of sufficient quality to meet our requirements.

2. Coal Sources The Eastlake Plant has stringent requirements as to the type and quality of the coal they burn, so as not to exceed their opacity and air emissions standards as stipulated by the Ohio Environmental Protection Agency and the Federal Environmental Protection Agency. This special coal is called "compliance coal" and its use at the Eastlake Station insures a consistent Class F fly ash. U.S. Ash personnel will have constant contact to insure that "compliance coal" is burned.

Our market research has shown that numerous suppliers of concrete within the State of New York would use a Class F fly ash of the quality of Eastlake Unit 5 resulting in quality concrete for your projects. We would appreciate your review of this document, so that we can schedule a meeting to discuss any further details.

Thank you again for your consideration of this fly ash.

Sincerely,

Michael Adams

U.S. ASH COMPANY
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ESSEXVILLE, MI 48732 • (517) 892-3521

FAX (517) 892-9868

LABORATORY TEST REPORT

DATE: JANUARY 1998 COMPOSITE

PLANT: EASTLAKE

CHEMICAL TEST DATA

SiO2 45.27 + Al2O3 24.60 + FE2O3 20.09	89.96
SO3	1.08
CaO	4.12
Moisture Content	0.16
L.O.I.	1.16

PHYSICAL TEST DATA

FINENESS #325 SIEVE (%)	20.50
Strength Activity Index (S.A.I.)	82.60
Water Requirement	98.80
Specific Gravity	2.58
Soundness (Autoclave Expansion %)	-0.05

This will certify that the foregoing "POZICON" is
a Class "F" pozzolan with the current
specifications of the ASTM C618, AASHTO M295, and

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2555 WEADOCK HWY. • P.O. BOX 60
ESSEXVILLE, MI 48732 • (517) 892-3521

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LABORATORY TEST REPORT

DATE: DECEMBER 1997 COMPOSITE

PLANT: EASTLAKE

CHEMICAL TEST DATA

SiO2	45.24	+ Al2O3	27.96	+ FE2O3	17.94		91.14
SO3							1.12
CaO							4.26
Moisture Content							0.20
L.O.I.							1.57

PHYSICAL TEST DATA

FINENESS #325 SIEVE (%)	22.50
Strength Activity Index (S.A.I.)	86.20
Water Requirement	99.20
Specific Gravity	2.55
Soundness (Autoclave Expansion %)	-0.02

This will certify that the foregoing "POZICON" is a Class "F" pozzolan with the current specifications of the ASTM C618, AASHTO M295, and other specifications as noted.

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LABORATORY TEST REPORT

DATE: NOVEMBER 1997 COMPOSITE

PLANT: EASTLAKE

CHEMICAL TEST DATA

SiO2 45.34 + Al2O3 27.86 + FE2O3 17.94	91.14
SO3	1.03
CaO	2.84
Moisture Content	0.26
L.O.I.	1.47

PHYSICAL TEST DATA

FINENESS #325 SIEVE (%)	17.00
Strength Activity Index (S.A.I.)	83.70
Water Requirement	98.80
Specific Gravity	2.54
Soundness (Autoclave Expansion %)	-0.04

This will certify that the foregoing "POZICON" is a Class "F" pozzolan with the current specifications of the ASTM C618, AASHTO M295, and other specifications as noted.

CONCRETE GROUP

DUFFERIN-CUSTOM CONCRETE
Concrete Supplier Quality Control Plan

1.0 GENERAL

1.1 PAYMENT

1.1.1. The Contractor shall agree to timely payment to the Concrete Supplier, of the concrete delivered on the job based on the acceptance of the concrete according to this Concrete Supplier Quality Control Plan.

1.2 SUBMISSION OF PLAN

1.2.1. The Concrete Supplier shall submit a complete Quality Control Plan to the Contractor as specified in the Contractor Quality Control Plan.

1.2.2 The Plan will form part of the Contractor Quality Control Plan and shall; 1) address material and quality aspects of the work; 2) be signed by an officer of the company; and 3) name the individual responsible for administration of the Concrete Supplier Plan. [Plan Administrator]

1.3 ACCEPTANCE / REJECTION OF PLAN

1.3.1 The Plan will be accepted when the Contractor and the Concrete Supplier have both signed the document. The document then becomes part of the Contractor Quality Control Plan.

1.3.2 Changes to the Plan will only be accepted upon both the Contractor and the Concrete Supplier acceptance, and both having signed any alterations to the Plan.

1.3.3 3 If, for any reason, the Contractor is found to be in default of the MTO Contract, the Contractor is responsible for the payment of any testing costs borne by the Concrete Supplier as they pertain to the Quality Control Plan and the contract.

1.4 PERSONNEL

1.41. Personnel are listed:

Plan Administrator ______________________________

Company Contact at Plant ______________________________

1.5 PLANT FACILITIES

1.4.1 Plant Locations:

Primary	1185 Martingrove Rd.	Phone	746-2222
Secondary	650 Commissioner St.	Phone	746-2222

Contact Person(s) CENTRAL DISPATCH

1.6 CONTRACTOR ACCESS

1.6.1 The Contractor shall be given access at anytime to production facilities, and batch records as necessary / required.

1.7 DOCUMENTATION AND RETENTION OF BATCH RECORDS

1.7.1 The Concrete Supplier shall retain and provide computerized batch records for each load of concrete upon request from Contractor.

1.8 ADDITIONAL SAMPLING AND TESTING

1.8.1 Additional Sampling and Testing as directed by the Contractor shall be carried out. The Concrete Supplier will be compensated for these additional costs the Contractor.

1.9 MATERIALS

1.91. Admixtures

The Concrete Supplier shall provide certification from the Admixture supplier that al materials used in the contract, are Contract Administrator approved and that they meet the requirements of CSA A23.1

1.9.2 Cementing and Supplementary Cementing Materials

The Concrete Supplier shall provide certification from the Cement and Supplementary Cementing Materials supplier(s) that all materials used in the contract are Contract Administrator approved and that meet the requirements of CSA A23.1

1.9.3 Aggregates

All Aggregates shall meet the requirements of the Contractor Quality Control contract documents.

1.9.4 Non-Conforming Materials

The Concrete Producer / Supplier will immediately notify the Contractor if any materials are found to be in non-conformance.

2.0 AIR VOIDS

2.0.1. The Concrete Supplier shall demonstrate, prior to the placement of concrete, that the proposed mix design(s) and materials can produce an Air Void system in the hardened concrete meeting the requirements of CSA A23.1, section 14.3 Air Entrainment - 14.3.4.

2.0.2 The Air Void analysis training shall be done according to CSA A23.1, section 17.1.2 Procedures - 17.1.2.1.

2.0.3. The Concrete Supplier shall be responsible for the Air Void system in the hardened concrete only up to the discharge of concrete from the R/M truck.

3.0 TESTING

3.0.1. Sampling, Making and Curing of Cylinders
Cylinders shall be sampled, made and cured in accordance to CSA A23.2, tests A23.2-1C (Sampling), A23.2-3C (Making and Curing), A23.2-5C (Slump) and A23.2-4C (Air-volume). Concrete tests not sampled, made and cured according to CSA shall not be considered valid and shall be disregarded by the Concrete Supplier.

3.0.2 Test Personnel
Only those individuals who are currently ACI-certified Concrete Field Testing Technicians shall test concrete.

Name	ACI #	Expiry Date
Dennis Baker	461-593-444	Feb. 2000
Robert Notari	501-193-908	Feb. 2002
Charlie Strazzeri	488-630-377	Feb. 2002
Frank Alaimo	462-789-181	Feb. 2001

3.0.3 Test Reports
Copies of all contractor test reports shall be immediately provided to the Concrete Supplier.

Acceptance of this Plan

Contract Number _______

____

____
Concrete Supplier Officer - Title

Date__________________ ____________________

CHAPTER 8 QUALITY CONTROL AND INSPECTION

8.1 General

In order to ensure the required qualities of concrete containing fly ash, quality control and inspection of concrete materials and construction methods shall be exercised.

[Commentary]
Since the qualities of concrete containing fly ash vary depending on the type and replacement ratio of fly ash, placing temperature, and curing methods, quality control of concrete materials and concreting methods must be adequately exercised with a complete grasp of the properties of concrete to achieve construction relevant to the purpose of the structure. Inspection is defined as confirmation by the owner or an entrustee of the inspection that a concrete structure having the required qualities relevant to its purpose is being constructed under adequate quality control exercised at adequate stages of construction.

8.2 Quality control and inspection of materials

(1) Quality control and inspection of fly ash shall be exercised in accordance with the Standard Specification [Construction].
(2) Quality control and inspection of cement, mixing water, aggregate, and admixtures other than fly ash shall be conducted in accordance with the Standard Specification [Construction].
(3) Should the quality of any material be judged inadequate by the inspection, appropriate measures shall be taken in accordance with the Standard Specification [Construction].

[Commentary]
Regarding (1): Quality control and inspection of fly ash should be exercised by confirming that the items specified in JIS A 6201 (Fly ash for use in concrete), i.e., silicon dioxide, moisture content, ignition loss, density, percentage retained on a 45-μm sieve, specific surface area, flow value ratio, and activity index, satisfy the specifications. Quality control and inspection of other items are also recommended when deemed necessary.

The test method for an activity index to evaluate strength-developing properties requires the replacement ratio and water-binder ratio to be 25% and 50%, respectively. However, these may widely differ from the actual proportions. In such a case, direct evaluation of the strength under the relevant conditions may be recommended depending on the purpose of use.

Since the specific surface area and ignition loss have strong effects on the properties of fresh concrete and strength development, it is advisable to measure them at shorter intervals as necessary. Tests should be basically conducted in accordance with JIS A 6201. However, the quality of fly ash may normally be confirmed by the test report submitted by the manufacturing plant.

In order to produce concrete with constant qualities, the quality of fly ash should be constant. It is important to confirm not only the fulfillment of the quality requirements for fly ash but also the narrowness of the fluctuation range of fly ash quality, particularly in a large-scale project involving a large quantity of concrete.

Regarding (2): When an air-entraining admixture for use with fly ash is included, tests should be conducted in accordance with JSCE-D 107. However, its quality may be confirmed by the test report submitted by the manufacturing plant.

Air-entraining admixtures for use with fly ash may not develop the required performance when used with admixtures other than those specified or with normal air-entraining admixtures, or when reclaimed water is used as the mixing water. It is therefore advisable to confirm the performance of the air-entraining admixture for use with fly ash beforehand using trial mixtures.

Regarding (3): The requirements of the Standard Specification [Construction] should be observed when exercising quality control and inspection of materials other than fly ash. Also, in case of nonconformity of any material to be used, the Standard Specification [Construction] should be referred to for remedial measures.

8.3 Quality control and inspection of construction

(1) Quality control and inspection of production of concrete containing fly ash shall be exercised in accordance with the Standard Specification [Construction].
(2) Quality control and inspection of concrete containing fly ash shall be exercised in accordance with the Standard Specification [Construction].
(3) Quality control and inspection of transportation, placing, and curing of concrete containing fly ash shall be exercised in accordance with the Standard Specification [Construction].
(4) Should concreting be judged inadequate by the inspection, appropriate measures shall be taken in accordance with the Standard Specification [Construction].

[Commentary]
Regarding (1): Concrete containing fly ash is produced at ready-mixed concrete plants or plants in construction sites. In either case, the production equipment and processes should be adequately controlled to ensure the production of concrete with the required qualities, similarly to the case of non-fly ash concrete. Accordingly, quality control and inspection of the production of concrete containing fly ash are required to be in accordance with the Standard Specification [Construction].

When concrete containing fly ash is produced, the characteristics imparted by fly ash are intended for the concrete, with the target performance being established. Accordingly, the attainment of the specified performance of resulting concrete must be confirmed by adequate control. When mixing concrete, it is important to confirm if the mixing is sufficient and if the specified quantities of components are mixed. Since the dispersibility of fly ash during mixing is relatively high, the required mixing time may be set the same as that of concrete with no fly ash. However, a slightly longer mixing time should be adopted in the beginning to allow for safety, and then an adequate mixing time should be established after confirming the quality stability.

Regarding (2): The performance items required for concrete containing fly ash and test methods for such items are basically the same as those for non-fly ash concrete. The quality control and inspection of concrete containing fly ash are therefore required as a rule to be in accordance with the Standard Specification [Construction].

When the replacement ratio of fly ash is established for a special purpose, such as to improve durability or reduce hydration heat, quality control should be exercised to maintain the specified replacement ratio over time, and inspection should be made accordingly to check if the intended quality is attained.

To confirm the uniformity and replacement ratio of fly ash in concrete, the following methods can be applied: “Simple test method of confirming mixing uniformity of fly ash as a mineral admixture (draft)” by the National Federation of Ready Mixed Concrete Industry Associations and JSCE-D 503 (Test method for replacement ratio of fly ash contained as a mineral admixture) (draft).

Though an early compressive strength is normally tested for exercising quality control based on compressive strength, early strength development of concrete containing fly ash as a mineral admixture is low, and the test results are strongly affected by fluctuations of the specimen temperature after molding and curing temperature. It is therefore important to establish the methods of producing and curing specimens taking account of these points. Several methods of judging concrete strength in a short time have been proposed. These methods provide the results in 1 hour at the earliest and 2 days at the latest after taking samples. However, these methods have been developed for non-fly ash concrete. When applying these methods to quality control of concrete containing fly ash, it is advisable to determine the correlation between early compressive strength and 28-day compressive strength beforehand or to conduct a 28-day compression test as well to confirm the attainment of the required qualities.

Regarding (3): Quality control and inspection of transportation, placing, and curing of concrete containing fly ash may be exercised similarly to the case of concrete with no fly ash. A transportation time is the time from the beginning of concrete mixing to the end of placing. Its fluctuations cause changes in workability, resulting in fluctuations of concrete qualities. The transportation time must be within the specified length, and it is desirable to exercise control to minimize both the transportation time and its fluctuation. The method and period of curing are critical items to fully develop the properties of concrete containing fly ash. These items should therefore be adequately established in consideration of the type and replacement ratio of fly ash and weather conditions, and control should be exercised with care.

Regarding (4): When the concreting is judged inadequate by the inspection, appropriate measures must be taken in accordance with the Standard Specification [Construction].

AS 3582.1-1998, Appendix A

APPENDIX A

MEANS FOR DEMONSTRATING COMPLIANCE WITH THIS STANDARD

(Informative)

A1 SCOPE This Appendix sets out the following different means by which compliance with this Standard can be demonstrated by the manufacturer or supplier:

(a) Evaluation by means of statistical sampling.

(b) The use of a product certification scheme.

(c) Assurance using the acceptability of the supplier's quality system.

(d) Other such means proposed by the manufacturer or supplier and acceptable to the customer.

A2 STATISTICAL SAMPLING Statistical sampling is a procedure which enables decisions to be made about the quality of batches of items after inspecting or testing only a portion of those items. This procedure will only be valid if the sampling plan has been determined on a statistical basis and the following requirements are met:

(a) The sample shall be drawn randomly from a population of product of known history. The history shall enable verification that the product was made from known materials at essentially the same time, by essentially the same processes and under essentially the same system of control.

(b) For each different situation, a suitable sampling plan needs to be defined. A sampling plan for one manufacturer of given capability and product throughput may not be relevant to another manufacturer producing the same items.

In order for statistical sampling to be meaningful to the customer, the manufacturer or supplier needs to demonstrate how the above conditions have been satisfied. Sampling and.the establishment of a sampling plan should be carried out in accordance with AS 1199, guidance to which is given in AS 1399.

A3 PRODUCT CERTIFICATION The purpose of product certification is to provide independent assurance of the claim by the manufacturer that products comply with the stated Standard.

The certification scheme should meet the criteria described in SAA HB 18.28 in that, as well as full type testing from independently sampled production and subsequent ~ verification of conformance, it requires the manufacturer to maintain effective quality planning to control production.

The certification scheme serves to indicate that the products consistently conform to the requirements of the Standard.

A4 SUPPLIER'S QUALITY SYSTEM Where the manufacturer or supplier can demonstrate an audited and registered quality management system complying with the 8 requirements of the appropriate or stipulated Australian or international Standard for a supplier's quality system or systems, this may provide the necessary confidence that the specified requirements will be met. The quality assurance requirements need to be agreed between the customer and supplier and should include a quality or inspection and test plan to ensure product conformity.

Guidance in determining the appropriate quality management system is given in AS/NZS ISO 9000.1: 1994 and AS/NZS ISO 9004.1: 1994.

AS OTHER MEANS OF ASSESSMENT If the above methods are considered inappropriate, determination of compliance with the requirements of this Standard may be assessed by being based on the results of testing coupled with the manufacturer's guarantee of product conformance.

Irrespective of acceptable quality levels (AQLs) or test frequencies, the responsibility remains with the manufacturer or supplier to supply products that conform with the full requirements of the Standard.

Appendix F: Comparison of QC Requirements for Cement and FA in CSA A3000 and Previous CSA A23.5 Standards

Property		*Current - A3000-03*		*Current - A3000-03*		
		GU - Portland Cement		**Type F - Fly Ash**		
		Result	**Frequency (*)**	**Result**	**Frequency (**)**	**Notes**
Chemical Requirements						
Loss on ignition, % max.		3.0	1 per 2000 t	8.0	Daily or 1 per 400 t	
Insoluble residuals, % max.		1.5	1 per 2000 t			
Sulphur trioxide (SO3), % max.						It shall be acceptable to exceed this limit, provided that the supplementary cementing material, when tested in combination with the particular Portland cement with which it is to be used, exhibits expansion not in excess of 0.020% at 14 days when tested in accordance with A3004-C5. In the test mix, 20% of the mass of Portland cement shall be replaced by an equal mass of supplementary cementing material, or for Type SF, 10%, or the anticipated maximum field replacement percentage, whichever is greater.
	C3A > 8.0% (before 2003, C3A >7.5%)	3.5	1 per 1000 t	5.0	Monthly or 1 per 3000 t	
	C3A < 7.5% (before 2003, C3A >7.5%)	3.0	1 per 1000 t			
Magnesium Oxide (MgO), % max.		5.0	1 per 2000 t			
CaO, %				<8	Monthly or 1 per 3000 t	For the purpose of classification, the tolerance is ±2% on the CaO limits.
Physical Requirements						
Fineness, 45um sieve, % retained		28	1 per 2000 t	34	Daily or 1 per 400 t	
Soundness (autoclave expansion or contraction), % expansion max.		1.0	1 per 1000 t	0.8	Monthly or 1 per 3000 t	
Setting Time, minutes						
	minimum	45	1 per 1000 t		na	
	maximum	375	1 per 1000 t		na	
Compressive Strength, MPa						
	3-day	14.5	1 per 2000 t		na	
	7-day	20.0	1 per 2000 t		na	
	28-day	26.5	1 per 2000 t		na	
Uniformity Requirements for Strength						
Maximum coefficient of variation, %		8.0	not specified			
Accelerated PA Index - 7d, % min. of control			na	-	-	
Uniformity Requirements						
Density - % max. variation			na			
Retained on 45um sieve, % max. variation					-	
Supplementary Optional Physical Requirements (New						
Density					Monthly or 1 per 3000 t	
Pozzolanic Activity Index - 28d, % min. of control				75	Monthly or 1 per 3000 t	These tests are optional.
Uniformity of air entraining admixture dosage - % max. variation				20	Monthly or 1 per 3000 t	These tests are optional.
Increase of drying shrinkage of mortar bars, % max.				-	-	-
Reactivity with Cement Alkalies - 14d, % min.					-	-
Control of Expansion due to alkali-silica reactivity						
% max. mortar expansion at 14d			na	0.1	Every 3 months	These tests are optional.
Uniformity Requirements						
Variation of air content, % max.			-	-	-	-
Moisture Content, % max.				3	-	
Heat of Hydration, 7d max. kJ/kg						These tests are optional.
	MH (before 2003, Type 20E)	300.0	1 per 4000 t	300	Every 3 months	
	LH (before 2003, type 40E)	275.0	1 per 4000 t	275	Every 3 months	
Sulphate Resistance: Maximum Expansion, % at 6 months						These tests only apply if certifying the product in respect to the parameter so noted.
	MS (before 2003, Type 20E)	0.050	1 per 4000 t	0.10	Every 3 months	
	HS (before 2003, Type 50E)	0.035	1 per 4000 t	0.05	Every 3 months	

Property		*Current - A3000-03*		*Current - A3000-03*		
		GU - Portland Cement		Type F - Fly Ash		
		Result	Frequency (*)	Result	Frequency (**)	Notes
Guidelines for the Use of Supplementary Cementing Materials in Concrete						The user is referred to ACI Manual of Concrete Practice, for fly ash, ACI 232.2R, Use of Fly Ash in Concrete.
New in the Standard Edition						
						Guide for the Evaluation of Alternative Supplementary Cementing Materials (SCMs) for Use in Concrete
Testing Frequency						
Water Requirement						
Air-Entraining Admixture Requirement						
Setting Properties and Strength Development						
Curing						
Flexural to Compressive Strength Ratio						
Drying Shrinkage						
Alkali-Aggregate Reactivity						
Form Pressures						
Durability						
Selecting Mix Proportions						
Lean Concrete vs. Rich Concrete						
Additional Notes:		**Additional Notes:**				Notes from Preface: In CSA Standard A3000:
Lot = an identifiable quantity of material such as loads in trucks, rail cars or boats, material in silo storage, or bagged material		(*) Either the manufacturer or the purchaser has the right to waive the noted frequency of testing and to specify an alternative for indicating compliance with				A5, A23.5, and A362 are merged into a single Standard: A3001, Cementitious Materials for Use in Concrete.
(1) No single sample to represent more than 500 tonnes or less than 4 kg No composite sample shall represent more 2000 tonnes		(**) For a source for which less than 6 months of production records are available, the sampling and testing frequency shall be 100 tonnes or daily, whichever comes first, for fineness and loss on ignition (fly ash only) and 1000 tonnes or monthly, whichever comes first, for all other tests.				A363, Cementitious Hydraulic Slag, is withdrawn with the publication of this Standard. with the publication of this Standard, cementitious hydraulic slag is included by definition as ground granulated blast furnace slag. The requirements for this product are incorporated in the specifications for supplementary cementing materials;
(2) Frequencies may be reduced when the source is shown to comply						Guidance is provided for blended hydraulic cements consisting of a Portland cement and up to three supplementary cementing materials.
(2a) Frequencies may be reduced up to 10 times the stated values when the source is shown to comply						A provision has been included for the testing of processing additions when slag, fly ash, or natural pozzolans are present.
(3) If average is equal to 20%, then allowable variation = 15% to 25%						A definition for hydraulic cement has been added; hydraulic cement is defined as either a Portland cement, a blended hydraulic cement, a mortar cement, or a masonry cement.
						The definition of blended hydraulic cement has been altered to accommodate more than a single supplementary cementing material.

Property		*Previous - A3000-98*		*Previous - A3000-98*		
		Type 10 - Portland Cement		**Type F - Fly Ash**		
		Result	**Frequency (1)**	**Result**	**Frequency (2)**	**Notes**
Chemical Requirements						
Loss on ignition, % max.		3.0	1 per 1000 t	8.0	1 per 1000 t	
Insoluble residuals, % max.		1.5	1 per 1000 t			
Sulphur trioxide (SO3), % max.						It shall be acceptable to exceed this limit, provided that the supplementary cementing material, when tested in combination with the particular Portland cement with which it is to be used, exhibits expansion not in excess of 0.020% at 14 days when tested in accordance with CSA Standard A465.2-C5. In the test mix, 20% of the mass of Portland cement shall be replaced by an equal mass of supplementary cementing material, or for Type SF, 10%, or the anticipated maximum field replacement percentage, whichever is greater.
	C3A > 8.0% (before 2003, C3A >7.5%)	3.5	1 per 500 t	5.0	1 per 1000 t	
	C3A < 7.5% (before 2003, C3A >7.5%)	3.0	1 per 500 t			
Magnesium Oxide (MgO), % max.		5.0	1 per 1000 t			
CaO, %				<8	1 per 500 t	For the purpose of classification, the tolerance is ±1% on the 8% limit.
Physical Requirements						
Fineness, 45um sieve, % retained		28	1 per 2000 t	34	1 per 100 t	
Soundness (autoclave expansion or contraction), % expansion max.		1.0	1 per 1000 t	0.8	1 per 1000 t	
Setting Time, minutes						
	minimum	45	1 per 1000 t		na	
	maximum	360	1 per 1000 t		na	
Compressive Strength, MPa						
	3-day	14.5	1 per 2000 t		na	
	7-day	20.0	1 per 2000 t		na	
	28-day	26.5	1 per 2000 t		na	
Uniformity Requirements for Strength						
Maximum coefficient of variation, %		8.0	not specified			
Accelerated PA Index - 7d, % min. of control			na	-	-	
Uniformity Requirements						
Density - % max. variation			na		-	
Retained on 45um sieve, % max. variation					-	
Supplementary Optional Physical Requirements (New						
Density					1 per 500 t	
Pozzolanic Activity Index - 28d, % min. of control				75	1 per 1000 t	
Uniformity of air entraining admixture dosage - % max. variation				20	1 per 1000 t	When air-entrained concrete is specified, the quantity of air-entraining admixture required to produce an air content of 18.0 % by volume of mortar shall not vary from the average established by the 10 preceding tests (or by all preceding tests if fewer than 10).
Increase of drying shrinkage of mortar bars, % max.						-
Reactivity with Cement Alkalies - 14d, % min.						-
Control of Expansion due to alkali-silica reactivity						The accelerated mortar bar test (CSA A23.2-25A) shall be conducted at the range of mass replacement levels of the cement by the supplementary cementing material. The minimum safe replacement level shall be the lowest replacement level where the table limit is satisfied. The base cement shall be a normal Portland cement meeting the requirements of CSA A23.2-25A and having an equivalent alkali content of 0.8 to 1.0%. The aggregate, for use in the test, shall produce a 14-day expansion which exceeds the 0.30% in CSA A23.2-25A. (The Spratt reactive limestone meets this requirement.) The use of reactive aggregates in concrete is governed by CSA Standard CAN/CSA-A23.1.
% max. mortar expansion at 14d			na	0.1	Every 3 months	
Uniformity Requirements						When air-entrained concrete is specified, the quantity of air-entraining admixture required to produce an air content of 18.0 % by volume of mortar shall not vary from the average established by the 10 preceding tests (or by all preceding tests if fewer than 10).
Variation of air content, % max.			na	20	1 per 1000 t	
Moisture Content, % max.				3	-	
Heat of Hydration, 7d max. kJ/kg						
	MH (before 2003, Type 20E)		1 per 4000 t	300	Every 3 months	At the option of the purchaser, these tests shall be performed. The report shall identify the minimum required percentage mass replacement to meet the required heat of hydration limits.
	LH (before 2003, type 40E)		1 per 4000 t	275	Every 3 months	
Sulphate Resistance: Maximum Expansion, % at 6 months						
	MS (before 2003, Type 20E)	0.050	1 per 4000 t	0.10	Every 3 months	At the option of the purchaser, these tests shall be performed. The test report shall state the C3A content of the cement, the minimum mass replacement required to meet the expansion limits, and either the % Al2O3 of the slag or the % CaO of the fly ash (as applicable). If, after compliance is established, the C3A content of the cement, or the Al2O3 of the slag, or the % CaO of the fly ash increases by 2.0% or more than that used during compliance testing, then retesting shall occur to reestablish compliance with this Standard. If the expansion is greater than 0.05% at 6 months but less than 0.10 % at one year, cement shall be considered to have passed.
	HS (before 2003, Type 50E)	0.035	1 per 4000 t	0.05	Every 3 months	

Property		*Previous - A3000-98*		*Previous - A3000-98*		
		Type 10 - Portland Cement		Type F - Fly Ash		
		Result	Frequency (1)	Result	Frequency (2)	Notes
Guidelines for the Use of Supplementary Cementing Materials in Concrete						The Guidelines from the 1986 version have been deleted. The user is referred to ACI Manual of Concrete Practice, for fly ash, ACI 232.2R-96, Use of Fly Ash in Concrete.
New in the Standard Edition						
Testing Frequency						
Water Requirement						
Air-Entraining Admixture Requirement			na			
Setting Properties and Strength Development						
Curing						
Flexural to Compressive Strength Ratio						
Drying Shrinkage						
Alkali-Aggregate Reactivity						
Form Pressures						
Durability						
Selecting Mix Proportions						
Lean Concrete vs. Rich Concrete						
Additional Notes:		**Additional Notes:**				Notes from Preface: In CSA Standard A23.5, Supplementary Cementing Materials:
Lot = an identifiable quantity of material such as loads in trucks, rail cars or boats, material in silo storage, or bagged material						(a) language has been added to allow preblending of specific SCMs;
(1) No single sample to represent more than 500 tonnes or less than 4 kg No composite sample shall represent more 2000 tonnes						(b) fly ash has been reclassified based on calcium content, and two subsets of Type C, Type CI and Type CH, have been added; (c) the maximum loss on ignition for Type F fly ash has been reduced from 12 % to 8 %; (d) a new test for tendency to entrap air with the use of silica fume has been added;
(2) Frequencies may be reduced when the source is shown to comply						(e) a new Appendix A has been added for optional requirements;
(2a) Frequencies may be reduced up to 10 times the stated values when the source is shown to comply						(f) the pozzolanic activity index has been harmonized with ASTM C 311 for fly ash and ASTM C 1240 for silica fume and moved to Appendix A;
(3) If average is equal to 20%, then allowable variation = 15% to 25%						(g) the slag activity index has also been moved to Appendix A; and (h) control of expansion due to alkali-silica reactivity has been changed to reference CAN/CSA-A23.2-25A.
						Test Method for Detection of Alkali-Silica Reactive Aggregate by the Accelerated Expansion of Mortar Bars, replacing previous reference to ASTM C 441. Guidelines for the Use of Supplementary Cementing Materials in Concrete in Appendix B now references ACI Manual of Concrete Practice for information and guidance.

Property		***Previous - A23.5-M86 R1992***			
		Type F - Fly Ash			
		Result	**Frequency (2)**	**Clause**	**Notes**
Chemical Requirements					
Loss on ignition, % max.		12.0	1 per Lot or 100 t		
Insoluble residuals, % max.					
Sulphur trioxide (SO3), % max.					
	C3A > 8.0% (before 2003, C3A >7.5%)	5.0	1 per Lot or 1000 t		
	C3A < 7.5% (before 2003, C3A >7.5%)				
Magnesium Oxide (MgO), % max.					
CaO, %					
Physical Requirements					
Fineness, 45um sieve, % retained		34	1 per Lot or 100 t		
Soundness (autoclave expansion or contraction), % expansion max.		0.8	1 per Lot or 1000 t		
Setting Time, minutes					
	minimum				
	maximum				
Compressive Strength, MPa					
	3-day	-	-		
	7-day	-	-		
	28-day				
Uniformity Requirements for Strength					
Maximum coefficient of variation, %					
Accelerated PA Index - 7d, % min. of control		68	1 per Lot or 1000 t		
Uniformity Requirements					
Density - % max. variation		5	-		
Retained on 45um sieve, % max. variation		5	- (3)		
Supplementary Optional Physical Requirements (New					
Density					
Pozzolanic Activity Index - 28d, % min. of control		75	1 per Lot or 1000 t		
Uniformity of air entraining admixture dosage - % max. variation		?			
Increase of drying shrinkage of mortar bars, % max.		0.03	1 per Lot or 1000 t		test may be made using any high-alkali cement in accordance with ASTM C311, if the PC to be used in the work is not known or is available at the time of the test
Reactivity with Cement Alkalies - 14d, % min.		60	1 per Lot or 1000 t		tests should not be requested unless the material is to be used with an aggregate that is regarded as deleteriously reactive with alkalies in cement
Control of Expansion due to alkali-silica reactivity					
% max. mortar expansion at 14d					
Uniformity Requirements					
Variation of air content, % max.		20	1 per Lot or 100 t		
Moisture Content, % max.		3.0	1 per Lot or 100 t		
Heat of Hydration, 7d max. kJ/kg					
	MH (before 2003, Type 20E)				
	LH (before 2003, type 40E)				
Sulphate Resistance: Maximum Expansion, % at 6 months					
	MS (before 2003, Type 20E)				
	HS (before 2003, Type 50E)				

Property		Previous - A23.5-M86 R1992			
		Type F - Fly Ash			
		Result	Frequency (2)	Clause	Notes
Guidelines for the Use of Supplementary Cementing Materials in Concrete					
New in the Standard Edition					
					First time requirements and guidelines for silica fume.
Testing Frequency				5.3.3.1	Samples representative of the production of a source shall be taken during each of six consecutive months.
Water Requirement				A4.2.1	Concrete mixes containing FA will normally require less water for a given slump.
				A4.2.2	Concretes containing some fly ashes will require more water.
Air-Entraining Admixture Requirement			1 per 1000 t	A4.3.1	Air-entraining admixture required to obtain optimum air content normally increases appreciably when FA is used (a function of carbon content of FA).
Setting Properties and Strength Development				A5.1	Slow strength development may be compensated for by an increase in TCM, an adjustment in the ratio of SCM to PC, the addition of an accelerating admixture, or modification in curing conditions.
Curing					
Flexural to Compressive Strength Ratio				A6.1.4	The ratio of flexural to compressive strength of concrete is not *generally* affected by the inclusion of FA.
Drying Shrinkage				A6.3	The effect of SCM *(after 28 days moist-curing)* on the draying shrinkage of concrete is generally small. With concrete not containing SCM, it is a function of the water content of the fresh concrete.
Alkali-Aggregate Reactivity				A6.6.1	Some SCM are effective in controlling alkali-silica reactions, but not alkali-carbonate reactions.
Form Pressures					
Durability					
Selecting Mix Proportions					
Lean Concrete vs. Rich Concrete				A6.1.2	Lean concrete benefits more from the use of SCM than rich concrete. The benefits that may accrue to rich concrete are increased levels of flexural and compressive strengths.
Additional Notes:					
Lot = an identifiable quantity of material such as loads in trucks, rail cars or boats, material in silo storage, or bagged material					
(1) No single sample to represent more than 500 tonnes or less than 4 kg No composite sample shall represent more 2000 tonnes					
(2) Frequencies may be reduced when the source is shown to comply					
(2a) Frequencies may be reduced up to 10 times the stated values when the source is shown to comply					
(3) If average is equal to 20%, then allowable variation = 15% to 25%					

Property		***Previous - A23.5-M82***			
		Type F - Fly Ash			
		Result	**Frequency (2a)**	**Clause**	**Notes**
Chemical Requirements					
Loss on ignition, % max.		12.0	1 per Lot or 100 t		
Insoluble residuals, % max.					
Sulphur trioxide (SO3), % max.					
	C3A > 8.0% (before 2003, C3A >7.5%)	5.0	1 per Lot or 1000 t		
	C3A < 7.5% (before 2003, C3A >7.5%)				
Magnesium Oxide (MgO), % max.					
CaO, %					
Physical Requirements					
Fineness, 45um sieve, % retained		34	1 per Lot or 100 t		
Soundness (autoclave expansion or contraction), % expansion max.		0.8	1 per Lot or 1000 t		
Setting Time, minutes					
	minimum				
	maximum				
Compressive Strength, MPa					
	3-day	-	-		
	7-day	-	-		
	28-day				
Uniformity Requirements for Strength					
Maximum coefficient of variation, %					
Accelerated PA Index - 7d, % min. of control		68	1 per Lot or 1000 t		
Uniformity Requirements					
Density - % max. variation		5	-		
Retained on 45um sieve, % max. variation		5	- (3)		
Supplementary Optional Physical Requirements (New					
Density					
Pozzolanic Activity Index - 28d, % min. of control		75	1 per Lot or 1000 t		
Uniformity of air entraining admixture dosage - % max. variation		?			
Increase of drying shrinkage of mortar bars, % max.		0.03	1 per Lot or 1000 t		test may be made using any high-alkali cement in accordance with ASTM C311, if the PC to be used in the work is not known or is available at the time of the test
Reactivity with Cement Alkalies - 14d, % min.		60	1 per Lot or 1000 t		test may be made using any high-alkali cement in accordance with ASTM C311, if the PC to be used in the work is not known or is available at the time of the test
Control of Expansion due to alkali-silica reactivity					
% max. mortar expansion at 14d					
Uniformity Requirements					
Variation of air content, % max.		20	1 per Lot or 100 t		
Moisture Content, % max.		3.0	1 per Lot or 100 t		
Heat of Hydration, 7d max. kJ/kg					
	MH (before 2003, Type 20E)				
	LH (before 2003, type 40E)				
Sulphate Resistance: Maximum Expansion, % at 6 months					
	MS (before 2003, Type 20E)				
	HS (before 2003, Type 50E)				

Property				
	Previous - A23.5-M82			
	Type F - Fly Ash			
	Result	Frequency (2a)	Clause	Notes
Guidelines for the Use of Supplementary Cementing Materials in Concrete				
New in the Standard Edition				
Testing Frequency				
Water Requirement			B4.2.1	Concrete mixes containing FA will normally require less water for a given slump.
			B4.2.2	Concretes containing some fly ashes will require more water.
Air-Entraining Admixture Requirement			B4.3.1	Air-entraining admixture required to obtain optimum air content normally increases appreciably when FA is used (a function of carbon content of FA).
Setting Properties and Strength Development			B4.6	FA retards the setting time of concrete by an amount that depends on many factors, including the SCM used, the amount of PC removed, and the concrete and ambient temperatures.
Curing			B5.1	Slow strength development may be compensated for by an increase in TCM, an adjustment in the ratio of SCM to PC, the addition of an accelerating admixture, or modification in curing conditions.
Flexural to Compressive Strength Ratio			B6.1.4	The ratio of flexural to compressive strength of concrete is not affected by the inclusion of FA.
Drying Shrinkage			B6.3	The effect of SCM on the draying shrinkage of concrete is generally small. With concrete not containing SCM, it is a function of the water content of the fresh concrete.
Alkali-Aggregate Reactivity			B6.6.1	Some SCM are effective in controlling alkali-silica reactions, but not alkali-carbonate reactions.
Form Pressures			5.2.2	Fluid pressure on forms shall be correlated to the capacity and type of placing equipment, the planned rate of placing concrete, the slump, temperature, cementitious materials and stiffening characteristics of the concrete (see Clause 19.3.2 in A23.1-M77). The use of SCM may retard the setting time of concrete resulting in increased lateral pressure on the forms.
Durability			5.3.2	When the CM is a combination of PC and SCM, the compressive strength at 28 days shall be at least equal to that of PC concrete meeting the requirement of Table 7 of A23.1-M77, for the conditions of exposure intended. In any case, the w/cm ratio shall not exceed the requirements of Table 7 of A23.1-M77.
Selecting Mix Proportions			5.3.4.2	When the owner requires the supplier to assume the responsibility for the concrete mix proportions, the supplier shall disclose the use of an SCM, and if requested, the mass of the SCM.
			5.3.4.3	When the owner assumes the responsibility for the mix proportions, the owner shall specify the SCM, if any, to be used and its content by mass per cubic metre of concrete.
Lean Concrete vs. Rich Concrete			B6.1.2	Lean concrete benefits more from the use of FA than rich concrete.
Additional Notes:	**Additional Notes:**			A25.3-M82 relies quite heavily on A23.1.
Lot = an identifiable quantity of material such as loads in trucks, rail cars or boats, material in silo storage, or bagged material				
(1) No single sample to represent more than 500 tonnes or less than 4 kg No composite sample shall represent more 2000 tonnes				
(2) Frequencies may be reduced when the source is shown to comply				
(2a) Frequencies may be reduced up to 10 times the stated values when the source is shown to comply				
(3) If average is equal to 20%, then allowable variation = 15% to 25%				

Appendix G: Notes from RAS Report Panel Review

Meeting Notes
RAS Panel Review
December 16, 2003
Toronto, Ontario

Attendees

EcoSmart Concrete Project	Phil Seabrook, Study Director
CANMET	Benoit Fournier
Cement Association of Canada	Richard McGrath
CIRCA	John Flynn
Contractor (Ellis Don)	Lloyd Keller
Canadian Standards Association (U of T)	Doug Hooton
Designer (RJC)	Ron Mazza
EcoSmart Concrete Project	Maggie Wojtarowicz
Lafarge	Robert Munro
Research (UNB)	Mike Thomas
Ready-Mixed Concrete Association	John Connely

General Comments:

- Keeping interviewee names confidential (to protect their commercial information) does not give companies the credit they may wish to be given.
- More QC does not necessarily = less risk!
- “replacement” needs a clearer definition.

What R/M want in FA
Munro (Lafarge)
- Effects on concrete.
- Constructability.
- Strength (ultimate) is not really an issue, neither is high strength potential. The issue is the rate of strength gain!

Suggestions for Additional Items to be Included in the Report
Connely (CRMCA)
- GHG associated with shipping.
- Cost associated with shipping (esp. over long distances, which is the case in the East).

Definition of EcoSmart
Munro (Lafarge)
- Need to clarify that the definition re: cost refers to total project cost, i.e., “capable of being implemented at no increase in total project cost”.
- Need to include all GHG impacts of HVFA in concrete, e.g., adding heat in the winter also generates GHG.

Cost Implications

Keller (Ellis Don)

- "You get to know what you're doing [with HVFA concrete]".
- Implication of "ethical pricing". Price should include the cost of materials but also the cost associated with the risk.
- Throughout the report, remove any mention of price in the negative context.
- When the technology becomes mainstream, pricing will become competitive. Currently pricing is not competitive, and it reflects the level of comfort with a new technology.

Definition of QC

Hooton (U of T)

- Provide a checklist of what constitutes appropriate / sufficient QC, e.g., uniformity of FA, uniformity of concrete, and how these would be measured.

Acceptance

Connely (CRMCA)

- Once in the provisions for HVFA are include in the NMS, the comfort level increases.

Mazza (RJC)

- Main issue here is familiarity of the project team with this technology.

Sustainable Concrete

Munro (Lafarge)

- Any type of concrete is a sustainable material, because of the operation energy savings implication. The GHG saved in replacing a portion of cement with fly ash is minimal compared to the GHG savings associated with the operation energy savings.

Specifications

Munro (Lafarge)

- The Report cannot make "blanket statements."
- The Report should focus on the "process" of what needs to be done on a project to implement HVFA concrete, but it is not possible to propose one set of FA percentages across Canada.

<u>Overall Reactions from Panel Members:</u>

Hooton (U of T)

1. Acceptance of HVFA

- Similarity to acceptance of high performance concrete
- Solution: pre-tender construction meetings, trial pours

2. Statements on QC are too general

- Need to develop a check list sheet on what adequate QC actually entails:
    - FA consistency
    - Concrete consistency
    - Designer (specs)
    - Contractor (formwork, curing)

3. Other parts of the world (p. 33)

- Need to indicate the risks faced in other parts of the world, e.g., extensive carbonation in Australia

Keller (Ellis Don)

1. Lack of understanding among users that FA is a component in a SYSTEM
- FA is a component of concrete, where concrete is a part of a building – need to understand how make the whole system work.
- Need to increase the "comfort level" of project teams, by doing trial pours as the basis for the concrete mix design. Trial mixes should be done on a "3 point [strength] curve" basis, not as a cookbook recipe.

2. Concerns over carbonation

Thomas (UNB)
1. Looking for guidelines (not just a description of the problem or current state of the situation)

2. Carbonation
- Low grade of concrete particularly of pour quality is particularly at risk

- Inadequate curing will lead to carbonation

3. Type of Fly Ash
- There is a lot of references to international; most of this fly ash is primarily from Bituminous coal
- In North America, FA varies from region to region because the type of coal burned varies from region to region. Therefore, international experience not universally applicable in North America.

Fournier (CANMET)
1. QC Program
- Report needs a clearer definition of what should be included in an adequate QC Program

2. Level of replacement vs. quality
- FA quality does not impact concrete quality at 25% replacement, but it will at >25%
- Data is required in the Report that shows this

3. Responsibility
- Need to identify where the responsibilities for the quality of the concrete lie

4. Report recommendation re: A3000 Review
- Does not agree that A3000 needs a complete review, although some review is necessary

5. What R/M want
- Assurance of strength as required at given age (i.e., stripping strength vs. ultimate strength)
- Need to define at what age the "high strength potential" statement is being made
- Need to define how one can manage strength development of HVFA concrete

Connely (CRMCA)

1. R/M industry is happy that they have been heard

2. Concerns
- Quality
- Constructability

3. Recommendation for future activities
- More would be achieved (in terms of GHG emission reduction) if low volume (e.g., 30%) was used across Canada instead of HVFA in a small number of projects

4. Need more consultation with CRMCA
- The R/M industry needs time to get familiar with HVFA concrete and get comfortable with using it
- CRMCA supports promotion of HVFA concrete and HPC (high performance concrete), not "EcoSmart concrete"
- CRMCA is ok with the promotion of "EcoSmart" concepts but not with the concept of "EcoSmart concrete", especially when EcoSmart is a trademarked name and makes the concrete sound like a proprietary product

5. Performance vs. Prescriptive
- Could not define what a performance spec would contain
- Accepts to review EcoSmart's idea of what performance spec should be, and to comment on what CRMCA would agree to

McGrath (CAC)

1. Responsibility
- Need to define who is assuming responsibility
    - R/M Producer
    - Engineer
    - Owner

2. Variability of FA
- With the variability of FA across Canada, QC similar to that for PC is needed

3. The notion of requiring more QC implies (perception) that there is more risk

4. Making quality concrete
- There are construction practices aside from materials issues

5. Beneficiation of pour quality FA also requires energy, and thus, increases the GHG

6. Residential concrete = low quality

7. p. 7
- Report should not generalize one contractor's experience and imply that it applies to all

Mazza (RJC)

1. Need to define Risk

2. Constructability Risk ("real" risk for this sector)

- Setting time
- Getting finishers on site on time
- What actually needs to be done on site

3. Recognition of uncertainty in changes

4. Blended cement

- Not aware of use

Munro (Lafarge)

1. The Report tends to greatly oversimplify the issues

2. Strength and uniformity are minor issues and easiest issues to address

3. Construction issues are Major, particularly issues for and with the contractor

4. There is a lack of track record for using HVFA concrete

5. Specifying minimum cement content = prescriptive spec

6. Salt Scaling

- The Report does not address sufficiently the issue of salt scaling
- Guidance is required for how to handle the salt scaling issue in the field

7. Carbonation

- The Report entirely omits the issue of carbonation
- Carbonation is the biggest issue for long-term durability

8. The Report needs to address long-term durability

9. Maturity and Durability

- Need to develop equivalent maturity evaluation for HVFA as there are for conventional concrete, since maturity of HVFA does not happen at the same time as for conventional concrete

10. Report comments on CSA

- The comments on CSA in the Report are exaggerated
- Doubling QC will not reduce the risk
- Preparing a test results report does not qualify as good QC

11. Alkali + Sulphate limits
- Proposing alkali + sulphate limits may eliminate in some instances FA that is generally used with good success

Flynn (Ontario Power Generation)
1. FA Producers
- FA producers should not escape the responsibility of making a quality product

2. Quality of product (FA)
- A power plant should know what it is generating, even if it is a by-product such as FA

3. Management System
- The Report should define a quality management system, instead of a prescription of frequency of tests (This position also supported by a number of the other Panel Members)
- Anticipated changes to the characteristics of the FA should be communicated to the concrete supplier
- Need to make a standard that outlines how communication should work
- Need to improve QC procedures, not QC limits or frequencies

<u>Comments on Recommendations</u>

Recommendations for EcoSmart
- EcoSmart should focus on “helping” not “solving”
- Only perceived (constructability) risks can be solved by case studies; real risks cannot
- R/M Association wants one solution for every single R/M producer in the country

Recommendations for CSA A23.1
- The Report should focus on real risks, not just the perceived risks
- Time and temperature maturity measurements/results don’t work for HVFA
    - Activation energy needs to be recalculated (see ASTM Procedure)
    - Should recommend “temperature match curing” (e.g., pushout cylinders), where strength gain is matched at the same temperature in the field as for cylinders
- QC should be “changed” not just “increased”
- Some FA varies from a power plant or in a region, whereas at other plants or in other regions it does not, and it is not possible to make one set of rules for all fly ashes
- Recommend that performing the existing QC tests be enforced
- The Factor of Safety should be on constructability (i.e., curing) and not on the ultimate strength
- Need for anticipating changes and planning for them
- R/M risks are minimized if they are provided with proper specs and proper information on how to produce according to specs

Recommendations for CSA A3001
- Increasing frequency doesn’t help ensure quality
- Recommend that when characteristics of a coal source change, require requalification of the FA
- Define in the report what the “methylene-blue test” is
- Uniformity can be measured by the fineness and the colour of the FA
- Recommend the foam index test for carbon
- Recommend the water demand test for concrete (not just mortar)
- Recommend specifications for fly ash alkali limits

Recommendations for R/M Producers

- Define what is “high W/CM” (discussion indicated that this was > 0.7)

Recommendations for FA Producers

- Getting the FA producers involved does not work if there is no partnership/collaboration between the FA producer, the FA marketer, if one is employed, and the R/M producer
- Where a marketer is employed, recommend the development of communication protocols between the FA producer and FA marketer, and between FA marketer and R/M producer to ensure appropriate quality control testing is implemented by the FA marketer.
- Where a FA supplier markets its FA directly to a R/M producer, recommend the development of communication protocols between the FA producer and R/M producer, to ensure appropriate quality control testing is implemented by the R/M producer.
- In either of the above cases, when boiler conditions change, for example, such as during start-up, appropriate QC testing could mean increased sample frequency, or testing of additional properties not tested under normal operating conditions for a pre-qualified FA. The communication protocols should include exchange of sufficient and meaningful data that reduces the risk to the R/M producer of producing poor quality concrete.

General Recommendations

- Curing should be made a pay item on contracts. There was some feeling that, since curing is often not done properly, we should not depend on it for prevention of carbonation and the development of the full potential of HVFA concrete.
- There should be a certification program for R/M producers to supply HVFA concrete

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December 21, 2003

Project: EcoSmart RAS

Subject: Summary – Results of Stakeholder Panel Review

Detailed notes from the meeting have been prepared separately. The following is intended to interpret the comments from the Panel, and the related discussion at the meeting, in terms of their impact on both the general direction for EcoSmart and specific aspects that should be considered for inclusion in the final version of the RAS Report.

In the introduction to the Panel, these items were presented:

> Perceived Risk varies as Familiarity (with the EcoSmart concrete technology)
>
> If you implement the changes recommended in RAS, will it abate risk?

General Assessment of the Panel Input

The Panel was a valuable exercise. There was healthy participation by all Members. Some commented that they appreciated this opportunity for input. In some cases, it gave the Member a chance to get concerns about EcoSmart's direction off his chest.

A number of the comments relate to matters outside the scope of the RAS. They relate to more global aspects of the EcoSmart program and to items that will / should be addressed in the Guidelines. They are recorded here for future reference.

There was overall support for the Report. But most felt that it should go much further.

EcoSmart Approach

There is confusion in the names – "sustainable concrete"{all concrete is sustainable}, "EcoSmart concrete"{this is a trademark, not a concrete}, "HVFA concrete"{much of what EcoSmart recommends if not what is normally called HVFA}. EcoSmart was encouraged to drop "EcoSmart concrete". One suggestion was "low GHG concrete.

Assessments of the effectiveness of EcoSmart concrete should include both Life Cycle aspects and the total energy footprint of the concrete (ie, including transportation and any additional heat required to cure).

Ready-mixed suggest a bottom-up approach, where all concrete is to have some (small) FA, rather than the top-down approach through designers / owners by EcoSmart.

Costing

It is too early in the implementation of EcoSmart concrete to determine the final cost comparison with conventional concrete. Eventually, market and competitive forces will take over and determine the actual cost. These include the reduced cost of the material, the increased cost of the construction and additional QC.

It was noted that we are still on the learning curve with concrete containing > 30% FA; the curve is much flatter with <30%.

Standards

A strong case was made for recommending a total quality management approach (eg. the ISO System) rather than adding to the current prescriptive standards. CSA and other international standards are now requiring new Standards to be "objective based".
The Panel took umbrage with my statement that the current A3001 is the least lenient in the world. They stated that A3001 was superior to others in that tests and criteria that were meaningless had been removed. Unfortunately, they had not been replaced with meaningful tests or criteria. So our approach should be to "improve", not totally rework.

Guidance is needed in what to put on mill certificates and how to interpret that data.

Report Presentation
We were strongly encouraged to present more details on the additional QC required. Increased QC, in itself, will not produce the required result. The use of Checklists for producer, ready-mixed, and contractor was recommended.

Costs should be removed because they are not yet defined. Costs are best presented as total project costs, not just 1 element.

Remove some of the negative statements. Also recognize (further) that you cannot make blanket statements for all FA in all on Canada.

Some commented that the nature of the risk needed further definition. Most felt that the contractor's risk was underestimated (some felt that this is the biggest risk).

Emphasize that EcoSmart concrete needs more TLC, particularly in cool weather.

Technical Aspects
There was strong feeling that the matter of carbonation was a risk not adequately addressed (this in not a major issue in BC, but research indicates that the rate of carbonation will double with a 50% FA mixture). The lack of adequate cover and curing is a component. The new A23.1 will have requirements that will assist. Risk increases exponentially with increased W/CM.

Salt scaling potential was not adequately recognized (as a risk).

The dilemma with regard to curing is whether, in the specification of EcoSmart concrete, we should assume that inadequate / non-compliant curing will exist. To date, we have taken the position that specified curing will occur. There was a suggestion that we need to find some test to measure curing. The use of "temperature-matched" curing is an interesting option.

With regard to strength, the age : strength aspect must be addressed, not just the ultimate value. The concept should be "…manage strength development for the Project…". Related to this is the need to have "equivalent durability".

Risks to the Stakeholders
The premise of the RAS is that more QC = reduced risk. Discussions by the Panel did not support this or, at a minimum, indicated that it was an oversimplification. We need more representative tests, not more tests of the same.

There was discussion about the "realm of comfort" (ie, 30% maximum). Some felt that the NMS was headed in the right direction.

The CIRCA representative felt that there is risk to the FA producer, and that they must get involved. They have the information necessary to predict FA quality (but it is not used for that purpose) – need the managed risk approach..

There was a strong feeling that the real risk lies in constructibility, not in uniformity of the ready-mixed concrete.

The concept in the Report of periodic complete qualification followed by frequent monitoring of a few key properties was largely supported. This will be developed further.

The possibility of industry certification {to produce HVFA concrete} was raised.

Action
It will be obvious that the Panel has suggested many items beyond the scope of the existing RAS. Some of these will be incorporated, but many will have to be left to future work.

We still have not received details of risk as identified by the ready-mixed industry. However, the general items have been presented in the Report. The Panel felt that the risk base was much broader than just ready-mixed.

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