Cretecon
Consulting

Glass Powder as an Alkali Aggregate Reaction Suppressant in Newfoundland and Labrador

St. John's, Newfoundland and Labrador

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February 3, 2013

CC: Dr. Amgad Hussein
Mr. Justin Skinner

Dear Mr. Penney:

Cretecon Consulting has undertaken a study on the mitigation of Alkali Aggregate Reaction in non-structural concrete as requested by AMEC, Environmental and Infrastructure.

Throughout this study, the utilization of recycled glass powder was the main alternative cementitious replacement material. The enclosed final project report presents the mitigation methods that our group has tested over the past four months. Included in this report is; a description of the project, a literary review of each alternative cementitious material tested, testing methodology, testing procedures, feasibility study of glass powder production in NL and an analysis of test results.

If there are any questions concerning this final report, Cretecon Consulting would be pleased to discuss them.

Best Regards,

Adam Mandville Megan Jarvis Vince Kerrivan Kallan Fitzgerald

Cretecon Consulting

Abstract

This project was requested by AMEC Environmental and Infrastructure to research and test methods of reducing Alkali Aggregate Reaction (AAR) in concrete, with special consideration for the potential use of glass powder in Newfoundland and Labrador (NL). A feasibility study was conducted for producing cement replacement grade glass powder in the province. In addition to this, three alternative cementitious materials; glass powder, fly ash, and silica fume; were investigated as partial replacements for general use (GU) portland cement. These substances, along with TerC^3 and GU cement, were studied to gauge their effectiveness in reducing AAR; which can cause spalling, loss of strength, and potential failure in concrete.

The feasibility research of implementing recycled glass powder production in NL is encouraging. Considering the Multi Material Stewardship Board (MMSB) is currently operating its glass recycling program at a loss, the large initial investment required for such an operation could be justified. Based on a breakeven analysis, construction and operation of a glass powder production facility, in province, has potential to be profitable. However, there are still many unknowns involved in such an endeavor, and a full implementation study should be completed, by an expert, before any further consideration is given.

The effectiveness of the various cement replacement in reducing AAR was measured using accelerated mortar bar tests. The results of these tests, as well as compressive strength tests, confirmed the effectiveness of glass powder as an alternative cementitious material. Glass Powder clearly demonstrates the ability to reduce AAR when compared to fly ash and silica fume. At 20% replacement, glass powder reduced the alkali aggregate reaction by 8 times, when compared with the GU portland cement control. Compressive strength was marginally reduced when using glass powder replacement; however this loss in strength could be regained with a more suitable mix design (aggregate, water/cement ratio, additives, etc.).

Further research into the effects of glass powder as a cement replacement, as well as a more in depth industry analysis, is required to fully understand glass powder’s potential in NL. However, if proven effective, glass powder production and implementation could improve upon both the province’s recycling and concrete industries.

Acknowledgements

Cretecon Consulting would like to acknowledge and thank the following people and organizations for their contribution to this project.

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- Justin Skinner, EN 8700 Professor
- Gary Ryan, Director of Programs, Multi Materials Stewardship Board (MMSB)
- Poraver®
- Shawn Oregan, Lab Technician, Memorial University
- Melaine Jarvis, Certified General Accountant

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1 Introduction

This project was requested by AMEC Environmental and Infrastructure to research and test methods of reducing Alkali Aggregate Reaction (AAR) in concrete. The project investigates the uses of three alternative cementitious materials, glass powder (GP), fly ash (FA) and silica fume (SF), for general use (GU) portland cement.

AAR occurs in concrete over time between highly alkaline cement paste and reactive silica particles found in common aggregates. The reaction forms an expanding gel, leading to spalling which weakens the concrete as can be seen in Figure 1 below. By substituting a portion of portland cement with a pozzolan (fine siliceous material), the excess alkalinity of the cement is neutralized consequently reducing AAR.

A literary review of prior research was conducted to learn more about AAR and methods of suppressing it. Some common alternative cementitious materials are fly ash and silica fume. Both are proven effective as an AAR suppressant. Some studies suggest glass powder could potentially be useful to reduce AAR as well. For this project, glass powder will be directly compared against fly ash and silica fume in their ability to reduce AAR.

Glass powder could have several potential benefits in concrete as an alternative cementitious material. It would reduce AAR thus making concrete more durable with a longer lifespan. The production and use of portland cement emits large quantities of greenhouse gases. By substituting a portion of the portland cement with glass powder, greenhouse gas emissions are decreased. Fly ash and silica fume accomplish this as well, but glass powder could be a cheaper alternative.

This project will also include a feasibility study for the use of glass powder in Newfoundland and Labrador (NL). Currently, Multi Materials Stewardship Board (MMSB) in St. John’s has no use for its recycled glass. This project will investigate the costs of and benefits of building a glass powder production facility in the province.

As research has already been conducted in this area, the report presented here will build upon the research and issues surrounding this topic and its relation to NL.

Figure 1: Characteristic AAR: Pattern Cracking

2 Literary Review

As part of this report, study and research has been completed to determine what causes AAR and the methods to mitigate this reaction. The findings of the literature review are presented throughout this section.

2.1 Alkali Aggregate Reaction (AAR)

AAR is a reaction that occurs between highly alkaline cement paste and reactive silica particles found in aggregates. The reaction produces a gel which exerts an expansive pressure on the concrete. Over time, this expansive pressure causes spalling and loss of strength of the concrete and could potentially lead to failure [1]. The cracking pattern (Figure 2) and the gel expansion (Figure 3) as a result of AAR are illustrated below.

The deterioration of concrete from AAR can be described in four steps [1]:

1. The alkaline solution attacks the silica particles in the aggregate converting it to a viscous alkali silicate gel.
2. Calcium ions react with the gel to convert it to a hard calcium silicate hydrate.
3. Remaining siliceous minerals are converted to alkali silicate gel. The resultant expansive pressure is stored in the aggregate.
4. The pressure accumulates and cracks form when the pressure is greater than the strength of the aggregate.

There are several methods of AAR mitigation. The two main factors causing AAR are the alkali content of the cement and the reactive silica content of the aggregate. By limiting either of these two factors, AAR can be reduced or eliminated. The use of cement with low alkali content would reduce AAR, as would the use of a non-reactive aggregate [2]. In some cases, low alkali cement or non-reactive aggregates are not readily available. In these instances, fine siliceous material, known as pozzolans, can be added to the concrete mixture to aid in the neutralization of the excessive alkalinity of the cement [2]. Pozzolans react with cement alkalis without forming an expansive gel.

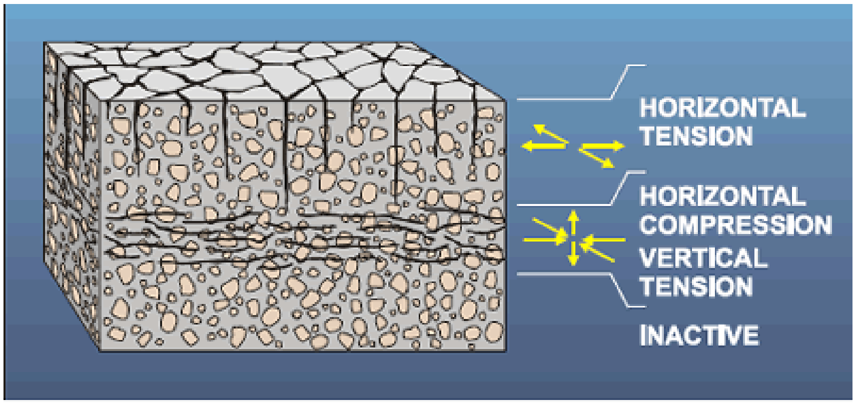

Figure 2: Idealized sketch of AAR cracking pattern in concrete mass [3]

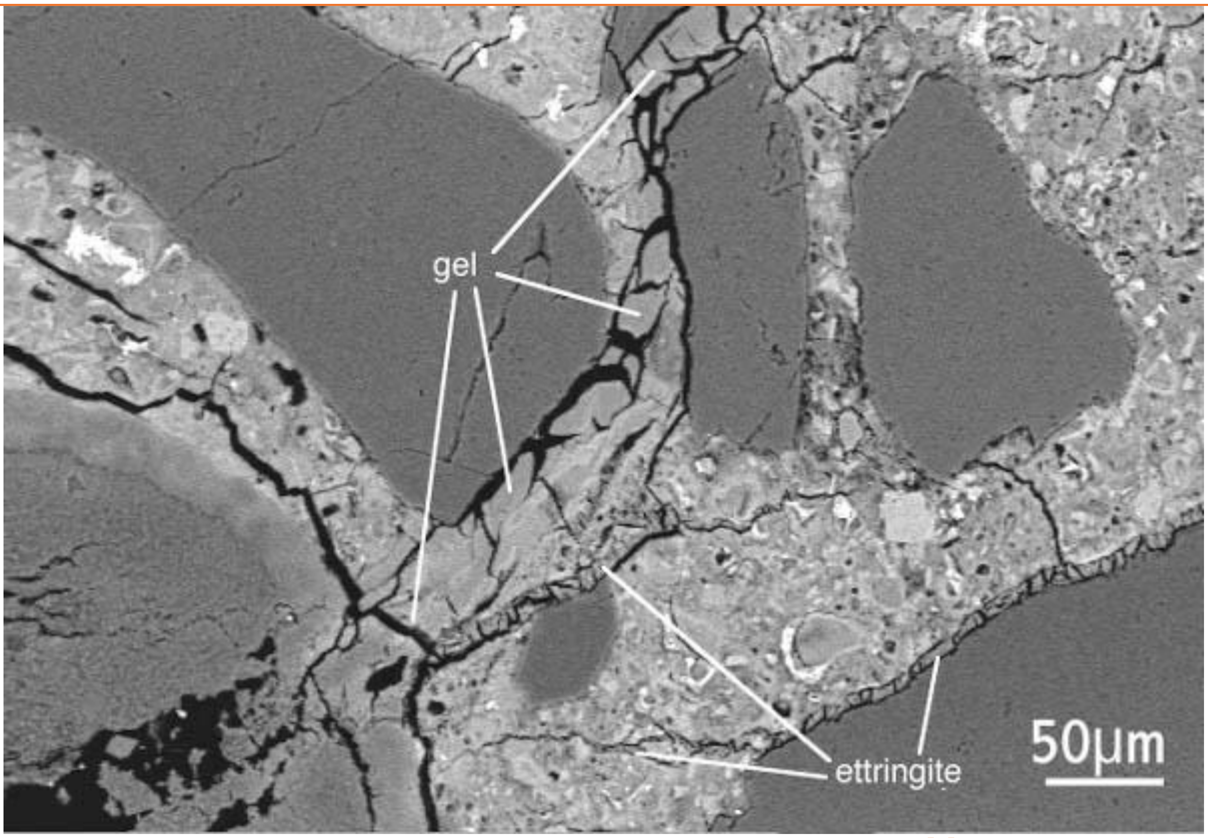

Figure 3: Magnified view of the gel which forms as a result of AAR [1].

2.2 Pozzolans

A pozzolan is defined as a siliceous material which alone possesses little or no cementitious value, but when finely divided and in the presence of moisture, chemically reacts with calcium hydroxide to form compounds possessing cementitious properties [4]. Materials with a high pozzolanic activity are useful as alternative cementitious materials and are used to replace a portion of cement in a concrete mixture.

Pozzolans can be natural or artificially created. Some commonly used pozzolans include fly ash, silica fume, metakaolin, and slag. Glass powder has also been proven to act as a pozzolan, if the particles are of a sufficiently small diameter. Smaller particles yield better results, and it is generally recommended that particle size be less than 75 [5].

There are many benefits to utilizing pozzolans as a partial substitute for cement in concrete mixtures. Since many pozzolans are by-products of industry processes, they are often cheaper than cement and, thereby, an economic benefit. Also, production of portland cement emits large quantities of greenhouse gases which are reduced by using pozzolans. Adding pozzolans to a concrete mixture can increase its physical strength and durability as well as its chemical resistance, which in turn extends its lifespan [6]. Through the proper use of pozzolans, AAR can be virtually eliminated from concrete.

2.3 Portland Cement

Portland cement is the main ingredient in concrete. It consists of a closely controlled chemical composition of calcium, silicon, aluminum, iron, and small amounts of other materials. Some materials used to create the aforementioned chemical combination are limestone, shells, chalk, shale, clay, slate, blast furnace slag, silica sand, and iron ore [7].

There are two different production processes which can be used in the manufacturing of portland cement, dry production and wet production. Both processes utilize quarried and crushed rock as their raw material. The main difference between the wet and dry processes is the presence of water when the raw material is mixed and fed through the heating kiln. After the material is heated, it is processed with the material listed above and forms a substance called clinker. Clinker is approximately 3-25 mm in diameter, and is the substance which is ground along with gypsum to create portland cement [7].

Concrete is designed to be strong and durable, and portland cement is what gives concrete these properties. These characteristics are produced through a chemical reaction between hydraulic cement and water. Portland cement hydrates to form new solids that become the foundation of hardened cement paste in concrete. Calcium-silicate-hydrate gel is the principal cementing component of concrete. It is responsible for setting, hardening, and strength development within the concrete [8].

The Cement Association of Canada operates 15 cement plants in five provinces, and produces over 98% of the cement used in Canada. The five provinces that produce cement are: Nova Scotia, Quebec, Ontario, Alberta, and British Columbia. The Cement Association of Canada in NL consists of only a distribution center of portland cement.

2.4 TerC^3

T3 is another alternative cementitious material that has been used in this project to test for the reduction of AAR in concrete. It is high-performance ternary blended cement manufactured with portland cement, fly ash, and silica fume. This triple blend contains 25% fly ash (class F), 5% silica fume, and 70% GU portland cement [9]. The cement test report and other information about the composition of T3 can be found in Appendix A.

The three materials used in this blend work synergistically to produce concrete that has superior strength, increased resistance to AAR, reducing chloride ion penetration, and improves long term durability [9]. The product meets all the requirements of ASTM C595/595 M-12 [10].

The blended cement contains post-industrial materials and can be used for projects where sustainable construction practices are required. During the production of this blended cement the fly ash, silica fume, and portland cement have been grinded to a smaller size creating more total surface area when compared to general use portland cement. Holcim (Canada) Inc. is the only producer of this type of blended cement product [10]. The cement is distributed to NL in bulk shipments to concrete batch plants [10]

2.5 Glass Powder

Glass powder is produced from post-consumer recycled glass material which comes from a variety of sources such as curbside pickup, fiberglass factories, and other glass recycling centers [2]. Glass powder can be used as a cement replacement in concrete mix designs. The use of glass powder affects the slump, compressive strength, and AAR resistance of the resultant concrete.

As is depicted in figure 4 below, as the percent of cement replacement with glass powder increases, so does the slump of the concrete mix [11]. This indicates that the workability increases, however too much glass powder will result in a highly liquid concrete batch [11].

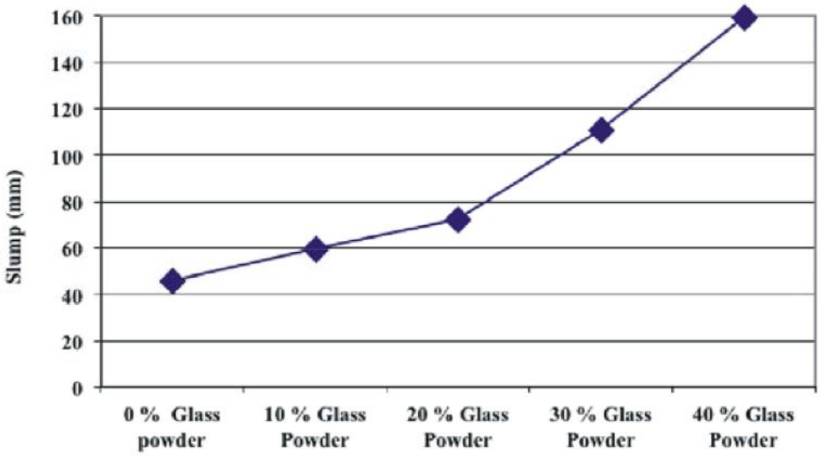

Figure 4: Percent of Glass Powder vs. Slump [11]

In relation to the increase in concrete slump, compressive strength decreases as percent of cement replacement with glass powder increases [11]. As shown below in figure 5, the compressive strength increases from the control at 10% glass powder, then proceeds to drop as more of the cement is replaced.

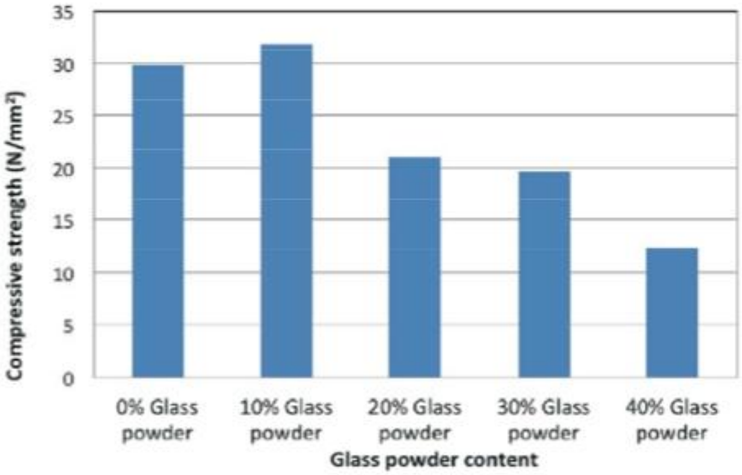

Figure 5: Percent of Glass Powder vs. Compressive Strength [11]

A further analysis of the compressive strengths of various mix designs, including glass powder, will be discussed in the results section of this report.

Due to its silica content, powered glass is considered a pozzolanic material and therefore displays properties similar to that of other pozzolanic materials such as fly ash, silica fume, metakaolin, and slag. Pozzolan materials are an effective AAR suppressant if used as an alternative cementitious material [12]. From previous research, it was determined that glass powder with less than 75 μm would act as a pozzolan and up to 30% glass powder could be incorporated as an effective cement replacement [12].

Glass powder is not readily available in NL. The province produces up to 5000 tonnes of recycled glass annually, but, unfortunately, there is no facility in NL which can process recycled glass to a sufficient amount to be used as a cement replacement powder.

For this project, glass powder was shipped from Poraver, a company located in Ontario. Recycled glass is turned into glass powder by first grinding, then mixing with water and certain chemicals after which it is granulated, expanded, cooled and finally sieved. The glass powder from Poraver had a particle size of less than 36 micrometers, and was used as a 10% and 20% cement replacement.

2.6 Silica Fume

Silica Fume, less commonly known as microsilica or condensed silica, is an alternative cementitious material which is commonly used as a replacement to portland cement in concrete mix designs [13]. It is produced as a byproduct in the manufacture of silicon or ferrosilicon alloys. During the process, silica fume rises as an oxidized vapor from of the reduction reaction of high-purity quartz with coal. The silica fume cools and condenses, and is then processed to remove impurities and control particle size [13]. Chemically, silica fume is an amorphous (crystalline) blend of silica dioxide (SiO_2) and various trace elements, depending on the fume type [14]. It is comprised of fine particles, about 100 times smaller than average cement particles, and averages approximately 0.1 μm in diameter, to a maximum of 1 μm. The silicon dioxide is the main component in silica fume, greater than 85% by mass, and is also the source of silica fume's pozzolanic properties [14].

The main benefits of silica fume as a cement additive or replacement is its role as a pozzolan. Pozzolans, as discussed earlier, help in reducing the effects of AAR in concrete mixes. It has been determined that a 7 to 10 percent cement replacement is the optimal mixture; however amounts up to 15 percent have been used [15]. The more silica fume is added, the stronger and more brittle the resultant concrete becomes [15]. Other benefits include increased cohesion and reduced bleeding in fresh concrete (liquid form), as well as reduced permeability and higher compressive strength in hardened concrete [14]. However, the workability of concrete can be reduced due to the addition of silica fume.

Silica fume is used as a concrete replacement material in NL; however other pozzolans are more readily available.

2.7 Fly Ash

Fly ash, less commonly known as flue-ash, is a finely divided residue that is produced with the combustion of coal. It is most commonly found as a byproduct in coal-fired electrical power plants [16]. The chemical properties of this coal byproduct can vary considerably depending upon the source and makeup of the coal being burned, but always consists of both silicon dioxide (SiO_2) and Calcium Oxide (CaO) [13].

Fly ash has pozzolanic properties, as discussed earlier. This means it possess little or no cementitious value on its own, however when mixed with water it will react with calcium hydroxide to form compounds that have cementitious properties [17]. Because of its pozzolanic properties, fly ash is commonly used as a replacement for portland cement in concrete.

When used as a cement replacement, fly ash enhances the performance of the resultant concrete. These performance advantages include improving the workability of the concrete, reducing the amount of required water, reducing segregation and concrete bleeding, as well as lowering the heat of hydration. Fly ash is also known for increasing the strength of concrete, reducing permeability, reducing corrosion of reinforcing steel, and reducing AAR [18]. For the purposes of this research, Class F fly ash was utilized.

2.8 Reactive/Non-Reactive Aggregates

Concrete consists of a combination of aggregates with different physical properties and chemical compositions. In some concrete, aggregates are more or less chemically inert. However, some aggregates have characteristics that allow them to react with the alkali hydroxide in cement causing expansion and cracking over a period of many years [19]. This characteristic is extremely important when choosing aggregates to mitigate AAR. Non-reactive aggregates are ideal for avoiding AAR, however, they are not as commonly used in concrete as reactive materials due to lower availability [19]. Only reactive aggregate was used for the purpose of this research, due to time and batch quantity constraints.

3 Methodology

During this project, experiments were completed on the reduction of AAR in concrete. Initially, the Design of Experiments (DOE) method was to be utilized for the project. DOE is used to enhance and increase the results while decreasing the total number of combination batches required during the experimental project. During the time of initial batch planning, the details of available resources at the AMEC lab were unknown. As a result of this, it was assumed that sufficient resources were available at lab that would allow for the effective use of the DOE. A minimum of 5 factors are required for an effective DOE approach. The 5 factors that were planned to be incorporated in the Design of Experiments included the ratio of fly ash to portland cement, the ratio of silica fume to portland cement, the ratio of powdered glass to portland cement, the ratio of slag to portland cement, and the use of reactive/non-reactive aggregate.

However, once informed of the resources available at the AMEC lab it was realized that design of experiments method would not be possible for this project. To complete one accelerated mortar bar expansion test a minimum of 3 bars were required per batch. With the availability of only 6 bar moulds, the testing was limited to a minimum of two batches to be completed per week (on every Monday starting Feb 18th, 2013). The mortar bar tests were batched only on Monday's since the demoulding occurred on Tuesday with initial reading requirements over the remaining of the week. A total of five days to complete set-up for the mortar bars was required and since the lab was not assessable during the weekend the only day to batch mortar bars was on the Monday of each week. Although there were adequate cube moulds available to be used in the completion of the mortar cube compressive strength tests, the required testing time and resources for the accelerated mortar bar expansion tests limited the total number of batches that could be completed in the project.

As a result of the resource limitations the original planned DOE method that required five factors would have resulted in a total of sixteen concrete batches. The limitations of resources and time allowed for only eight batches to be completed. Through meetings with the client it was identified that just one variable would be changed during the experiment, the percentage of portland cement. The portland cement would be replaced with varying percentages of silica fume, fly ash and glass powder only with two control batches of general use concrete and TerC^3 blended hydraulic cement. Slag was not used since it is not readily available in NL and a known reactive aggregate was used to ensure AAR would occur.

Through research it was determined that fly ash and silica fume are currently used in the concrete industry to suppress expansion caused by AAR. An average value of portland cement replacement for fly ash and silica fume are 20% to 30% [20] and 7% to 10% [15], respectively. The third replacement material was provided by AMEC as the main study material to be tested. The study requested by AMEC required that a literary review of glass powder and glass aggregate be completed in order to determine the best type of glass material to be tested. Through analysis of the EN 8700 AMEC group of 2011 report and the "Value-added Utilisation of Waste Glass in Concrete" report by Ahmad Shayan [12] it was determined that only glass as a powder would be tested. Therefore, during the experiment we tested several different percent combinations of each alternative cementitious material. The controls for the experiment are general use concrete and TerC^3. General use concrete is known to perform poorly when tested for AAR and will therefore be used as a comparison for all other testing. TerC^3 is hydraulic blended cement used for high strength applications and is known to greatly reduce AAR. A disadvantage of TerC^3 is that it is expensive cement and is usually only used for projects of high importance.

The batch combinations are presented below in Tables 1 & 2. Table 1 is a detailed list of the Accelerated Mortar Bar Expansion Test batch design. It lists the mass of cement, fly ash, silica fume, glass powder, water and aggregate that is incorporated in each batch design. As well, table 2 is a detailed list of material masses for each batch of the Mortar Cube Compressive Strength Test batch designs.

Table 1: Mortar Bar Expansion Test Batch Design

Batch #	Batch Name	Symbol	Mass (g)					
			Cement	Fly Ash	Silica Fume	Glass Powder	Water	Aggregate
1	General Use	GU	440	0	0	0	193.6	990
2	TerC^3	TerC^3	440*	0	0	0	193.6	990
3	25% Fly Ash	25FA	330	110	0	0	193.6	990
4	10% Silica Fume	10SF	400	0	40	0	193.6	990
5	20% Glass Powder	20GP	352	0	0	88	193.6	990
6	20% Glass Powder + 10% Fly Ash	20GP+10FA	308	44	0	88	193.6	990
7	10% Glass Powder	10GP	396	0	0	44	193.6	990
8	10% Glass Powder + 10% Fly Ash	10GP+10FA	352	44	0	44	193.6	990

Table 2: Mortar Cube Compressive Strength Test Batch Design

Batch #	Batch Name	Symbol	Mass (g)					
			Cement	Fly Ash	Silica Fume	Glass Powder	Water	Aggregate
1	General Use	GU	600	0	0	0	360	2000
2	TerC3	TerC^3	600*	0	0	0	360	2000
3	25% Fly Ash	25FA	450	150	0	0	360	2000
4	10% Silica Fume	10SF	540	0	60	0	360	2000
5	20% Glass Powder	20GP	480	0	0	120	360	2000
6	20% Glass Powder + 10% Fly Ash	20GP+10FA	420	60	0	120	360	2000
7	10% Glass Powder	10GP	540	0	0	60	360	2000
8	10% Glass Powder + 10% Fly Ash	10GP+10FA	480	60	0	60	360	2000

4 Testing Procedures

Cretecon Consulting conducted all experimental testing at the AMEC field lab located at 36 Pippy Place, St. John's, NL. All concrete batching and testing was performed by members of Cretecon under the guidance and supervision of AMEC lab employees. All safety requirements while in the lab were to that of AMEC policy. Material Safety Data Sheets (MSDS) for all lab materials handles can be found in Appendix B.

For the experiment, eight (8) different concrete mixes were tested with differently proportioned combinations of cementitious materials. The cementitious materials tested included glass powder, fly ash, and silica fume. Two control materials were also tested; one being general-use (GU) cement and the other being TerC^3 hydraulic blended cement.

To study the effects of glass powder on AAR in concrete, Cretecon preformed two separate experimental tests; the accelerated mortar bar expansion test, as well as the mortar cube compression test. Both testing methods were performed to the required ASTM standards. The mortar bar test is a 14-day test that measures expansion and/or shrinkage in a concrete specimen. The compression test is a standard concrete test that measures the compressive strength of the concrete. The compression test took place at the 7th, 14th, and 28th day after the day of batching. Two extra cubes for each mix design were made, and will be tested on day 56 by AMEC personnel.

4.1 Accelerated Mortar Bar Expansion Test

This 14-day test was completed in compliance with ASTM C1260-07 (Standard Test Methods for Potential Alkali Reactivity of Aggregates, Mortar Bar Method), found in Appendix C [21]. For each mix design, three (3) test specimens were created. All the aggregates which were used in this test method were graded in accordance with the requirements present in Table 3. All material used was dried and de-hydrated prior to being sieved. After the aggregate had been separated according to sieve sizes, each of the various sizes was stored individually in clean containers until required for batching.

Table 3: Mortar Bar Grading Requirements

Sieve Size		Aggregate Composition
Passing	**Retained**	**Mass %**
5 mm	2.5 mm	10
2.5 mm	1.25 mm	25
1.25 mm	630 ųm	25
630 ųm	315 ųm	25
315 ųm	160 ųm	15

Mixing of the mortar was in compliance with the requirements of ASTM C 305. The summarized procedure for mixing was as follows;

1) Add water and cementitious materials to mixing bowl; mix on slow for 30 seconds.
2) While still mixing, add aggregate slowly over 30 seconds.
3) Stop mixer, change speed to medium speed for 30 seconds.
4) Stop mixer, cover material and let stand for 90 seconds.
5) Mix material again for 60 seconds on medium speed.

Test specimens were moulded within a total elapsed time of two minutes and fifteen seconds after the completion of the original mixing. Prior to moulding, the testing apparatus were completely covered with WD40. WD40 serves as an acceptable parting agent because it does not affect the setting of cement, nor does it leave any residue that will inhibit the penetration of water into the concrete. The moulds (Figure 6) were filled in two equal layers, each layer being compacted with a tamper. Special attention was given to the ends of the bars where the mortar required extra compaction to thoroughly settle under the gauge studs. After the top layer was compacted, the mortar was cut flush with the top of the mould, and the surface was finally made smooth with a few strokes of a trowel.

Figure 6: Mortar Bar Test Mould

After the bars were casted, they were immediately placed in a moist room for 24 hours, where they were left to set. The following day the bars were removed from the moulds and marked for identification. Following the initial readings on day one, the bars were submerged for the next 24 hours in tap water and placed in an oven at approximately 80 °C. After the readings on day two, the bars were placed into a sodium hydroxide solution, where they stay for the remainder of the testing duration.

Figure 7: Mortar Bars in NaOH solution

Submerging the specimens in the sodium hydroxide solution (Figure 7) accelerates the AAR, which would normally take place over multiple years. This allows for short-term analysis of the effects AAR will have on different mix designs. The solution consisted of 40 grams of sodium hydroxide for every 1 liter of distilled water. An adequate volume of mixture was used in order to have the mortar bars completely submerged. Large Rubbermaid containers allowed for sufficient storage of the bars gave sufficient spacing, and limited moisture loss. The mortar bars were, again, stored in a convection oven at a controlled temperature of 80.0°C ± 2.0°C.

Figure 8: AAR Testing Apparatus

During testing, the containers were removed from the oven one at a time. Only once the bars in the first container were measured and returned to the oven would the next container be removed. Bars were also removed from the solution one at a time, where they were immediately dried with a damp towel. To ensure reading accuracy, special attention was given to drying the two metal measuring studs at each end of the bars. After being dried, the measurement of the bar was taken in the apparatus shown in Figure 8, where the value was read as soon as the bar was in position. Once all three bars (like those shown in Figure 9) were measured they would be returned to the solution and then replaced in the oven. It was made sure that the total elapsed time for drying and measuring was less than 20 seconds, and the total time the containers were removed from the oven was less than 5 minutes. Subsequent measurements of the bars were taken 3 days a week, typically on Mondays, Wednesdays, and Fridays; for a total of 14 days. All testing results can be found in the results section of this report.

Figure 9: Bars during reading time

4.2 Mortar Cube Compression Strength Test

This test was completed in compliance with ASTM C109/109M-12, Standard Test Method for Compressive Strength of Hydraulic Mortars (Using 2" or 50mm Cube Specimens), found in Appendix C [22]. For each mix design, six (6) test specimens were made. All aggregates that were used in this test were dried and de-hydrated, then graded in accordance with the requirements in Table 4. Once the material was collected from each different size sieve, it was stored altogether in one clean container until required for use in a batch. This differs from the aggregate used for the mortar bars since individual weights of the each aggregate size were required, whereas for the cubes, one weight for the aggregate as a whole was required.

Table 4: Mortar Cube Grading Requirements

Sieve Size		Aggregate Composition
Passing	Retained	Mass %
2.5 mm	1.25 mm	25
1.25 mm	630 ųm	25
630 ųm	315 ųm	25
315 ųm	160 ųm	15

Mixing of the mortar was in compliance with the requirements of ASTM C 305. The summarized procedure for mixing that was used is as follows;

1) Add water and cementitious materials to mixing bowl; mix on slow for 30 seconds.
2) While still mixing, add aggregate slowly over 30 seconds.
3) Stop mixer, change speed to medium speed for 30 seconds.
4) Stop mixer, cover material and let stand for 90 seconds.
5) Mix material again for 60 seconds on medium speed.

Test specimens were moulded within a total elapsed time of two minutes and thirty seconds after completion of the original mixing. Similar to the mortar bar moulds, the cube moulds were first covered in WD40, which serves as an acceptable parting agent. Mortar was first placed in layers of about 22mm, or half the mould height, in each of the cube mould compartments. These layers were then tamped in four rounds of 8 tamps per round, for a total of thirty-two tamps. Each round would be at right angles to the previous round. The thirty-two tamps would be completed in one mould compartment before moving to the next. When the tamping of the first layer for each cube was complete, the second layer of mortar was placed, followed by a second round of tamping that matches the first round. After completion of the tampering, the mortar was cut flush with the top of the mould, and the surface was finally made smooth with a few strokes of a trowel.

Figure 10: Cube Moulds

Immediately upon completion of the moulding, the test specimens were placed into a moist room where they were allowed to cure for twenty-four hours. Once curing was completed, the cubes were removed from the moulds (Figure 10), identified with a marker, and replaced back into the moist room until the time of testing. Compression tests were completed on days 7, 14, and 28. The test was completed immediately after the cube was removed from the moist room. Prior to testing, the cubes were surfaced dried and any loose sand grains or encrustations were removed from the faces that would be in contact with the bearing blocks of the testing machine.

For testing, each specimen was carefully placed onto the testing machine below the center of the upper bearing block. A load was continuously applied to the specimen at a constant rate within in the range of 0.15 MPa/s to 0.35 MPa/s until failure of each specimen was reached. Compressive strength of each specimen was calculated by dividing the maximum load carried by each cube by the cross-sectional area. All testing results can be found in the results section of this report.

5 Feasibility Study

If glass powder is to be a real solution to AAR reduction in concrete, it must be readily available to the NL concrete industry. For this to occur, glass powder must be able to be produced in the province, and at a comparable price to other solutions such as fly ash. An investigation into the implementation/feasibility of the production of cement replacement grade glass powder within NL is required.

5.1 Recycled Glass in NL

Currently, glass recycling in NL is conducted by both the government and the private sector. Beverage companies, specifically beer companies such as Molson and Labatt, operate their own deposit-refund system. These programs do not alter the bottles in any way. The bottles are simply reused in the same form, as beverage containers. Because this program is already reusing glass in an efficient manner, it would not be considered a source for glass powder production.

The government also operates a glass recycling program through the MMSB [23]. MMSB is a Crown agency of the Government of NL, which was formed in 1996 to "develop, implement and manage waste diversion and recycling programs on a province-wide basis" [23]. Recycling programs within MMSB include the Used Beverage Container Recycling Program, the Tire Recycling Program, Used Oil Recycling Program, Household Hazardous Waste Collection Program and a Residential Backyard Composting Program. Glass recycling in particular falls under the Used Beverage Container Recycling Program.

The Used Beverage Container Recycling Program is a deposit-refund system which is financed through an 8 cent consumer deposit on non-alcoholic beverage containers and a 20 cent consumer deposit on alcoholic beverage containers [23]. Once a bottle is returned to a Green Depot for recycling, a 5 cent refund is given for non-alcoholic containers and a 10 cent refund for alcoholic containers [23]. The majority of containers which are processed in this program are composed of non-glass materials such as plastics or aluminum [23]. More than 160 million used beverage containers were collected and recycled in 2010-11, however only 5000 tonnes of glass is recycled by MMSB, annually in NL [23] [24].

Due to the limited glass processing capabilities of MMSB, glass that is recycled in NL is crushed only to a 1" minus size and contains contaminants and impurities such as stoppers, labels, and other foreign objects [24]. The main purpose of this processing is to reduce the volume of the glass for shipping [24]. In order for this glass to be used as a source for glass powder, additional processing would be required to further reduce the particle size as well as to remove the impurities [24]. Currently, MMSB ships their 1" minus, contaminated product to New Brunswick (NB), costing approximately $200,000.00 annually, where it is processed into a glass cullet which is sold as a general product for various uses [24].

One of these uses is as an ingredient in the production of glass powder. A grinding process turns the recycled glass cullets into glass powder which measures a maximum of 75 µm in diameter [25] [12]. The powder is then mixed with water and an assortment of chemicals, granulated, expanded, cooled, and finally sieved to create glass powder which can be used a cement replacement [25]. Therefore, MMBS collected recycled glass could be a source for glass powder production in NL, however more glass processing infrastructure would be required within the province.

5.2 Feasibility Cost

As stated earlier, MMSB's recycled glass is a potential source of glass powder in NL, however the product would require further processing which is currently only available via shipping to New Brunswick (NB). If cement replacement glass powder is to be implemented in NL, the appropriate processing facilities would be required within the province. The government or private industry would need to fund upgrades to existing glass processing facilities or construct a new facility capable of the additional processing.

An investigation into the costs associated with construction of such a facility in Nova Scotia (NS) was conducted by SNC-Lavalin Inc. in 2006. The following tables are a breakdown of the start-up and operational costs associated with implementing a post-consumer recycled glass handling facility in Nova Scotia (NS). The proposed facility was based on a specialized processing system capable of sorting glass by colour and removing a high level of contaminants [26]. This facility would be able to process recycled glass into a ½" minus cullet product, similar to the NB facility, where MMSB is currently shipping glass for processing. Machinery included in cost estimate for this facility included a glass crusher, conveyors for manual sorting, screens, a magnet, an eddy current separator, specialized colour separation equipment, and specialized ceramic/metal removal equipment [26].

Table 5: Capital Cost Estimate for Post-Consumer Glass Handling Facility

Item	Cost
Land Purchase	--
Site Preparation - Site grading, excavation, clearing, grubbing, etc. Assumptions:• size of site: 150m x 150m; • 0.25 m of excavation and backfill for the site at $10/m.	$56,250
Access Road	--
Onsite Paving Assumptions:• 1000 m2 of the site would require paving, at a cost of $20/m2	$20,000
Glass Handling Building - To accommodate a tipping floor, two loading bays, and loader operations it was assumed the building would have to be approximately 1000m2. The unit cost of the metal prefabricated building with radiant heating and ventilation system, including concrete floor is estimated to be $750/m2.	$750,000
Office - includes septic and water	$50,000

Weigh Scale	$250,000
Power Supply - Extend Power Supply @ $25/m	--
Processing Equipment - Based on information from Andela for specialized system to process glass to specifications typically required for container manufacturing.	$1,800,000
Loader	$150,000
Fencing and Gates - 3m fence around perimeter of site (approx.600m) at $55/m. Assumptions:• $2000 for gates; • $300 for signage.	$35,300
Landscaping	$10,000
Sub-Total	$3,121,550
Contingency (10%)	$312,155
Engineering (15%)	$515,056
TOTAL	**$3,948,761**

As can be seen, a facility capable of processing recycled glass to a ½” minus cullet product has a substantial start-up cost. Some of these costs could be cut in the case of implementing a similar facility in NL. For example, an existing building could be remodeled instead of constructing a new structure; however this is a good base cost for determining the feasibility of such an undertaking.

Processing recycled glass to this extent yields high operation and maintenance (O/M) costs. Processing the glass from a recycled container into a ½” minus cullet or powder creates a large amount of wear and tear on the required machinery, due to the abrasive nature of the glass [26]. Also, due to possible exposure to harmful particulates during the crushing operation, specialized ventilation equipment is required to ensure worker safety [26]. The following table gives an outline of the possible annual O/M costs associated with a recycled glass processing plant.

Table 6: Annual O/M Cost Estimate for Post-Consumer Glass Handling Facility

Item	Cost
Staffing - Four permanent employees @ $15/hour + 35% payroll burden	$168,480
Maintenance (@ $5/tonne) - based on 12,000 tonnes/year	$60,000
Loader Operation - 5 hr/day @ 5 days/week@ 52 weeks/year@$40/hr	$52,000
Transportation to Scoudouc, NB	--
Snow Clearing	$10,000
Power Lighting, misc.	$1,500
TOTAL	**$291,980**

Given that this cost analysis was completed in 2006, inflation should be considered from that time to 2013. From this, we can determine what the costs of constructing and operating a glass processing facility would be in today's dollars if a similar facility were to be constructed and operated in NL. The change in cost due to inflation was calculated using the Bank of Canada's Inflation Calculator [27]. The results are indicated in the Table 7 below.

Table 7: Inflation Cost Correction 2006 – 2013

Item	2006 Cost	2013 Cost
Capital Cost	$3,948,761	**$4,426,846**
Annual Operation/Maintenance Cost	$291,980	**$327,331**

However, since this facility can only produce a ½" minus glass cullet, more processing would be required to grind the glass into a powder suitable for cement replacement. As stated earlier, cullets must be grinded into powder, mixed with water and an assortment of chemicals, granulated, expanded, cooled, and finally sieved to create glass powder, which can be used as a cement replacement [25]. This would require the facility to be upgraded to include the necessary machinery, and as a result costs would actually be higher than depicted in the table above [26]. For the purpose of this investigation, a conservative assumed cost of $1,000,000.00 will be made to reduce the ½" cullet to a <75 micrometer powder. This $1,000,000.00 is an assumption for the extra processing equipment required to produce the finished glass powder product. This cost was chosen based on a limited knowledge of the required processes and further investigation will be required if a more in-depth analysis is to be completed in the future.

Table 8: Total Costs

Item	2013 Cost
Capital Cost + Assumed Costs for Extra Processing Equipment	**$5,426,846**
Annual Operation/Maintenance Cost	**$327,331**

These numbers will be used as a best case price for implementation of a glass powder production facility in NL. The potential capital return on constructing a recycled glass processing facility capable of producing cement replacement glass powder will determine the feasibility of such an investment.

5.3 Breakeven Analysis

Through consultation with Melaine Jarvis, CGA, a breakeven analysis was produced using the following assumptions:

- Start-up loan monthly payments are included in the analysis to better indicate project feasibility; even though this is not normal practice in a breakeven analysis (Normally only the interest payment on the loan is included).

- Interest rate of 4% for start-up loan.
- Payback period of 20 years.
- Price of finished glass powder product per tonne ranges from $150 to $250 [See Appendix D]. This is based on the price of fly ash, portland cement, and silica fume. Fly ash and portland cement cost approximately $250 per tonne in NL [28] Silica Fume can cost anywhere from $250-$700 per tonne [28].
- The 5000 tonnes of recycled glass collected by MMSB annually will have 100% conversion to glass powder product (best case assumption). This volume will fluctuate throughout the project duration, and has the potential to increase as the project matures.

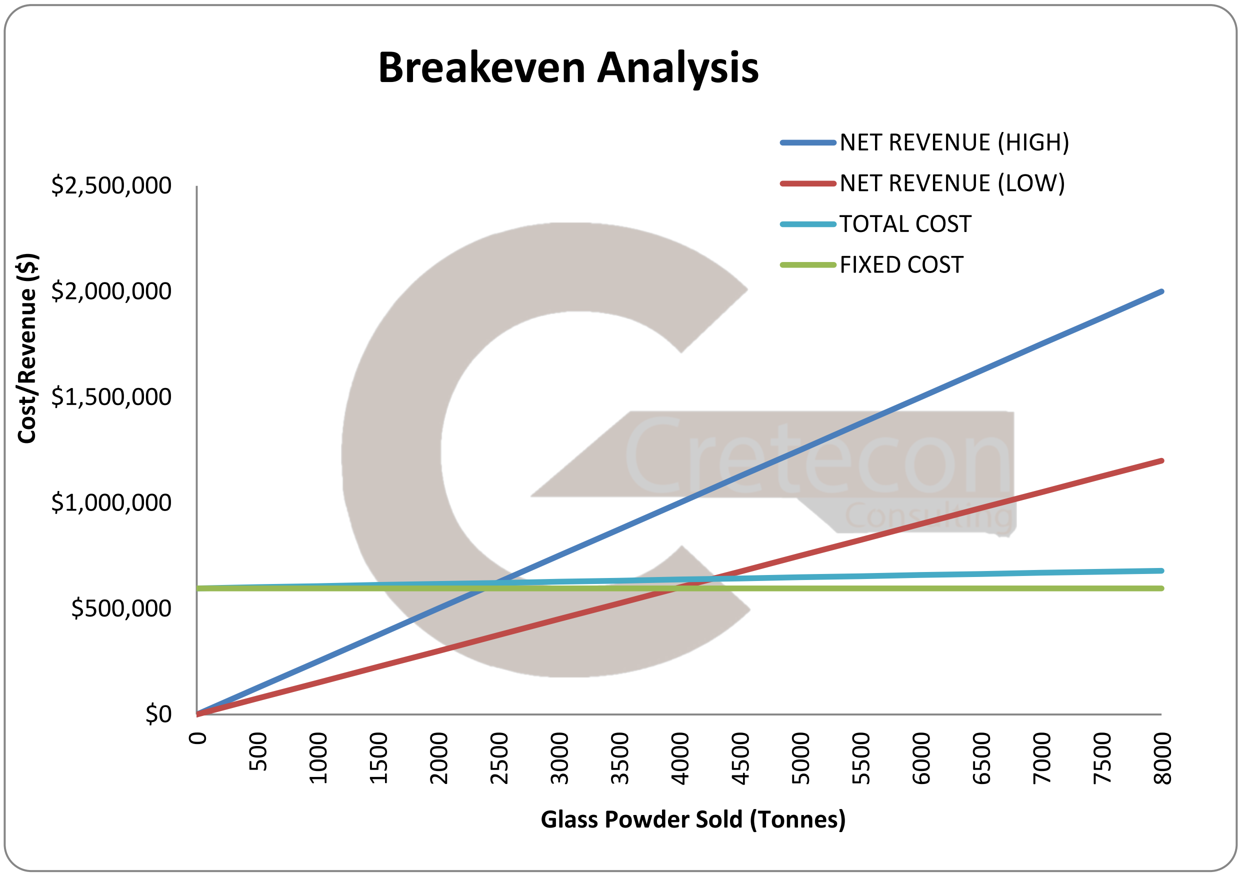

Figure 11: Breakeven Analysis

The breakeven analysis (Figure 11) displays annual net revenue plotted against the annual total and fixed costs. The fixed costs include costs for operation and maintenance and loan payments. The total costs include the fixed costs as well as variable costs. Variable costs result from the loader operation and maintenance which will increase depending on the amount of glass powder produced.

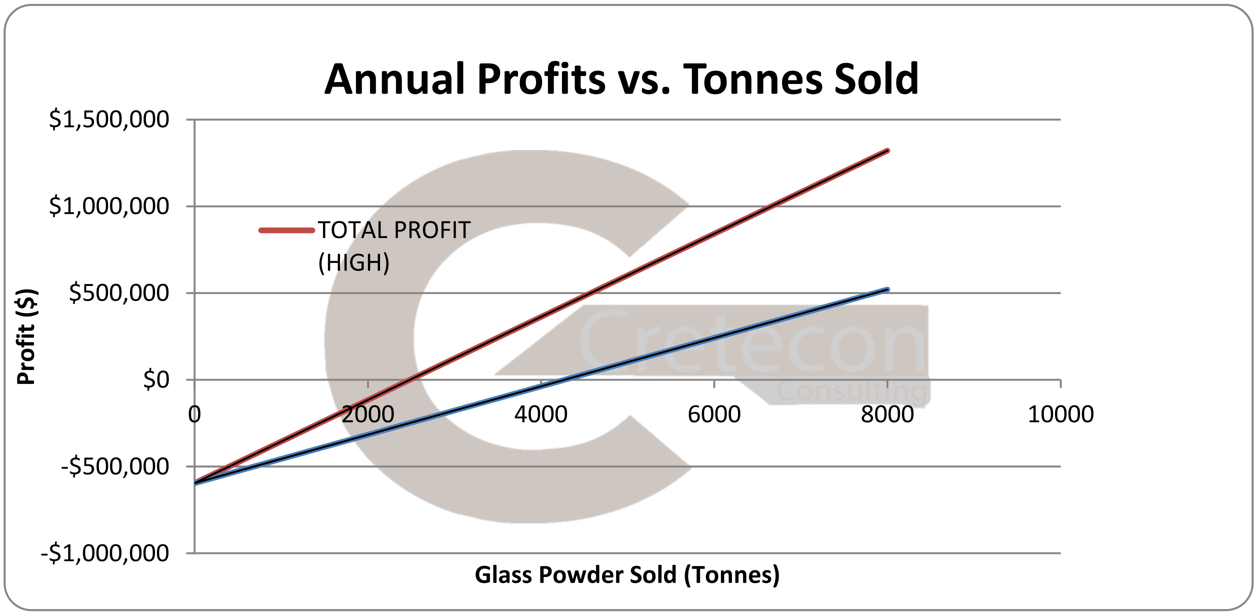

Figure 12: Annual Profit vs. Tonnes Sold

Annual Profits vs. Tonnes Sold (Figure 12) indicates the minimum number of tonnes that must be sold annually to make a profit. For the low price of glass powder ($150/tonne), 4323 tonnes of glass powder must be sold to break even. If all 5000 tonnes are sold, a profit of $101,550 can be made (Table 9). For the high price of glass powder ($250/tonne), 2594 tonnes must be sold to break even (Table 9). If all 5000 tonnes are sold, a profit of $601,500 can be made.

Table 9: Breakeven and Profits

Price	Tonnes Sold to Breakeven	Profits (Based on 5000 Tonnes Sold)
Low Price (150/tonne)	4323	$101,550
High Price (250/tonne)	2594	$601,500

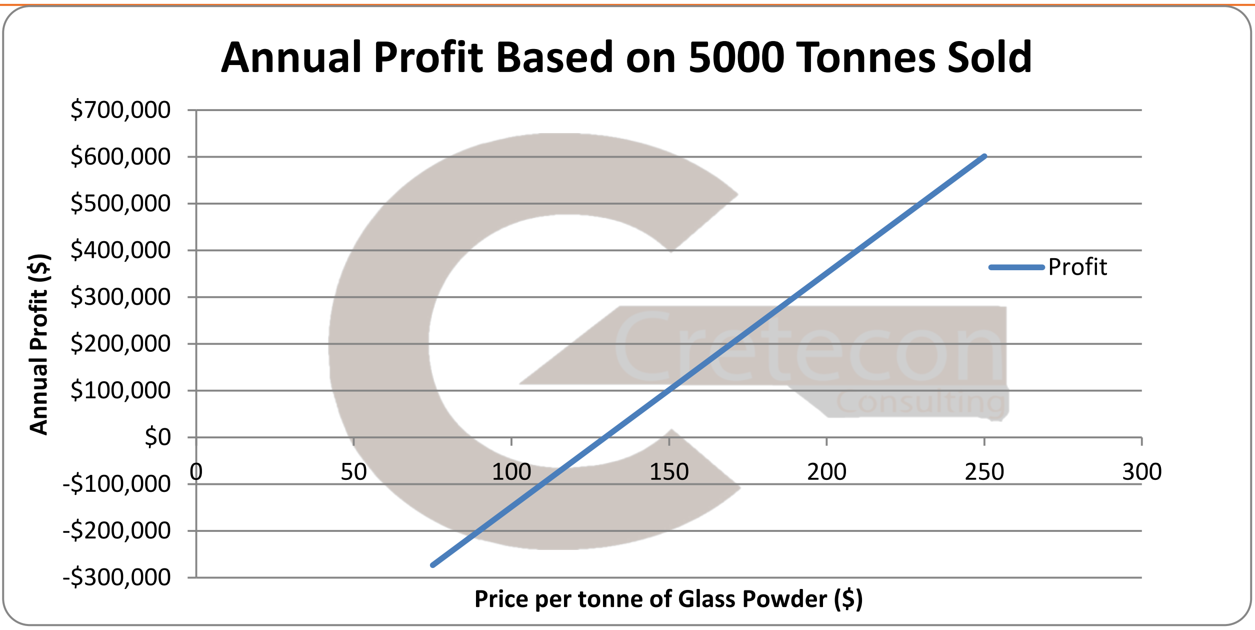

Figure 13: Annual Profit Based on 5000 Tonnes Sold

As presented in Figure 13 the Annual Profit Based on 5000 Tonnes Sold, a minimum price of $130/tonne must be charged in order to breakeven.

5.4 Feasibility Summary

The results of the investigation into the feasibility of implementing recycled glass powder production in NL are promising. Based on the breakeven analysis, such a venture could be profitable, even when incorporating monthly payments on the initial start-up loan. Possible annual profits were shown to range from $101,550 (selling at $150/tonne) to $601,500 ((selling at $250/tonne). Considering MMSB is currently operating its glass recycling program at a loss, the large initial investment may be justifiable, if the business could become profitable. It should also be noted that MMBS indicated that the use of glass as a packaging material is declining [24]. However, if glass powder were to be produced in province, MMSB could increase their marketing toward recycling glass and the annual collection of 5000 tonnes/year could be increased, as long as glass is used in the packaging industry. There are still many unknowns involved in such an endeavor, and a full implementation study should be completed by an expert before any further action is taken.

6 Test Results

6.1 AAR Test Results

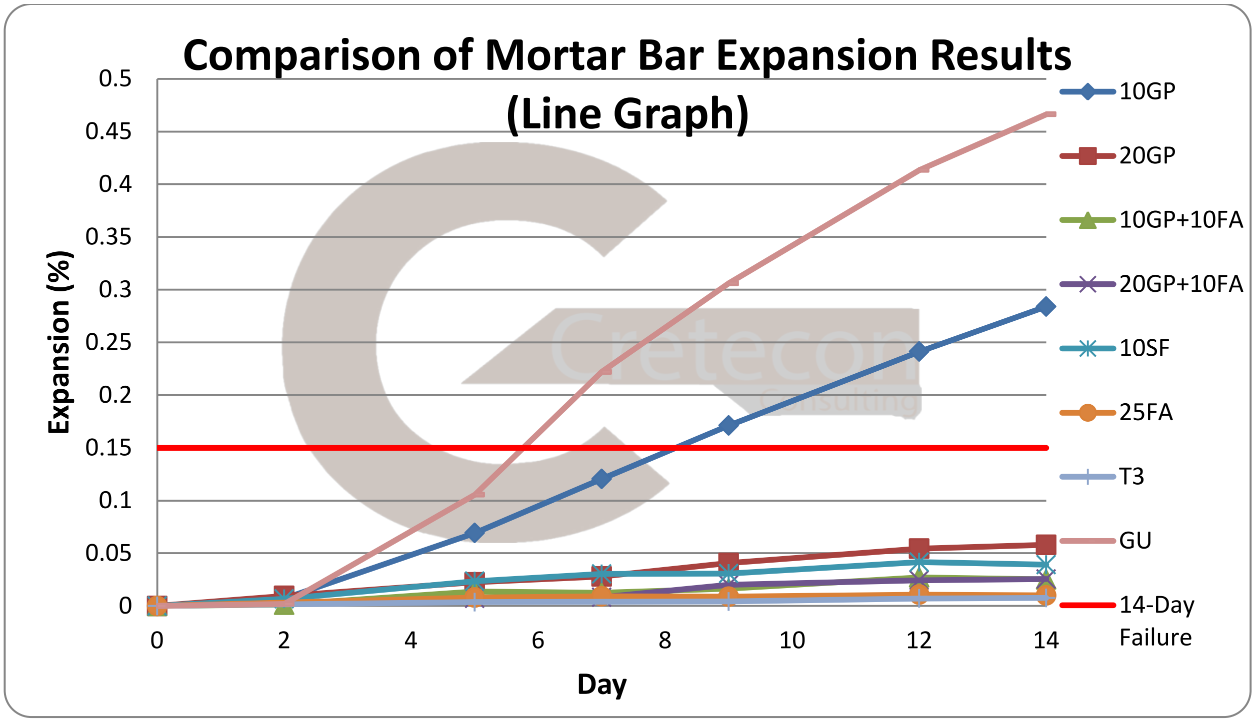

Figure 14: Comparison of Mortar Bar Expansion Results (Line Graph)

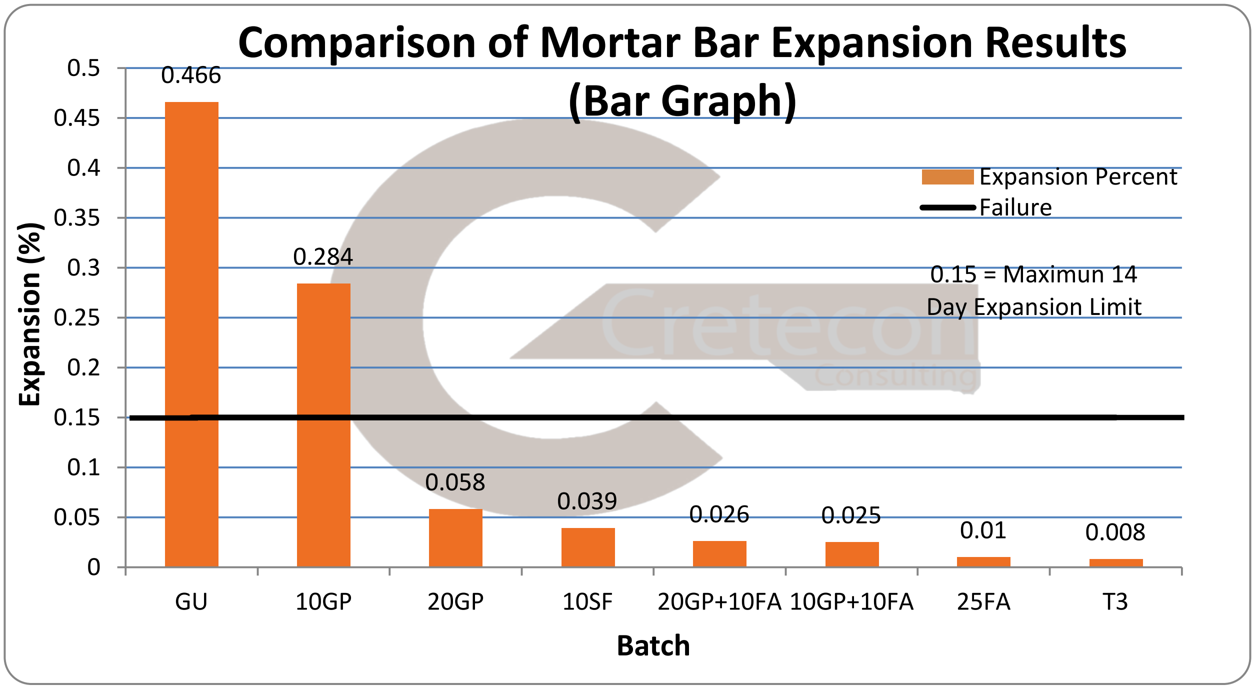

Figure 15: Comparison of Mortar Bar Expansion Results (Bar Graph)

6.2 Analysis of Results

6.2.1 Controls

Both controls performed as expected. GU expanded the most which was excepted since there are no alternative cementitious materials added to help minimize AAR. TerC^3 performed the best against AAR which was also expected since TerC^3 is a hydraulic blended cement with additives to mitigate AAR.

Figure 16: TerC3 Mortar Bar. No Signs of Expansion.

Figure 17: GU Mortar Bar. Expansion Cracks Visible.

6.2.2 Fly Ash and Silica Fume

25FA performed extremely well and was almost equal to TerC^3. 10SF also performed well and was lower than the acceptable limit for percent expansion. Both 25FA and 10SF agreed with prior research conducted and are effective at reducing AAR.

Figure 18: 25FA Mortar Bar. No Signs of Expansion.

Figure 19: 10SF Mortar Bar. No Signs of Expansion.

6.2.3 Glass Powder

The 10GP batch failed the expansion test, although the batch still performed better than GU. 20GP performance improved significantly, and mortar bars passed the expansion test. This demonstrates that AAR is reduced as more glass powder is added to a concrete mixture. 20GP performance was on par with materials currently used in industry such as silica fume and fly ash. 20GP could be considered as a viable replacement for silica fume and fly ash from an AAR perspective.

Figure 20: 20GP Mortar Bar. No Signs of Expansion.

Figure 21: 10GP Mortar Bar. Expansion Cracks Visible.

6.2.4 Glass Powder + Fly Ash

The 20GP+10FA and 10GP+10FA batches performed at a similar level. It appears that the additional glass powder in the 20GP+10FA mixture had little effect at reducing AAR. This does not agree with the results obtained from glass powder only where additional glass powder reduced AAR. This suggests when glass powder is in the presence of fly ash, the fly ash has more control over AAR mitigation. This being said, glass powder is still effective in this mixture since it reduces the amount of portland cement used with no significant loss of compressive strength.

Figure 22: 10GP/10FA Mortar Bar. No Signs of Expansion.

Figure 23: 20GP/10FA Mortar Bar. No Signs of Expansion.

6.3 Compressive Testing

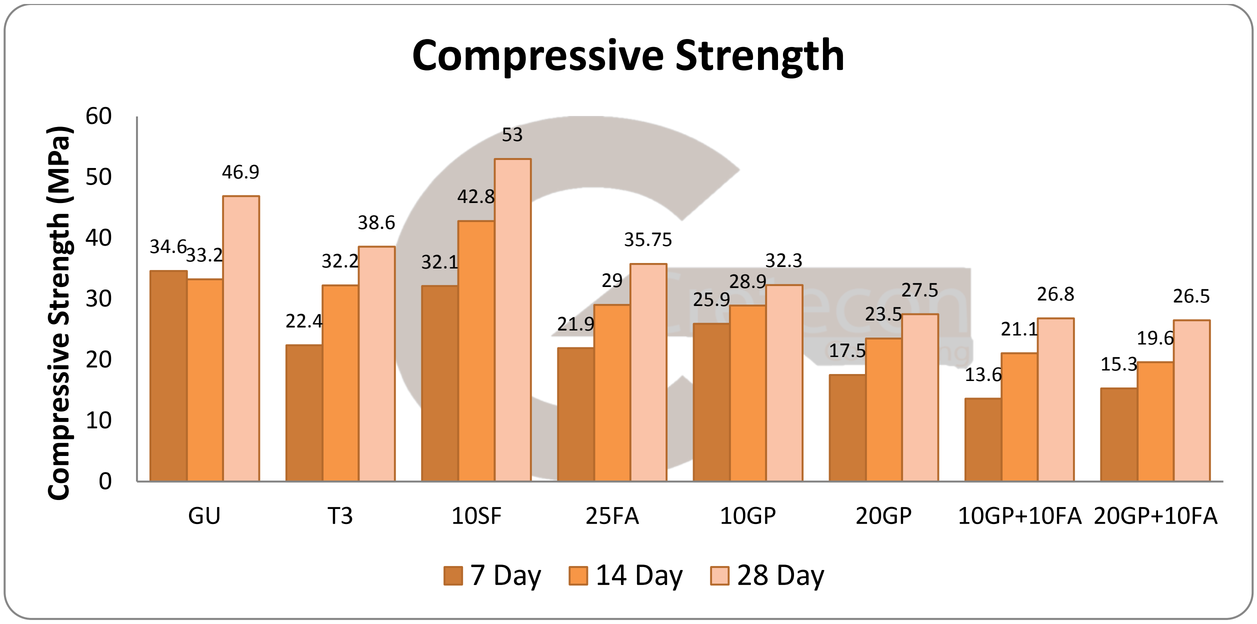

Figure 24: Results of Compression Testing

For the compressive strength, no set value was pre-determined before testing. Each batch contained 2000 g of aggregate, 600 g of cement/alternative cementitious material and, 360 g of water. In order to design for a pre-determined strength, these values would need to be manipulated differently for each batch. For comparative analysis, all component masses were kept at the constant values listed above.

6.3.1 Controls

The results for GU and TerC^3 were not as anticipated. Industry specifications dictate that TerC^3 should yield a higher strength than normal GU concrete. These testing results indicate the opposite. GU formed a higher than expected compressive strength.

6.3.2 Fly Ash and Silica Fume

Silica Fume performed as expected, given that its primary use is to increase strength. Silica Fume displayed highest compressive strength with a 28 day strength of 53 MPa. 25FA performed well, nearly matching the strength of TerC^3.

6.3.3 Glass Powder

The strength of glass powder was lower than the controls batches. 20GP was weaker than 10GP suggesting an inverse relationship between glass powder replacement and strength (i.e. as %GP increases strength decreases). However, the values observed could be acceptable for various applications. With alterations to the mix design (aggregate, water/cement ratio, etc.) glass powder concrete could potentially be used in the majority of situations.

6.3.4 Glass Powder + Fly Ash

The Glass Powder and Fly Ash results were similar to the glass powder results. The strength is adequate for many situations and could be improved with minor changes in the mix design.

6.4 Summary of Results

The results of the accelerated mortar bar tests and compression tests are encouraging for the use of glass powder as an alternative cementitious material. Glass Powder clearly demonstrates the ability to reduce AAR when compared to fly ash and silica fume. At 20% replacement, glass powder reduced the AAR by 8 times when compared with general use portland cement. Compressive strength was marginally reduced when using glass powder replacement but strength could be optimized with a more suitable mix design. See Appendix E, F, and G for detailed lab workings and results.

7 Conclusions

Alkali Aggregate Reaction (AAR) causes spalling, loss of strength, and potential failure in concrete. Glass powder was proven effective as an AAR suppressant. When 20% glass powder was used as a general use portland cement replacement, it performed approximately as well as established, industry used pozzolans (fly ash, silica fume, etc.). Regarding compression, glass powder mixtures displayed slightly decreased strength compared to general use and fly ash mixtures. The resultant strength was an adequate value; and with concrete additives or proper manipulation of the aggregate or water/cement ratio, the strength loss can be regained.

Currently there is no use for recycled glass in Newfoundland and Labrador (NL). With sufficient investment, glass powder as a cement replacement material is a potential application. For glass powder to be a solution in the NL concrete industry, it must become readily available. High costs would be associated with constructing a facility capable of producing cement replacement grade glass powder. If glass powder could be sold at a comparable price to general use portland cement and/or fly ash, there exists a potential for profit.

More research into the full effects of glass powder as a cement replacement is necessary, and a more in depth cost analysis is required to fully understand the potential industry. However, if proven effective, glass powder production and implementation in NL could expand the province's recycling capabilities as well as improve the AAR resistance of concrete in NL.

8 Recommendations

Unfortunately, due to the time constraints of this project, not all concepts could be studied. Because of this, and through the processes involved in this research, various suggestions for future research came to fruition. The following is a summation of these recommendations:

- Additional batches to be tested:
    - 30% Glass Powder – This would give a better representation of the critical point at which glass powder replacement hinders concrete rather than helping.
    - 10% Fly Ash – This could be compared with 10GP+10FA and 20GP+10FA batches to see the effects of the addition of glass powder.
    - Glass Powder mixed with silica fume – Silica fume could provide the extra strength that glass powder lacked during compression testing while suppressing AAR as well.
    - Non-Reactive Aggregates – Some testing could be performed with non-reactive aggregates to check for AAR.

- Larger sample size to provide more accurate results.

- Future projects would benefit from several testing iterations over a longer time period to determine the best possible batch designs.

- Future testing of glass powder through incorporation into the design of low importance structures such as curb and gutter, sidewalks, simple foundations, concrete paving, etc.

- Comprehensive cost benefit analysis of a glass powder production facility in NL.

- Investigate demand of glass powder product through interviewing construction companies.

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APPENDIX A

TerC^3 Data

Marketing Cement

Holcim

Holcim (Canada) Inc.
Atlantic Provinces

www.holcim.ca

DATE: April1, 2013

Dear Holcim Customer,

This letter is to inform the Newfoundland and Labrador concrete industry of the change in Holcim Canada's product availability. In June 2009, we transitioned from GUb-SF (HSF) to GUb-F/SF (TerC^3). TerC^3 cement meets or exceeds various specification requirements for GUb-SF (HSF), MS or HS cement types in concrete construction applications.

The composition of TerC^3 helps to address construction issues such as heat of hydration and rapid slump loss. The chemical reactivity of TerC^3 improves long term durability by increasing resistance to alkali aggregate reactivity and reducing chloride ion penetration.

The introduction within the Newfoundland and Labrador market is in accordance with Holcim Canada's philosophy of supplying industry leading products. TerC^3 is a cementing material of choice particularly for bridge and marine construction throughout Eastern Canada.

TerC^3 is ternary blend cement that is comprised of normal GU Portland, class F fly ash and silica fume. It has been used extensively on projects such as bridges, overpasses, marine structures, and waste water treatment plants.

TerC^3 has been approved for use in Newfoundland and Labrador, Nova Scotia, New Brunswick, and PEI bridge structures and there is considerable experience behind the C-XL exposure class for 45 MPa concrete.

Attached you will find a description of the various CSA classes of exposure. TerC3 is best suited for classes C-XL, C1, A1 and S1, which define the most aggressive environments for concrete applications.

Our technical services group is available to provide necessary support if required. Should you have any questions, please feel free to contact David Summers, Market Manager, NL at 709-682-2601.

Yours sincerely,

D.Black

Dave Black

Regional Sales Manager
Atlantic Canada

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Table 1

Definitions of C, F, N, A, and S classes of exposure

(See Clauses 3, 4.1.1.1.1, 4.1.1.5, 4.4.4.1.1.1, 4.4.4.1.1.2, 6.6.7.5.1,
and 8.13.3, Tables 2 and 17, and Annex L.)

C-XL Structurally reinforced concrete exposed to chlorides or other severe environments with or without freezing and thawing conditions, with higher durability performance expectations than the C-1, A-1, or S-1 classes.

C-1 Structurally reinforced concrete exposed to chlorides with or without freezing and thawing conditions.

Examples: bridge decks, parking decks and ramps, portions of marine structures located within the tidal

and splash zones, concrete exposed to seawater spray, and salt water pools.

C-2 Non-structurally reinforced (i.e., plain) concrete exposed to chlorides and freezing and thawing.
Examples: garage floors, porches, steps, pavements, sidewalks, curbs, and gutters.
C-3 Continuously submerged concrete exposed to chlorides, but not to freezing and thawing.
Examples: underwater portions of marine structures.
C-4 Non-structurally reinforced concrete exposed to chlorides, but not to freezing and thawing.
Examples: underground parking slabs on grade.
F-1 Concrete exposed to freezing and thawing in a saturated condition, but not to chlorides.
Examples: pool decks, patios, tennis courts, freshwater pools, and freshwater control structures.
F-2 Concrete in an unsaturated condition exposed to freezing and thawing, but not to chlorides.
Examples: exterior walls and columns.
N Concrete not exposed to chlorides, nor to freezing and thawing.
Examples: footings and interior slabs, walls, and columns.
A-1 Structurally reinforced concrete exposed to severe manure and/or silage gases, with or without

freeze-thaw exposure. Concrete exposed to the vapour above municipal sewage or industrial effluent,

where hydrogen sulphide gas might be generated.

Examples: reinforced beams, slabs, and columns over manure pits and silos, canals, and pig slats; and

access holes, enclosed chambers, and pipes that are partially filled with effluents.

A-2 Structurally reinforced concrete exposed to moderate to severe manure and/or silage gases and liquids,

with or without freeze-thaw exposure.

Examples: reinforced walls in exterior manure tanks, silos and feed bunkers, and exterior slabs.

A-3 Structurally reinforced concrete exposed to moderate to severe manure and/or silage gases and liquids,

with or without freeze-thaw exposure in a continuously submerged condition. Concrete continuously

submerged in municipal or industrial effluents.

Examples: interior gutter walls, beams, slabs, and columns; sewage pipes that are continuously full

(e.g., forcemains); and submerged portions of sewage treatment structures.
A-4 Non-structurally reinforced concrete exposed to moderate manure and/or silage gases and liquids,
without freeze-thaw exposure.
Examples: interior slabs on grade.
S-1 Concrete subjected to very severe sulphate exposures (Tables 2 and 3).
S-2 Concrete subjected to severe sulphate exposure (Tables 2 and 3).
S-3 Concrete subjected to moderate sulphate exposure (Tables 2 and 3).
Notes:

(1) “C” classes pertain to chloride exposure.
(2) “F” classes pertain to freezing and thawing exposure without chlorides.
(3) “N” class is exposed to neither chlorides nor freezing and thawing.
(4) All classes of concrete exposed to sulphates shall comply with the minimum requirements of S class noted in Tables 2

and 3. In particular, Classes A-1 to A-4 in municipal sewage elements could be subjected to sulphate exposure.

Table 2
Requirements for C, F, N, A, and S classes of exposure

(See Clauses 4.1.1.1.1, 4.1.1.3, 4.1.1.4, 4.1.1.5, 4.1.1.6.2, 4.1.1.10.1, 4.1.1.10.3, 4.1.2.1, 4.3.1, 7.4.2.1, 8.7.3, 8.7.6.1, 8.13.3, and 8.13.5, Tables 1 and 2, and Annex L.)

Class of exposure*	Maximum water-to-cementing materials ratio†	Minimum specified compressive strength (MPa) and age (d) at test†	Air content category as per Table 4	Curing type (see Table 20)			Chloride ion penetrability requirements and age at test‡
				Normal concrete	HVSCM 1	HVSCM 2	
C-XL	0.40	50 within 56 d	1 or 2§	3	3	3	< 1000 coulombs within 56 d
C-1 or A-1	0.40	35 at 28 d	1 or 2§	2	3	2	< 1500 coulombs within 56 d
C-2 or A-2	0.45	32 at 28 d	1	2	2	2	—
C-3 or A-3	0.50	30 at 28 d	2	1	2	2	—
C-4** or A-4	0.55	25 at 28 d	2	1	2	2	—
F-1	0.50	30 at 28 d	1	2	3	2	—
F-2	0.55	25 at 28 d	2††	1	2	2	—
N‡‡	As per the mix design for the strength required	For structural design	None	1	2	2	—
S-1	0.40	35 at 56 d	2	2	3	2	—
S-2	0.45	32 at 56 d	2	2	3	2	—
S-3	0.50	30 at 56 d	2	1	2	2	—

---

*See Table 1 for a description of classes of exposure.

†The minimum specified compressive strength may be adjusted to reflect proven relationships between strength and the water-to-cementing materials ratio. The water-to-cementing materials ratio shall not be exceeded for a given class of exposure.

‡In accordance with ASTM C 1202, an age different from that indicated may be specified by the owner. Where calcium nitrite corrosion inhibitor is to be used, the same concrete mixture, without calcium nitrite, shall be prequalified to meet the requirements for the permeability index in this Table. For field testing, the owner shall specify the type of specimen and location from which it is taken. If cores are required, the concrete cores shall be taken in accordance with Clause 6.1.2.3.3 of CSA S413.

§Use air content category 1 for concrete exposed to freezing and thawing. Use air content category 2 for concrete not exposed to freezing and thawing.

**For class of exposure C-4, the requirement for air-entrainment should be waived when a steel trowelled finish is required. The addition of supplementary cementing materials may be used to provide reduced permeability in the long term, if required.

††Interior ice rink slabs and freezer slabs with a steel trowelled finish have been found to perform satisfactorily without entrained air.

‡‡See Clause 8.12 for concrete mixes for concrete floors.

Marketing - Cement
Holcim (Canada) inc.
435 Jean-Neveu Street
Longueuil (Québec)
Canada J4G 2P9

Phone ....(450) 651-1117
Fax................(450) 651-2695
www.holcim.ca

December 13, 2012

CEMENT TEST REPORT
Joliette Plant

Blended High Sulphate Resistant Hydraulic Cement
GUb-F/SF or Ter C^3
Production Period: November 2012

Chemical Analysis (%)

Alkalis (Na_2O equi.)	1.0
Loss on ignition (≤ **6.0 %**)........	2.4
SiO_2	31.0
Al_2O_3	8.7
Fe_2O_3	5.3
CaO	46.4
MgO	1.3
SO_3	2.9

Physical Tests

Fineness: Blaine	449 m^2/kg
Residue 45 μ (≤ **24 %**).	11 %
Autoclave expansion (≤ **0.8 %**) ..... (A3004-B5)	0.05 %
Expansion in water (≤ **0.020**) .... (A3004-C5)	0.002 %
Setting Time:	
Initial (≥ **45 and** ≤ **480 minutes**)	165 min.
Final..	285 min.
Heat of hydration	292 kJ/kg
Compressive Strength:	
3 days (≥ **14.5 MPa**)........................	25.2 MPa
7 days (August) (≥ **20.0 MPa**)............	32.8 MPa
28 days (≥ **26.5 MPa**) .... (October)	48.5 MPa

---

Above results indicate that the cement represented by this sample complies with all requirements of current specification CSA A3001-08 (revision 2011).

Annick Tremblay

For more information concerning
the cement test report, please contact
our technical services at 1 866 598-8750 ext. 6207
or : jean-claude.leduc@holcim.com

Annick Tremblay
Section Manager - Quality

APPENDIX B

Material Safety Data Sheets

poraver
North America

MATERIAL SAFETY DATA SHEET

MSDS DATE: 25/05/2010

SECTION 1: PRODUCT AND COMPANY IDENTIFICATION

PRODUCT NAME:	**Mikrover**
SYNONYMS:	Ground Glass
MANUFACTURER:	PORAVER North America Ltd.
ADDRESS:	2429 Bowman Street Innisfil, Ontario L9S 3V6
PREPARATION INFORMATION:	Prepared by Research and Development
TELEPHONE:	(705) 431-0022
FAX PHONE:	(705) 431-2701
CHEMICAL NAME:	Glass
CHEMICAL FAMILY:	Glass Oxides
CAS NUMBER:	65997-17-3
CHEMICAL FORMULA:	Not Applicable
CANADIAN WHMIS CLASSIFICATION:	Not Controlled / Not Regulated
PRODUCT USE:	Glass Manufacture

SECTION 2: COMPOSITION/INFORMATION ON INGREDIENTS

Ingredient	Chemical Formula	Typical % By Weight	CAS #
Glass Oxides	O_2SI	100 %	65997-17-3

SECTION 3: HAZARDS IDENTIFICATION

WHMIS HAZARDOUS INGREDIENTS................: None

POTENTIAL HEALTH EFFECTS

ROUTES OF ENTRY....................................: Inhalation.

EYES..: This product is an eye irritant due to the mechanical abrasion of the crystals.

SKIN...: This product is a skin irritant due to the mechanical abrasion of the crystals.

INGESTION..: Small glass particles present in this product may cause injury to the trachea, stomach and intestines.

INHALATION..: This product is a nuisance dust. OSHA PEL (total particulate, not otherwise regulated) 15 mg/m^3, (respirable particulate, not otherwise regulated) 5 mg/m^3. ACGIH TLV (nuisance particulates) 10 mg/m^3 (inhalable), 5 mg/m^3 (respirable).

ACUTE HEALTH HAZARDS............................: None known.

CHRONIC HEALTH HAZARDS.........................: Chronic exposure to respirable dust in excess of appropriate exposure limits may cause lung disease.

IRRITANCY..; This product will irritate the skin through mechanical abrasion of the crystals.

SENSITIZATION..; None Known.

CARCINOGENICITY......................................; None Known.

REPRODUCTIVE TOXICITY...........................; None Known.

TERATOGENICITY..; None Known.

MUTAGENICITY...; None Known.

TOXICOLOGICALLY SYNERGISTIC PRODUCTS.; None Known.

SECTION 4: FIRST AID MEASURES

EYES..: Flush eye with running water for 15 minutes, consult a doctor.

SKIN..: Wash skin with soap and water; consult a doctor if irritation develops.

INGESTION...: Consult a doctor.

INHALATION...: Remove to fresh air. If breathing difficulty is encountered, seek medical aid.

NOTES TO PHYSICIANS OR FIRST AID PROVIDERS...: Glass particles present in this product can cause internal injury to the trachea, stomach and intestines.

SECTION 5: FIRE-FIGHTING MEASURES

FLAMMABLE LIMITS IN AIR, UPPER...........: Not Applicable.
(% BY VOLUME) LOWER...........: Not Applicable.
FLASH POINT..: Not Available.
AUTOIGNITION TEMPERATURE..................: Not Available.
CONDITIONS OF FLAMMABILITY................: Not Flammable.
NFPA HAZARD CLASSIFICATION
HEALTH: 0 FLAMMABILITY: 0 REACTIVITY: 0 OTHER: 0
HMIS HAZARD CLASSIFICATION
HEALTH: 0 FLAMMABILITY: 0 REACTIVITY: 0 PROTECTION: 0
EXTINGUISHING MEDIA...........................: Use extinguishing media appropriate to the primary cause of the fire.
SPECIAL FIRE FIGHTING PROCEDURES.....: None.
UNUSUAL FIRE AND EXPLOSION HAZARDS.: None Known.
HAZARDOUS DECOMPOSITION PRODUCTS.: None Known.
SENSITIVITY TO MECHANICAL IMPACT.......: None SENSITIVITY TO STATIC DISCHARGE..: None

SECTION 6: ACCIDENTAL RELEASE MEASURES

ACCIDENTAL RELEASE MEASURES......; Shovel up or vacuum up material and dispose of waste in accordance with local, state / provincial and federal regulation.

SECTION 7: HANDLING AND STORAGE

HANDLING AND STORAGE..................: Respirable dust may be generated during processing, handling and storage. Stored in a cool, dry, ventilated area. Protect against physical damage. Use adequate ventilation and dust collection. Practice good housekeeping. Do not allow dust to collect on walls, floors, sills, ledges, machinery, or equipment.

SECTION 8: EXPOSURE CONTROLS/PERSONAL PROTECTION

VENTILATION..........................: Provide local and/or general exhaust to control dust generation below exposure limits. Local exhaust ventilation is generally preferred because it can control the emissions of the contaminant at its source, preventing dispersion of it into the general work area.
RESPIRATORY PROTECTION.....: Wear a NIOSH approved mask for control of nuisance dust. Respirable dust levels should be monitored regularly.
EYE PROTECTION....................: Wear safety glasses with side shields to protect against eye contact.
SKIN PROTECTION...................: Wear general purpose work gloves to protect skin from irritation.

SECTION 9: PHYSICAL AND CHEMICAL PROPERTIES

PHYSICAL STATE...: Solid
APPEARANCE...: White beads
ODOR...: None
ODOUR THRESHOLD...................................; None
PHYSICAL STATE...: Solid
pH AS SUPPLIED...: Not Applicable
pH (Other)..: 10.7 (100 g in 1 l of water)
COEFFICIENT OF WATER/OIL DISTRIBUTION....;Not Available
BOILING POINT...: Not available
MELTING POINT..: approximately 750 ° C
FREEZING POINT...: approximately 750 ° C
VAPOR PRESSURE (mmHg)...........................: Not applicable
VAPOR DENSITY (AIR = 1)............................: Not applicable
SPECIFIC GRAVITY (H_2O = 1) @ 25 ° C............: 0.27 – 0.9
EVAPORATION RATE... BASIS (=1)...................: Not applicable
SOLUBILITY IN WATER................................: Insoluble
PERCENT SOLIDS BY WEIGHT.......................: 100
PERCENT VOLATILE BY WT...........................: 0
VOLATILE ORGANIC COMPOUNDS (VOC)........: None
MOLECULAR WEIGHT..................................: Not Applicable
VISCOSITY..: Not Applicable

SECTION 10: STABILITY AND REACTIVITY

STABILITY: Stable
CONDITIONS TO AVOID (STABILITY): None known
INCOMPATIBILITY (MATERIAL TO AVOID): None known
HAZARDOUS DECOMPOSITION OR BY-PRODUCTS: None known
HAZARDOUS POLYMERIZATION: Will not occur
CONDITIONS TO AVOID (POLYMERIZATION): None Known

SECTION 11: TOXICOLOGICAL INFORMATION

TOXICOLOGICAL INFORMATION: This product contains trace amounts of heavy metals such as lead, chromium and antimony. As well as trace amount of silica. Users need to be aware of their presence even though they are lower than any required reporting limit.

SECTION 12: ECOLOGICAL INFORMATION

ECOLOGICAL INFORMATION: None Known

SECTION 13: DISPOSAL CONSIDERATIONS

WASTE DISPOSAL METHOD: Dispose of waste in accordance with local, state / provincial and federal regulation

SECTION 14: TRANSPORT INFORMATION

U.S. DEPARTMENT OF TRANSPORTATION
PROPER SHIPPING NAME: Not regulated
HAZARD CLASS: Not applicable
ID NUMBER: Not applicable
PACKING GROUP: Not applicable
LABEL STATEMENT: Not applicable

WATER TRANSPORTATION
PROPER SHIPPING NAME: Not regulated
HAZARD CLASS: Not applicable
ID NUMBER: Not applicable
PACKING GROUP: Not applicable
LABEL STATEMENTS: Not applicable

AIR TRANSPORTATION
PROPER SHIPPING NAME: Not regulated
HAZARD CLASS: Not applicable
ID NUMBER: Not applicable
PACKING GROUP: Not applicable
LABEL STATEMENTS: Not applicable

CANADIAN TDG
PROPER SHIPPING NAME: Not regulated
HAZARD CLASS: Not applicable
ID NUMBER: Not applicable
PACKING GROUP: Not applicable
SPECIAL SHIPPING INFORMATION: None

SECTION 15: REGULATORY INFORMATION

CANADIAN WHMIS CLASSIFICATION: Not Controlled / Not Regulated
U.S. FEDERAL REGULATIONS
TSCA (TOXIC SUBSTANCE CONTROL ACT): All ingredients listed on the TSCA inventory

SECTION 16: OTHER INFORMATION

DISCLAIMER: The information in this Material Safety Data Sheet (MSDS) is believed to be correct as of the date issued. Poraver North America Ltd. makes no warranties, expressed or implied, statutory or otherwise, including, but not limited to, any implied warranty or condition of merchantability or fitness for a particular purpose or course of performance or usage of trade. The user is responsible for determining whether the Poraver product is fit for a particular purpose and suitable for the user's method of use or application. Given the variety of factors that can affect the use and application of the Poraver product, some of which are uniquely within the user's knowledge and control, it is essential that the user evaluate the Poraver product to determine whether it is fit for a particular purpose and suitable for the user's method of use or application.

Holcim

MATERIAL SAFETY DATA SHEET

Material: Silica Fume

Approved by	**W. Galloway**	**Senior Vice President**	Date of revision	**01. January 2011**	**Page 1 of 4**

Control Number: XA.11.106

Section I - Identification

Supplier

Name: **Holcim (Canada) Inc.**

Address **2300 Steeles Ave. W. 4th floor**
Concord, Ontario, L4K 5X6

Telephone: **905-761-7100**

Emergency Information

Contact: (CANUTEC)
Telephone: (613) 996-6666

Note: The CANUTEC number is to be used only in the event of chemical emergencies involving a spill, fire, exposure or accident involving chemicals.

WHMIS Classification: D2A, E

Material Uses: Silica Fume is used as a supplementary cementitious or pozzolanic material for cement, concrete or concrete products.

Product Codes: Silica Fume (ASTM C1240, CSA A.3001-03). This MSDS covers many different types of Silica Fume. Individual constituents will vary.

Formula: Silica fume is a byproduct of producing silicon metal or ferrosilicon alloys

Chemical Family: Silica fume consists primarily of amorphous (non-crystalline) silicon dioxide (SiO2).

Chemical Name and Synonyms: Silica Fume, Amorphous Silica, Condensed Silica Fume (CSF)

Section II - Components

Hazardous Ingredients

Component	CAS #	% by Weight	OSHA PEL (mg/m^3)	ACGIH TLV-TWA (mg/m^3)
Silicon Dioxide	69012-64-2	75 – 100		TLV® withdrawn
Crystalline Silica	14808-60-7	< 0.5	[(10) / (% SiO_2 + 2)] (R) [(30) / (% SiO_2 + 2)] (T)	0.025 (R)

(T) = Total Dust ; (R) = Respirable Fraction

Trace constituents: Silica fume has a variable composition depending upon the raw materials used (quartz, coal and wood chips) in the electric furnaces for the production silicon metal or ferrosilicon alloys. Small amounts of naturally occurring, but potentially harmful, chemical compounds might be detected during chemical analysis. These trace compounds might include free crystalline silica, potassium and sodium compounds; heavy metals including cadmium, chromium, nickel and lead; and organic compounds

Section III – Hazards Identification

Emergency Overview

Silica Fume is a light grey to white submicron powder that poses little immediate hazard. A single short-term exposure to the dry powder is not likely to cause serious harm.

Potential Health Effects

- *Relevant Routes of Exposure:* Eye contact, skin contact, inhalation, and ingestion
- *Effects resulting from eye contact:* Exposure to airborne dust may cause immediate or delayed irritation or inflammation. Eye contact with larger amounts of dry powder may cause moderate eye irritation. Such exposures require immediate first aid (see section IV) and medical attention to prevent significant damage to the eye.
- *Effects resulting from skin contact:* Discomfort or pain cannot be relied upon to alert a person to a hazardous skin exposure. Consequently, the only effective means of avoiding skin injury or illness involves minimizing skin contact. Exposed persons may not feel discomfort until hours after the exposure has ended and significant injury has occurred. Exposure to Silica Fume may cause drying of the skin with consequent mild irritation or more significant effects attributable to aggravation of other conditions.
- *Effects resulting from inhalation:* Silica Fume contains small amounts of free crystalline silica. Prolonged exposure to respirable free crystalline silica can aggravate other lung conditions and cause silicosis, a disabling and potentially fatal lung disease and/or other diseases. Risk of injury or disease depends on duration and degree of exposure. (Also see "Carcinogenic potential" below.) Exposure to Silica Fume may cause irritation to the moist mucous membranes of the nose, throat, and upper respiratory system. It may also leave unpleasant deposits in the nose.
- *Effects resulting from ingestion:* Although small quantities of dust are not known to be harmful, ill effects are possible if larger quantities are consumed. Silica Fume should not be eaten.

- *Carcinogenic potential: NTP, OSHA, or IARC has not listed Silica Fume as a carcinogen.* It may, however, contain trace amounts of substances listed as carcinogens by these organizations. Crystalline silica, which is present in Silica Fume in small amounts, has been listed by IARC and NTP as a known human carcinogen (Group I) through inhalation. Hexavelant chromium is listed by IARC, EPA, NTP and OSHA as Group I known carcinogen by inhalation.
- *Medical conditions which may be aggravated by inhalation or dermal exposure*:

☐ Pre-existing upper respiratory and lung diseases

☐ Unusual (hyper) sensitivity to hexavalent chromium (chromium$_{+6}$) salts.

Section IV – First Aid

Eyes: Immediately flush eyes thoroughly with water. Continue flushing eye for at least 15 minutes, including under lids, to remove all particles. Call physician immediately.

Skin: Wash skin with cool water.

Inhalation of Airborne Dust: Remove to fresh air. Seek medical help if coughing or other symptoms do not subside. (Inhalation of gross amounts of Silica Fume requires immediate medical attention.)

Ingestion: Do not induce vomiting. If conscious, have the victim drink plenty of water and call a physician immediately.

Section V – Fire & Explosion Data

Flash Point:	*Not Combustible*	Auto Ignition Temperature:	*Not Combustible*
Lower Explosive Limit:	*None*	Upper Explosive Limit	*None*
Extinguishing Media:	*Not Combustible*	Unusual Fire and Explosion Hazards:	*None*
Hazardous Combustion Products:	*None*		
Special Fire Fighting Procedures:	*None.* (Although Silica Fume poses no fire-related hazards, a self-contained breathing apparatus is recommended to limit exposure to combustion products when fighting any fire.)		

Section VI – Accidental Release Measures

Collect dry material using a scoop. Avoid actions that cause dust to become airborne. Avoid inhalation of dust and contact with skin. Wear appropriate personal protective equipment as described in Section VIII.

Scrape up wet material and place in an appropriate container. Allow the material to "dry" before disposal. Do not attempt to wash Silica Fume down drains.

Dispose of waste material according to local, state, and federal regulations.

Section VII – Handling & Storage

Keep Silica Fume dry until used. Normal temperatures and pressures do not affect the material. Promptly remove dusty clothing or clothing which is wet with cement fluids and launder before reuse. Wash thoroughly after exposure to dust or wet cement mixtures or fluids.

Section VIII – Exposure Control/Personal Protection

Skin Protection: Prevention is essential to avoiding potentially severe skin injury. If contact occurs, promptly wash affected area with soap and water. Where prolonged exposure to unhardened Silica Fume products might occur, wear impervious clothing and gloves to prevent skin contact. Where required, wear sturdy boots that are impervious to water to eliminate foot and ankle exposure. Do not rely on barrier creams; barrier creams should not be used in place of impervious gloves and clothing. Periodically wash areas contacted by Silica Fume. Wash again at the end of the work. If irritation occurs, immediately wash the affected area and seek treatment

Respiratory protection: Avoid actions that cause dust to become airborne. Use local or general ventilation to control exposures below applicable exposure limits. Use NIOSH/MSHA-approved (under 30 CFR 11) or NIOSH-approved (under 42 CFR 84) respirators in poorly ventilated areas, if an applicable exposure limit is exceeded, or when dust causes discomfort or irritation. (Advisory: Respirators and filters purchased after July 10, 1998, must be certified under 42 CFR 84.)

Ventilation: Use local exhaust or general dilution ventilation to control exposure within applicable limits.

Eye Protection: In conditions where user may be exposed to splashes or puffs of Silica Fume, wear safety glasses with side shields or goggles. In extremely dusty or unpredictable environments, wear unvented or indirectly vented goggles to avoid eye irritation or injury. Contact lenses should not be worn when working with Silica Fume.

Section IX – Physical & Chemical Properties

Appearance:	*Grey or White Powder*	Vapor Pressure:	*Not Applicable*
Odor:	*No Distinct Odor*	Vapor Density:	*Not Applicable*
Physical State:	*Solid (Powder)*	Boiling Point:	*Not Applicable*
pH (in water):	*5 - 9*	Melting Point:	*Not Applicable (i.e. >1000 °C)*
Solubility in Water:	*Negligible*	Specific Gravity (H_2O = 1)	2.2-2.5
Evaporation Rate:	*Not Applicable*		

Section X – Stability & Reactivity

Stability:	*Stable*
Incompatibility:	*Silica Fume may be incompatible with acids, ammonium salts, and aluminum metal. In contact with fluorine, oxygen difluoride or chlorine trifluoride, it can cause fire. Reaction with hydrofluoric acid (HF) forms SiF4, a toxic gas*
Conditions to Avoid:	*Unintentional contact with water.*
Hazardous Decomposition:	*Will not spontaneously occur. Heating above 1000 °C can result in the formation of crystalline SiO2 modifications as cristobalite/tridymite which may cause pulmonary fibrosis (silicosis).*
Hazardous Polymerisation:	*Will not occur.*

Section XI – Toxicological Information

For a description of available, more detailed toxicological information, contact Holcim (Canada) Inc. (Contact Details in Section I).

Section XII – Ecological Information

Ecotoxicity:	*No recognized unusual toxicity to plants or animals*
Relevant Physical & Chemical Properties:	*See Sections IX & X*

Section XIII – Disposal

Dispose of waste material according to local, state, and federal regulations. (Since Silica Fume is stable, uncontaminated material may be saved for future use.) Dispose of bags in an approved landfill or incinerator.

Section XIV – Transportation Data

Hazardous Materials Description/Proper Shipping Name:	*Silica Fume is not hazardous under U.S. Department of Transportation (DOT) regulations and Canadian Transportation of Dangerous Goods (TDG) Regulation*
Hazard class:	*Not applicable*
Identification class:	*Not applicable*
Required label text:	*Not applicable*
Hazardous substances/reportable quantities (RQ):	*Not applicable*

Section XV – Other Regulatory Information

Status under USDOL-OSHA Hazard Communication Rule, 29	*Silica Fume is considered a hazardous chemical under this*

CFR 1910.1200:	*regulation, and should be part of any hazard communication program.*
Status under CERCLA/Superfund, 40 CRF 117 and 302:	*Not listed.*
Hazard Category under SARA (Title III), Sections 311 and 312:	*Silica Fume qualifies as hazardous substance with delayed health effects under Sections 311 and 312.*
Status under SARA (Title III), Section 313:	*Not subject to reporting requirements under Section 313.*
Status under TSCA (as of May 1997):	*Some substances in Silica Fume are on the TSCA inventory list.*
Status under the Federal Hazardous Substances Act:	*Silica Fume is a hazardous substance subject to statutes promulgated under the subject act.*
Status under California Proposition 65:	*This product contains chemicals (trace metals) known to the State of California to cause cancer, birth defects or other reproductive harm. California law requires the manufacturer to give the above warning in the absence of definitive testing to prove that the defined risks do not exist.*
Status under Canadian Environmental Protection Act:	*Not listed.*
Status under Workplace Hazardous Materials Information System (WHMIS):	*Silica Fume is considered to be a hazardous material under the Hazardous Products Act as defined by the Controlled Products Regulations (Class D2A – Chronic Toxic Effect and Class E – Corrosive Material) and is therefore subject to the labelling and MSDS requirements of WHMIS.* *This product has been classified according to the hazard criteria of the CPR and the MSDS contains all the information required by the CPR*

Section XVI – Other Information

Silica Fume should only be used by knowledgeable persons. A key to using the product safely requires the user to recognize that Silica Fume chemically reacts with water, and that some of the intermediate products of this reaction (that is, those present while a Silica Fume product is setting) pose a far more severe hazard than does Silica Fume itself.

While the information provided in this material safety data sheet is believed to provide a useful summary of the hazards of Silica Fume as it is commonly used, this sheet cannot anticipate and provide all of the information that might be needed in every situation. Inexperienced product users should obtain proper training before using this product.

In particular, the data furnished in this sheet do not address hazards that may be posed by other materials mixed with Silica Fume to produce Silica Fume products. Users should review other relevant material safety data sheets before working with this Silica Fume or working on Silica Fume products, for example, Silica Fume concrete.

SELLER MAKES NO WARRANTY, EXPRESSED OR IMPLIED, CONCERNING THE PRODUCT OF THE MERCHANTABILITY OR FITNESS THEREOF FOR ANY PURPOSE OR CONCERNING THE ACCURACY OF ANY INFORMATION PROVIDED BY HOLCIM (CANADA), EXCEPT THAT THE PRODUCT SHALL CONFORM TO CONTRACTED SPECIFICATIONS.

The information provided herein was believed by Holcim (Canada) Inc. to be accurate at the time of preparation or prepared from sources believed to be reliable, but it is the responsibility of the user to investigate and understand other pertinent sources of information to comply with all laws and procedures applicable to the safe handling and use of product and to determine the suitability of the product for its intended use. Buyer's exclusive remedy shall be for damages and no claim of any kind, whether as for product delivered or for non-delivery of product, and whether based on contract, breach of warranty, negligence, or otherwise, shall be greater in amount than the purchase price of the quantity of product in respect of which damages are claimed. In no event shall Seller be liable for incidental or consequential damages, whether Buyer's claim is based on contract, breach of warranty, negligence or otherwise.

THE SEFA GROUP
Marketing • Manufacturing • Transportation

MATERIAL SAFETY DATA SHEET

for
Class F Fly Ash from
Bituminous Coal

This document has been prepared to comply with OSHA's Hazard Communication Standard, 29 CFR 1910.1200.
Revision Date: June 2010

SECTION I GENERAL INFORMATION

The SEFA Group
217 Cedar Road
Lexington, SC 29073

Emergency Information (803) 520-9000
General Information (803) 520-9000

SECTION II PRODUCT COMPOSITION AND MAJOR CONSTITUENTS

Components	Formula/CAS	Typical Percentage	OSHA PEL (mg/m^3)	ACGIH TVL (mg/m^3)
Silica, Amorphous	SiO_2 7631-86-9	41.0 - 58.0%	6	10
Silica, Crystalline	$SiO_2 + 2$ 14808-60-7	3.0 - 7.0%	.1	.1
Aluminum Oxide	Al_2O_3 1344-28-1	18.1 - 28.6%	15	10
Iron Oxide	Fe_2O_3 1309-37-1	3.9 - 26.0%	10	5
Calcium Oxide	CaO 1305-78-8	0.8 – 6.0%	5	2
Magnesium Oxide	MgO 1309-48-4	0.7 - 1.4%	10	10
Titanium Oxide	TiO_2 13463-67-7	1.0 - 1.9%	10	10

SECTION III PHYSICAL & CHEMICAL CHARACTERISTICS

Appearance & Odor Fine gray dust with no apparent odor

Boiling Point	N/A	**Evaporation Rate**	N/A
Vapor Pressure	N/A	**Melting Point**	>2500° F
Vapor Density	N/A	**Solubility in Water**	Insoluble
Specific Gravity	2.0 – 3.0		

SECTION IV FIRE & EXPLOSION DATA

Flash Point Non-flammable & non-explosive
Extinguishing Method N/A
Unusual Fire & Explosion Hazards N/A

SECTION V REACTIVITY DATA

Stability	Stable	**Hazardous Decomposition or By-Products**	None
Incompatibility	None	**Conditions to Avoid**	None

SECTION VI HEALTH HAZARDS

Exposure Routes	Inhalation, Skin Contact, Eye Contact
Acute Health Hazards	Possible irritation of eyes, skin & respiratory system.
Chronic Health Hazards	Prolonged or repeated exposure to excessive levels of crystalline silica may cause silicosis, a fibrosis of the lungs.
Signs & Symptoms of Exposure	Irritation of eyes, skin & mucous membranes of the respiratory system.
Note	Respirable crystalline silica has been classified by the International Agency for Research on Center (IARC) as a probable human carcinogen.

Emergency & First Aid Procedures

Skin	Brush away ash particles. Flush effected area, preferably using soap & water.
Eyes	Do not rub. Flush effected area with water for at least 15 minutes.
Ingestion	Rinse mouth with water. Seek medical attention if necessary.
Inhalation	Remove person to fresh air. Clear nasal passages. If effected person is not breathing, contact emergency medical services and begin standard life support techniques.

SECTION VII PRECAUTIONS FOR SAFE HANDLING & USE

In Case of Spill	Wet ash with water mist to help reduce airborne concentrations before removal. Remove spilled material with shovel or vacuum, or wash down with water. Do not use compressed air. Fly ash is not considered a hazardous waste under EPA's Resource Conservation and Recovery Act (RCRA). Coal fly ash may be disposed of by adding the material to cement mixtures, asphalt additives and as agricultural soil modifiers.
Waste Disposal	Cover material to prevent airborne dust and dispose of in a landfill according to federal, state and local regulations for non-hazardous waste.
Storage & Handling Precautions	Avoid conditions which result in dusting and in uncontrolled runoff of rainwater from storage areas. Avoid inhalation of dust.

SECTION VIII CONTROL MEASURES

Respiratory Protection	NIOSH-approved respirator if exposures approach TLV/PEL.
Protective Gloves	Work or chemical gloves should be used to reduce skin irritation of dust when workers must directly handle the material.
Eye Protection	Goggles or safety glasses should be worn. Eye station should be readily accessible.
Other Protective Equipment	Protective clothing should be worn as necessary for individuals with sensitive skin to prevent direct skin contact.
Work/Hygienic Practices	Wash hands and face after handling fly ash and before smoking or consuming food or beverages, apply cosmetics or using toilet facilities. Local exhaust systems should be employed in confined spaces.

SECTION IX SPECIAL PRECAUTIONS

Handling & Storage	Store in a dry place.
Other	Avoid creating dust. Practice good hand-washing techniques, washing prior to eating and drinking.

APPENDIX C

ASTM Standards

A23.2-8A
Measuring mortar-strength properties of fine aggregate

1 Scope

This Test Method provides requirements for the measurement of the mortar-strength properties of fine aggregate for concrete by means of a compression test on specimens made from a mortar of plastic consistency and gauged to a definite water-to-cementing materials ratio. It is used for the determination of the effect on mortar strength of organic impurities determined in accordance with CSA A23.2-7A.

2 Reference publications

CSA (Canadian Standards Association)
A23.1-09
Concrete materials and methods of concrete construction

A23.2-7A-09
Test for organic impurities in fine aggregates for concrete

A3005-08
Test equipment and materials for cementitious materials for use in concrete and masonry

ASTM International (American Society for Testing and Materials)
C 87-05
Standard Test Method for Effect of Organic Impurities in Fine Aggregate on Strength of Mortar

C 670-03
Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

3 Significance and use

3.1

This Test Method provides a means for the acceptance of fine aggregate with respect to organic impurities.

3.2

This Test Method is applicable to samples, when tested in accordance with CSA A23.2-7A, producing a supernatant liquid colour greater than standard colour plate No. 3 or colour solution.

4 Basis for comparison

Unless otherwise specified or permitted, strengths at 7 d are compared in accordance with the following procedures:

(a) Mix three batches of mortar with the aggregate treated in sodium hydroxide and three batches with the untreated aggregate on the same day.

(b) Mould three 50 mm cubes from each batch.
(c) Test the three cubes from each batch at the age of 7 d.

5 Apparatus

The apparatus shall consist of the following:
(a) a flow table, flow mould, and caliper conforming to the requirements of CSA A3005;
(b) a mixer, bowl, and paddle as described in CSA A3005;
(c) a tamper, made of a non-absorptive, nonabrasive, non-brittle material (e.g., a rubber compound having a Shore A durometer hardness of 80 ± 10 or seasoned oak wood rendered non-absorptive by immersion for 15 minutes in paraffin at approximately 200 °C) having a cross-section of 13 × 25 mm and a convenient length of about 150 mm with a tamping face that is flat and at right angles to the length of the tamper;
(d) a trowel with a steel blade 100 mm to 150 mm in length, with straight edges; and
(e) cube moulds 50 mm in dimension conforming to the requirements of CSA A3005.

6 Temperature

The temperature of the mixing water, moist closet, and storage tank shall be maintained at 23 °C ± 2.0 °C.

7 Preparation of fine aggregate and mortar

7.1 Fine aggregate

Compare the strength of mortar made with fine aggregate that has been washed in sodium hydroxide solution with the strength of mortar made with the same fine aggregate that has not been washed in sodium hydroxide solution. Wash the fine aggregate in a 3% solution of sodium hydroxide followed by thorough rinsing in water. Repeat the treatment a sufficient number of times to produce a washed material having a colour lighter than the standard described in CSA A23.2-7A. Wash the aggregate so that the loss of fines is minimized and the washed aggregate has a fineness modulus within 0.10 of that of the unwashed aggregate. Check the washed and rinsed aggregate with a suitable indicator such as phenolphthalein or litmus to ensure that all sodium hydroxide has been removed prior to preparation of the mortar.

7.2 Mortar

7.2.1

Mix the mortar in a mechanical mixer in accordance with the procedure described in Clauses 7.2.6 to 7.2.11.

7.2.2

Proportion the mortar to produce a consistency of 100 ± 5% as determined by the flow test (see Clause 8).

7.2.3

Remove oversize particles by sieving on the 5.0 mm or 2.5 mm sieve if the particles are so large that the adjustment bracket cannot provide adequate clearance. Indicate the quantity of material removed if this procedure is employed.

Note: *The clearances between the paddle and the bowl specified in CSA A3005 are suitable when using standard mortar.*
Caution: To permit the mixer to operate freely and to avoid serious damage to the paddle and bowl when coarser aggregates are used, it may be necessary to set the clearance adjustment bracket to provide greater clearances than those specified. A clearance of approximately 5.0 mm has been found to be

satisfactory for this method when used with fine aggregate from which the material retained on the 5.0 mm sieve has been removed.

7.2.4

Use water and cement in quantities that will yield a water-to-cement ratio of 0.6 by mass. It has been found that 600 g of cement and 360 mL of water will usually be adequate for a six-cube batch.

7.2.5

Using fine aggregate that has been brought to a saturated surface-dry condition, prepare a quantity of aggregate estimated to provide slightly more than needed to produce a batch of the desired consistency. The quantity of sand used with this amount of cement may vary from 1200 g for fine sand to 2000 g or more for coarse sand.

Note: *When the absorption is known, the aggregate may be prepared for testing by adding to a known mass of dry aggregate the amount of water it will absorb, mixing thoroughly, and permitting the aggregate to stand in a covered pan for* 30 min *before use.*

7.2.6

After placing all the mixing water in the bowl, add the cement to the water. Mix with the mixer at a slow speed (140 r/min ± 5 r/min) for 30 s.

7.2.7

While still mixing at a slow speed over a 30 s period, add a measured quantity of aggregate estimated to provide the proper consistency. The quantity of aggregate used may be determined by subtracting from a known quantity of prepared aggregate the mass of the portion remaining after mixing.

7.2.8

Stop the mixer, change to medium speed (285 r/min ± 10 r/min), and mix for 30 s.

7.2.9

Stop the mixer and let the mortar stand for 1-1/2 min. During the first 15 s of this interval, quickly scrape down into the batch any mortar that has collected on the sides of the bowl; for the remainder of this interval, cover the bowl with the lid.

7.2.10

Finish by mixing for 1 min at medium speed (285 r/min ± 10 r/min). If the flow appears to be too high, additional sand may be added after the first 30 s of this mixing period. If so, stop the mixer briefly, add the sand, and then complete the additional 30 s of mixing.

7.2.11

In any case requiring a remixing interval, any mortar adhering to the sides of the bowl shall be quickly scraped down into the batch with the scraper prior to remixing.

7.2.12

Make a determination of the flow.

8 Flow test

8.1

Carefully wipe the flow-table top clean and dry, and place the flow mould at the centre. Immediately after completing the mixing operation, place a layer of mortar about 25 mm in thickness in the mould and tamp 20 times with the tamper. Ensure that the tamping pressure is just sufficient to produce uniform filling of the mould. Fill the mould with mortar and tamp as specified for the first layer. Cut off the mortar to a plane surface, flush with the top of the mould, by drawing the straight edge of the trowel (held nearly perpendicular to the mould) with a sawing motion across the top of the mould. Wipe the tabletop clean and dry, being especially careful to remove any water from around the edge of the flow mould. Lift the mould away from the mortar 1 min after completing the mixing operation. Immediately drop the table through a height of 13 mm, ten times in 6 s. The flow is the resulting increase in average diameter of the mortar mass, measured on at least four diameters at approximately equal angles, expressed as a percentage of the original diameter.

8.2

Should the flow be too great, return the mortar to the mixing vessel, add additional sand, mix for 30 s at medium speed, and make another determination of the flow. If more than two trials must be made to obtain a flow of 100% ± 5%, consider the mortar to be a trial mortar and prepare test specimens from a new batch.

8.3

If the mortar is too dry, discard the batch.

8.4

Determine the quantity of sand used by subtracting the mass of the portion remaining after mixing from the mass of the initial sample.

9 Moulding test specimens

9.1 Making specimens

Start moulding the specimens within a total elapsed time of not more than 2 min and 30 s after completion of the original mixing of the mortar batch. Place a layer of mortar about 25 mm (approximately 1/2 of the depth of the mould) in all of the cube compartments. Tamp the mortar in each cube compartment 32 times in about 10 s in four rounds, each round to be at right angles to the other and consisting of eight adjoining strokes over the surface of the specimen, as illustrated in Figure 1. Ensure that the tamping pressure is just sufficient to produce uniform filling of the moulds. Complete the four rounds of tamping (32 strokes) of the mortar in one cube before going to the next. When the tamping of the first layer in all of the cube compartments is completed, fill the compartments with the remaining mortar and then tamp as specified for the first layer.

During tamping of the second layer, bring in the mortar forced out onto the tops of the moulds after each round of tamping, by means of gloved fingers and the tamper, upon completion of each round and before starting the next round of tamping. On completion of the tamping, the tops of all cubes will probably extend slightly above the tops of the moulds. Bring in the mortar that has been forced out onto the tops of the moulds with a trowel and smooth off the cubes by drawing the flat side of the trowel (with the leading edge slightly raised) once across the top of each cube at right angles to the length of the mould. Then, for the purpose of levelling the mortar and making the mortar that protrudes above the top of the mould of more uniform thickness, draw the flat side of the trowel (with the leading edge slightly raised) lightly once along the length of the mould. Cut off the mortar to a plane surface flush with the top of the mould by drawing the straight edge of the trowel (held nearly perpendicular to the mould) with a sawing motion over the length of the mould.

Note: *When a duplicate batch is to be made immediately for additional specimens, the flow test may be omitted and the mortar allowed to stand in the mixing bowl for* 90 s *and then remixed for* 15 s *at medium speed* (285 r/min ± 10 r/min) *before starting the moulding of the specimens.*

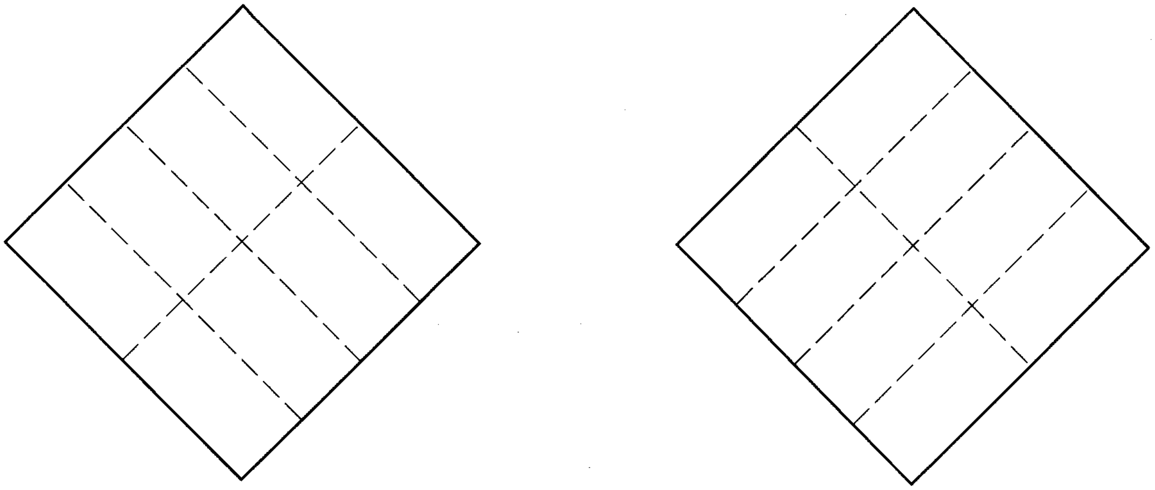


Figure 1
Tamping order
(See Clause 9.1.)

9.2 Storage of test specimens

Immediately upon completion of moulding, place the test specimens in a moist closet or moist room. Keep all test specimens, immediately after moulding, in the moulds on the base plates in the moist closet or moist room from 20 to 24 h with their upper surfaces exposed to the moist air, but protected from dripping water. If the specimens are removed from the moulds before 24 h, keep them on the shelves of the moist closet or moist room until they are 24 h old and then immerse the specimens, except those for the 24 h test, in saturated lime water in storage tanks constructed of non-corroding materials. Keep the storage water clean by changing as required.

10 Determination of compressive strength

10.1

Test the specimens immediately after their removal from the moist closet in the case of 24 h specimens and from storage water in the case of all other specimens. If more than one specimen at a time is removed from the moist closet for the 24 h tests, keep these specimens covered with a damp cloth until the time of testing. If more than one specimen at a time is removed from the storage water for testing, keep these specimens in water at a temperature of 23 °C ± 2 °C and of sufficient depth to completely immerse each specimen until the time of testing.

10.2

Surface-dry each specimen and remove any loose sand grains or encrustations from the faces that will be in contact with the bearing blocks of the testing machine. Check these faces by applying a straightedge and inserting a 0.05 mm thick feeler gauge.* If the bearing surface departs from the plane by more than 0.05 mm, grind the face or faces to plane surfaces or discard the specimen.

**Results much lower than the true strength will be obtained by loading faces of the specimen that are not truly plane surfaces. Therefore, it is essential that specimen moulds be kept scrupulously clean, as otherwise large irregularities in the surfaces will occur. Instruments for cleaning the moulds should always be softer than the metal in the moulds to prevent wear. If grinding of specimen faces is necessary, it can be accomplished best by rubbing the specimen on a sheet of fine emery paper or cloth glued to a plane surface, using only moderate pressure. Such grinding is tedious for more than a few hundredths of a millimetre; where more grinding than this is found necessary, the specimen should be discarded.*

13.2

The single laboratory coefficient of variation has been determined to be 5.4%. Therefore, strength ratios of two properly conducted tests in the same laboratory are not expected to differ from each other by more than 15.3 % of their average. The maximum range (difference between highest and lowest) of the three individual ratios used in calculating the average are not expected to exceed 17%.

Notes:

(1) *Reprinted, with permission, from ASTM C 87,* Standard Test Method for Effect of Organic Impurities in Fine Aggregate on Strength of Mortar, *copyright ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428.*

(2) *These numbers represent, respectively, the (1s %) and (d2s %) limits as described in ASTM C 670.*

A23.2-25A

Test method for detection of alkali-silica reactive aggregate by accelerated expansion of mortar bars

1 Scope

This Test Method allows detection within 16 d of the potential for deleterious expansion of concrete aggregates due to alkali-silica reaction, by means of mortar bars subjected to accelerated test conditions.

2 Reference publications

CSA (Canadian Standards Association)
A23.1-09
Concrete materials and methods of concrete construction

A23.2-1A-09
Sampling aggregates for use in concrete

A23.2-14A-09
Potential expansivity of aggregates (procedure for length change due to alkali-aggregate reaction in concrete prisms at 38 °C)

A23.2-15A-09
Petrographic examination of aggregates

A23.2-27A-09
Standard practice to identify degree of alkali-reactivity of aggregates and to identify measures to avoid deleterious expansion in concrete

A23.2-28A-09
Standard practice for laboratory testing to demonstrate the effectiveness of supplementary cementing materials and lithium-based admixtures to prevent alkali-silica reaction in concrete

A3001-08
Cementitious materials for use in concrete

ASTM International (American Society for Testing and Materials)
C 109/C 109M-08
Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50 mm] Cube Specimens)

C 151/C 151M-09
Standard Test Method for Autoclave Expansion of Hydraulic Cement

C 305-06
Standard Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars for Plastic Consistency

C 490/C 490M-08
Standard Practice for Use of Apparatus for the Determination of Length Change of Hardened Cement Paste, Mortar, and Concrete

C 511-06
Standard Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes

C 670-03
Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction

C 856-04
Standard Practice for Petrographic Examination of Hardened Concrete

D 1193-06
Standard Specification for Reagent Water

Other publications
Davies, G., and Oberholster, R.E. 1987a. *An Interlaboratory Test Programme on the NBRI Accelerated Test to Determine the Alkali-Reactivity of Aggregates.* National Building Research Institute Special Report BOU 92-1987. Pretoria: CSIRO.

Davies, G., and Oberholster, R.E. 1987b. Use of the NBRI Accelerated Test to Evaluate the Effectiveness of Mineral Admixtures in Preventing the Alkali-Silica Reaction. *Cement and Concrete Research* 17: 97–107.

Grattan-Bellew, P.E. 1990. Canadian Experience with the Mortar Bar Accelerated Test for Alkali-Aggregate Reactivity. *Canadian Developments in Testing Concrete Aggregates for Alkali-Aggregate Reactivity,* 17–34. Ontario Ministry of Transportation Engineering Materials Report 92.

Oberholster, R.E., and Davies, G. 1986. An Accelerated Method for Testing the Potential Alkali-Reactivity of Siliceous Aggregates. *Cement and Concrete Research* 16: 181–189.

3 Definitions

In addition to the definitions in Clause 3 of CSA A23.1, the definitions of CSA A3001 apply in this Test Method.

4 Significance and use

4.1

This Test Method provides a means of screening aggregates for their potential reactivity. It is based on the NBRI Accelerated Test Method.

Note: *For additional information, see Olberholster and Davies (1986) Davies and Olberholster (1987a) and (1987b), Grattan-Bellew (1990), and Bérube and Fournier (2000).*

4.2

Criteria to determine the potential deleteriousness of expansions measured in this Test Method are given in CSA A23.2-27A. When excessive expansions are developed, supplementary information should be developed to confirm that the expansion is actually due to alkali reactivity. Sources of such supplementary information include

(a) petrographic examination of the aggregate (see CSA A23.2-15A) to determine whether known reactive constituents are present; and
(b) examination of the specimens after tests (see ASTM C 856) to identify the products of alkali reactivity.

4.3

When it has been concluded from the results of tests performed, using this Test Method and supplementary information, that a given aggregate should be considered potentially deleteriously reactive, additional studies using alternative methods (see CSA A23.2-14A) may be appropriate to develop further information on the potential reactivity.

4.4

This Test Method can be used to demonstrate the effectiveness of supplementary cementing materials to prevent alkali-silica reaction in concrete in accordance with CSA A23.2-28A.

5 Apparatus

The apparatus shall conform to the requirements of ASTM C 490, except as follows:

(a) Square hole, woven-wire cloth sieves shall conform to the requirements of CAN/CGSB-8.2.
(b) The mixer, paddle, and mixing bowl shall conform to the requirements of ASTM C 305, except that the clearance between the lower end of the paddle and the bottom of the bowl shall be 5.1 mm ± 0.3 mm.
(c) The tamper and trowel shall conform to the requirements of ASTM C 109.
(d) The containers shall be of such a design that the bars can be totally immersed in either the water or 1 N NaOH solution. The containers shall be made of material that can withstand prolonged exposure to 80 °C and shall be inert to a 1 N NaOH solution.* The containers shall be so constructed that, when used for storing specimens, the loss of moisture is prevented by tight-fitting covers, by sealing, or both. The bars in the solution shall be placed and supported so that the solution has access to the whole of the bars; therefore, it shall be ensured that the specimens do not touch the sides of the container or each other. The specimens, if stood upright in the solution, shall not be supported by the metal gauge stud.
(e) The convection oven shall have temperature control maintaining 80 °C ± 2.0 °C.

**The NaOH solution will corrode glass or metal containers.*

6 Reagents and materials

6.1 Sodium hydroxide

USP or technical grade sodium hydroxide may be used provided that the Na^+ and OH^- concentrations of the storage solution in Clause 6.3 are shown by chemical analysis to lie between 0.99 N and 1.01 N.

Note: *Sodium hydroxide should be kept in sealed containers until use, as it will absorb moisture and carbon dioxide if exposed to air.*

6.2 Water

Unless otherwise indicated, references to water shall be understood to mean reagent water conforming to Type IV of ASTM D 1193.

6.3 Storage solution

Each 1.0 L of sodium hydroxide solution shall contain 40.0 g of NaOH dissolved in 900 mL of water and shall be diluted with additional distilled or deionized water to obtain 1.0 L of solution.* The volume proportion of sodium hydroxide solution to mortar bars in a storage container shall be 4 ± 0.5 volumes of solution to 1 volume of mortar bars.†

**Precaution: before using NaOH, review*
(a) the safety precautions for using NaOH;
(b) first aid for burns; and

(c) *the emergency response to spills as described in the manufacturer's Materials Safety Data Sheet or other reliable safety literature. NaOH can cause very severe burns and injury to unprotected skin and eyes. Suitable personal protective equipment should always be used. These should include full-face shields, rubber aprons, and gloves impervious to NaOH. Gloves should be checked periodically for pin holes.*

†*The volume of a mortar bar may be taken as* 184 mL.

6.4 Cement

A supply of cement meeting the requirement of general use portland cement (Type GU) as specified in CSA A3001 shall be used. The total alkali content of the cement shall be 0.90% ± 0.10%, calculated as Na_2O + 0.658 K_2O (i.e., the Na_2O equivalent). In addition, the autoclave expansion determined as per ASTM C 151 shall be less than 0.20 %.

6.5 Control aggregate

A supply of Spratt alkali-silica reactive control aggregate shall be prepared as described in Clause 8.2.

Note: *This aggregate is available from the Materials Engineering and Research Office, Ontario Ministry of Transportation.*

7 Conditioning

7.1

The temperature of the moulding room, apparatus, and dry materials shall be determined at not less than 20 °C and not more than 26 °C. The temperature of the mixing water and of the moist closet or moist room shall be 23 °C ± 2.0 °C.

7.2

The relative humidity of the moulding room shall be maintained at not less than 50%. The moist closet or room shall conform to ASTM C 511.

7.3

The storage oven in which the specimens are stored in the containers shall be maintained at a temperature of 80 °C ± 2.0 °C.

8 Sampling and preparation of test specimens

8.1 General

8.1.1

Materials proposed for use as fine aggregate in concrete shall be processed as described in Clause 8.2 with a minimum of crushing. Materials proposed for use as coarse aggregates in concrete shall be processed by crushing to produce, as nearly as practicable, a graded product from which a sample can be obtained. The sample shall have the grading specified in Table 1 and be representative of the composition of the coarse aggregate as proposed for use.

8.1.2

When a given quarried material is proposed for use both as coarse and as fine aggregate, test it only by selection of an appropriate sample crushed to the fine aggregate sizes, unless there is reason to expect that the coarser size fractions have a different composition than the finer sizes and that these differences might significantly affect expansion due to reaction with the alkalis in cement. In this case, the coarser size fractions shall be tested in a manner similar to that employed in testing the fine aggregate sizes.

8.2 Grading

All aggregates to which this Test Method is applied shall be graded in accordance with the requirements in Table 1. Aggregates in which sufficient quantities of the sizes specified in Table 1 do not exist shall be crushed until the required material has been produced. If aggregates contain insufficient amounts of one or more of the larger sizes listed in Table 1, and if no larger material is available for crushing, the first size in which sufficient material is available shall contain the cumulative percentage of material down to that size as determined from the grading specified in Table 1. When such procedures are required, a special note shall be made to that effect in the test report. After the aggregate has been separated into the various sieve sizes, each size shall be washed with a water spray over the sieve to remove adhering dust and fine particles from the aggregate. The portions retained on the various sieves shall be dried and, unless used immediately, stored individually in a clean container provided with a tight-fitting cover.

Note: *In order to produce a graded aggregate sample that is representative of the original coarse aggregate material, the following procedure may be used.*

(a) Start with a representative 6 kg (including 2 kg of each fraction 5 mm to 20 mm) subsample prepared by quartering or other suitable means to ensure a representative portion of the original sample collected following CSA A23.2-1A.

(b) Using a small jaw crusher (or other appropriate equipment), crush the coarse aggregate particles by multiple passes.

(c) Sieve the material over a 5 mm sieve between each pass until all material passes the sieve. Care should be exercised not to close the opening between the jaws or the disks too rapidly because this may produce significant amounts of fine dust.

(d) Separate the material into the various size fractions required for the test.

(e) If insufficient quantities of some of the fractions are produced, ground the particles using a disk pulverizer by progressive passes. The material can be sieved over a suitable sieve between each pass until all material passes the sieve. The material is then separated into the smaller size fractions and blended with the previously produced material.

Table 1
Grading requirements

(See Clauses 8.1.1, 8.2, and 8.4.3.)

Sieve size		
Passing	**Retained**	**Mass, %**
5 mm	2.5 mm	10
2.5 mm	1.25 mm	25
1.25 mm	630 µm	25
630 µm	315 µm	25
315 µm	160 µm	15

8.3 Cement

Portland cement meeting the requirements of Clause 6.4 shall be used. Cement for use in this test shall be passed through a 710 µm sieve to remove lumps before use.

8.4 Preparation of test specimens

8.4.1

Make at least three test specimens for each aggregate.

8.4.2

Prepare the specimen moulds in accordance with the requirements of ASTM C 490, except that the interior surfaces of the mould shall be covered with a release agent.* Consider a release agent acceptable if it serves as a parting agent without affecting the setting of the cement and without leaving any residue that will inhibit the penetration of water into the specimen.

**TFE-Fluorocarbon (Teflon) tape complies with the requirements for a mould release agent.*

8.4.3

The dry materials for the test mortar shall be proportioned using 1 part cement to 2.25 parts graded aggregate by mass. The quantities of dry materials to be mixed at one time in the batch of mortar for making three specimens shall be 440 g of cement and 990 g of aggregate made up by recombining the portions retained on the various sieves (see Clause 8.2) in the grading prescribed in Table 1. For natural fine aggregates, a water-to-cement ratio equal to 0.44 by mass shall be used. For crushed coarse aggregates or manufactured sands, a water-to-cement ratio equal to 0.50 by mass shall be used.

Notes:

(1) *Ruggedness tests indicate that mortar bar expansions were less variable at a fixed water-to-cement ratio than when gauged to a constant flow.*

(2) *The water-to-cement ratios selected should give acceptable workability in most cases.*

8.4.4

Mix the mortar in accordance with the requirements of ASTM C 305.

8.4.5

Mould test specimens with a total elapsed time of not more than 2 min and 15 s after completion of the original mixing of the mortar batch. Fill the moulds with two approximately equal layers, each layer being compacted with the tamper. Work the mortar into the corners, around the gauge studs, and along the surfaces of the mould with the tamper until a homogeneous specimen is obtained. After the top layer has been compacted, cut off the mortar flush with the top of the mould and smooth the surface with a few strokes of the trowel.

9 Procedure

9.1

Place each mould in the moist cabinet or room immediately after moulds have been filled. Leave the specimens in the moulds for 24 h ± 2 h. Remove the specimens from the moulds and, while they are being protected from loss of moisture, properly identify and measure for initial length. Make and record the initial and all subsequent measurements to the nearest 0.002 mm. Place the specimens made with each aggregate sample in a storage container with sufficient tap water, at room temperature, to totally immerse them. Seal and place the containers in an oven at 80 °C ± 2.0 °C for a period of 24 h.

9.2

Remove the containers from the oven one at a time. Remove other containers only after the bars in the first container have been measured and returned to the oven. Remove the bars one at a time from the water and dry their surfaces with a towel, paying particular attention to the two metal gauge measuring studs. Take the zero measurement of each bar immediately after drying, and read as soon as the bar is in position.* Complete the process of drying and measuring within 15 s ± 5 s of removing the specimen from the water. Ensure that the elapsed time between removal of the container from the oven and completion of the measurements is no more than 5 min. After measurement, leave the specimen on a towel until the remainder of the bars have been measured. Place all three specimens in a container with the 1 N NaOH, preheated at 80 °C ± 2.0 °C. Totally immerse the samples. Seal the container and return it to the oven.

**The comparator bar should be measured prior to each set of specimens since the heat from the mortar bars may cause the length of the comparator to change. The lower measuring stud of the comparator should be wiped dry after each measurement to prevent corrosion.*

9.3

Undertake subsequent measurements of the specimens periodically, with at least three intermediate readings for 14 d after the zero reading, at approximately the same time each day. In some cases, if measurements are continued beyond the 14 d period, take at least one reading per week. Follow the measuring procedure described in Clause 9.2, but return the specimens to their containers after measurement.

10 Calculation

The difference between the zero length of the specimen and the length at each period of measurement shall be calculated to the nearest 0.001% of the effective length and recorded as the expansion of the specimen for that period. The average expansion of the three specimens shall be reported to the nearest 0.01% as the expansion for a given period.

11 Use of a control material

11.1

When testing is conducted, the laboratory shall demonstrate its ability to conduct the test. At the time of testing or at least every six months, testing with a known reactive aggregate shall be conducted.

11.2

As a means of validating the testing laboratory and validating the testing process, Spratt aggregate shall be tested. After 14 d in solution, the expansion of mortar bars made with Spratt aggregate shall be between 0.30% and 0.55%. After 28 d of testing, the expansion shall be between 0.47% and 0.98 %. When expansion data are obtained that fall outside these limits, mortar cast with aggregates from the beginning of the first test of the Spratt aggregate until the beginning of the next test with Spratt aggregate shall be retested.

Note: *Spratt coarse aggregate is available in 25 kg bags from the Soils and Aggregates Section, Materials Engineering and Research Office, Ontario Ministry of Transportation.*

12 Reporting

The report shall include the following information:

(a) identification of the laboratory performing the test (i.e, name and address);
(b) name of the technician who sampled the aggregate;
(c) date the sample was taken;
(d) sample number or identification marks;
(e) name of the technician performing the test;
(f) name and signature of the person responsible for the review and approval of the test report;
(g) type and source of aggregate, location of aggregate within the source (e.g., bench level, area within a pit, etc.);
(h) type and source of portland cement;
(i) alkali content of cement as percentage potassium oxide (K_2O), sodium oxide (Na_2O), and calculated sodium oxide (Na_2O) equivalent;
(j) average length change percentage at each reading of the specimens;
(k) any relevant information concerning the preparation of aggregates, including the grading of the aggregate when it differs from that given in Clause 8.2;
(l) any significant features revealed by examination of the specimens and the sodium hydroxide solution during and after the test;*
(m) amount of mixing water expressed as water-to-cement ratio;
(n) a graph of the length change data from the time of the zero reading to the end of the period of testing;
(o) a graph of the length change data from the time of the zero reading to the end of the 14 d period of the control aggregate; and
(p) expansion of mortar bars made with the Spratt aggregate tested closest in time to that of the results of the sample being reported.

**In some cases, the solution might become cloudy due to the presence of alkali-silica gel.*

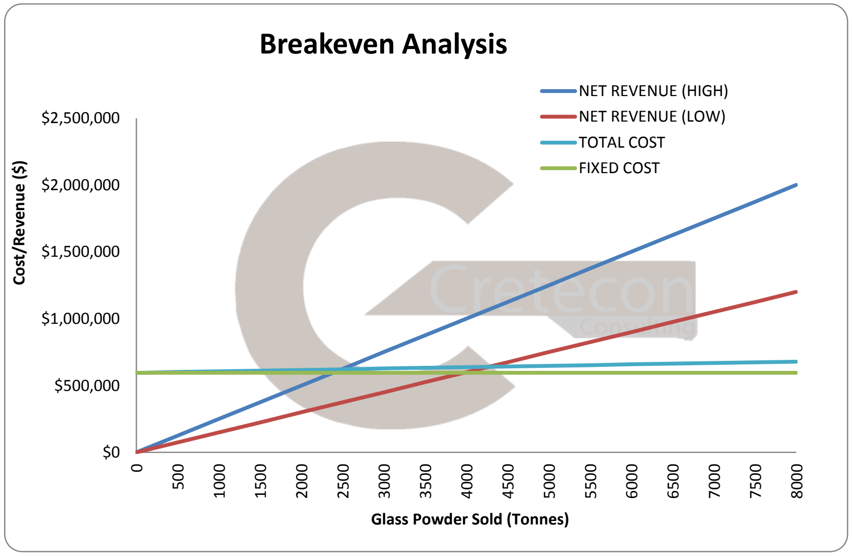
APPENDIX D

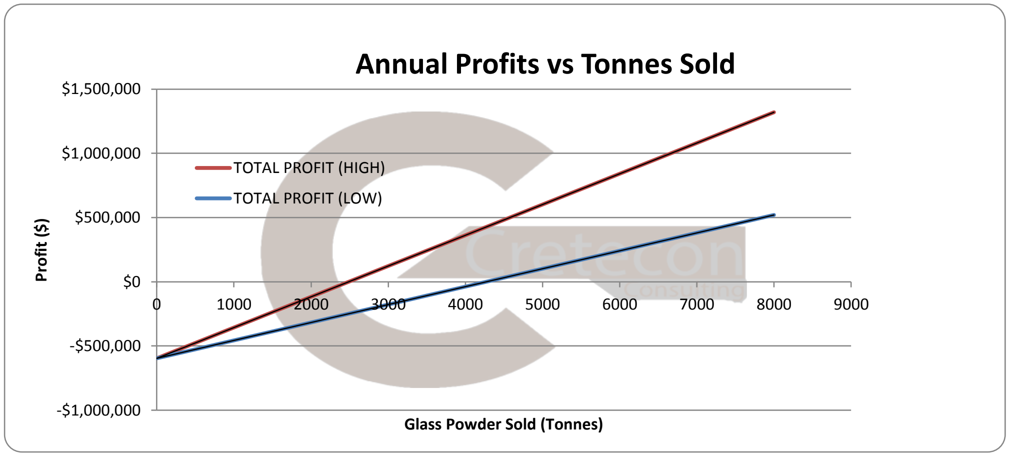
Feasibility Tables

BREAK-EVEN ANALYSIS BASED ON FIRST YEAR FIGURES

FIXED COST	596,205	$ 596,205.04	(168480+10000+1500)*1.12+174388.79
VARIABLE COST	$ 10.45	9.33*1.12	10.4496
NUMBER OF UNITS	500		
UNIT PRICE (LOW)	$ 150.00		
UNIT PRICE (HIGH)	$ 250.00		

NET UNITS	NET REVENUE (LOW)	NET REVENUE (HIGH)	FIXED COST	VARIABLE COST	TOTAL COST	TOTAL PROFIT (LOW)	TOTAL PROFIT (HIGH)
0	$0	$0	$596,205	$0	$596,205	-$596,205	-$596,205
500	$75,000	$125,000	$596,205	$5,225	$601,430	-$526,430	-$476,430
1000	$150,000	$250,000	$596,205	$10,450	$606,655	-$456,655	-$356,655
1500	$225,000	$375,000	$596,205	$15,674	$611,879	-$386,879	-$236,879
2000	$300,000	$500,000	$596,205	$20,899	$617,104	-$317,104	-$117,104
2500	$375,000	$625,000	$596,205	$26,124	$622,329	-$247,329	$2,671
3000	$450,000	$750,000	$596,205	$31,349	$627,554	-$177,554	$122,446
3500	$525,000	$875,000	$596,205	$36,574	$632,779	-$107,779	$242,221
4000	$600,000	$1,000,000	$596,205	$41,798	$638,003	-$38,003	$361,997
4500	$675,000	$1,125,000	$596,205	$47,023	$643,228	$31,772	$481,772
5000	$750,000	$1,250,000	$596,205	$52,248	$648,453	$101,547	$601,547
5500	$825,000	$1,375,000	$596,205	$57,473	$653,678	$171,322	$721,322
6000	$900,000	$1,500,000	$596,205	$62,698	$658,903	$241,097	$841,097
6500	$975,000	$1,625,000	$596,205	$67,922	$664,127	$310,873	$960,873
7000	$1,050,000	$1,750,000	$596,205	$73,147	$669,352	$380,648	$1,080,648
7500	$1,125,000	$1,875,000	$596,205	$78,372	$674,577	$450,423	$1,200,423
8000	$1,200,000	$2,000,000	$596,205	$83,597	$679,802	$520,198	$1,320,198





LOAN AMORTIZATION SCHEDULE

ENTER VALUES

Loan amount	$5,426,846.00
Annual interest rate	4.00%
Loan period in years	20
Number of payments per year	12
Start date of loan	6/1/2013

Optional extra payments	

LOAN SUMMARY

Scheduled payment	$32,885.62
Scheduled number of payments	240
Actual number of payments	240
Total early payments	
Total interest	$248,196.12

LENDER NAME	

PMT NO	PAYMENT DATE	BEGINNING BALANCE	SCHEDULED PAYMENT	EXTRA PAYMENT	TOTAL PAYMENT	PRINCIPAL	INTEREST	ENDING BALANCE	CUMULATIVE INTEREST
1	6/1/2013	$5,426,846.00	$32,885.62	$0.00	$32,885.62	$14,796.13	$18,089.49	$5,412,049.87	$18,089.49
2	7/1/2013	$5,412,049.87	$32,885.62	$0.00	$32,885.62	$14,845.45	$18,040.17	$5,397,204.41	$36,129.65
3	8/1/2013	$5,397,204.41	$32,885.62	$0.00	$32,885.62	$14,894.94	$17,990.68	$5,382,309.48	$54,120.33
4	9/1/2013	$5,382,309.48	$32,885.62	$0.00	$32,885.62	$14,944.59	$17,941.03	$5,367,364.89	$72,061.37
5	10/1/2013	$5,367,364.89	$32,885.62	$0.00	$32,885.62	$14,994.40	$17,891.22	$5,352,370.49	$89,952.58
6	11/1/2013	$5,352,370.49	$32,885.62	$0.00	$32,885.62	$15,044.38	$17,841.23	$5,337,326.10	$107,793.82
7	12/1/2013	$5,337,326.10	$32,885.62	$0.00	$32,885.62	$15,094.53	$17,791.09	$5,322,231.57	$125,584.90
8	1/1/2014	$5,322,231.57	$32,885.62	$0.00	$32,885.62	$15,144.85	$17,740.77	$5,307,086.72	$143,325.68
9	2/1/2014	$5,307,086.72	$32,885.62	$0.00	$32,885.62	$15,195.33	$17,690.29	$5,291,891.39	$161,015.97
10	3/1/2014	$5,291,891.39	$32,885.62	$0.00	$32,885.62	$15,245.98	$17,639.64	$5,276,645.41	$178,655.60
11	4/1/2014	$5,276,645.41	$32,885.62	$0.00	$32,885.62	$15,296.80	$17,588.82	$5,261,348.61	$196,244.42
12	5/1/2014	$5,261,348.61	$32,885.62	$0.00	$32,885.62	$15,347.79	$17,537.83	$5,246,000.82	$213,782.25
13	6/1/2014	$5,246,000.82	$32,885.62	$0.00	$32,885.62	$15,398.95	$17,486.67	$5,230,601.87	$231,268.92
14	7/1/2014	$5,230,601.87	$32,885.62	$0.00	$32,885.62	$15,450.28	$17,435.34	$5,215,151.59	$248,704.26
15	8/1/2014	$5,215,151.59	$32,885.62	$0.00	$32,885.62	$15,501.78	$17,383.84	$5,199,649.81	$266,088.10
16	9/1/2014	$5,199,649.81	$32,885.62	$0.00	$32,885.62	$15,553.45	$17,332.17	$5,184,096.36	$283,420.26
17	10/1/2014	$5,184,096.36	$32,885.62	$0.00	$32,885.62	$15,605.30	$17,280.32	$5,168,491.06	$300,700.58
18	11/1/2014	$5,168,491.06	$32,885.62	$0.00	$32,885.62	$15,657.32	$17,228.30	$5,152,833.74	$317,928.89
19	12/1/2014	$5,152,833.74	$32,885.62	$0.00	$32,885.62	$15,709.51	$17,176.11	$5,137,124.23	$335,105.00
20	1/1/2015	$5,137,124.23	$32,885.62	$0.00	$32,885.62	$15,761.87	$17,123.75	$5,121,362.36	$352,228.75
21	2/1/2015	$5,121,362.36	$32,885.62	$0.00	$32,885.62	$15,814.41	$17,071.21	$5,105,547.95	$369,299.96
22	3/1/2015	$5,105,547.95	$32,885.62	$0.00	$32,885.62	$15,867.13	$17,018.49	$5,089,680.83	$386,318.45
23	4/1/2015	$5,089,680.83	$32,885.62	$0.00	$32,885.62	$15,920.02	$16,965.60	$5,073,760.81	$403,284.05
24	5/1/2015	$5,073,760.81	$32,885.62	$0.00	$32,885.62	$15,973.08	$16,912.54	$5,057,787.73	$420,196.59
25	6/1/2015	$5,057,787.73	$32,885.62	$0.00	$32,885.62	$16,026.33	$16,859.29	$5,041,761.40	$437,055.88
26	7/1/2015	$5,041,761.40	$32,885.62	$0.00	$32,885.62	$16,079.75	$16,805.87	$5,025,681.65	$453,861.75
27	8/1/2015	$5,025,681.65	$32,885.62	$0.00	$32,885.62	$16,133.35	$16,752.27	$5,009,548.30	$470,614.02
28	9/1/2015	$5,009,548.30	$32,885.62	$0.00	$32,885.62	$16,187.12	$16,698.49	$4,993,361.18	$487,312.52
29	10/1/2015	$4,993,361.18	$32,885.62	$0.00	$32,885.62	$16,241.08	$16,644.54	$4,977,120.10	$503,957.06
30	11/1/2015	$4,977,120.10	$32,885.62	$0.00	$32,885.62	$16,295.22	$16,590.40	$4,960,824.88	$520,547.46

PMT NO	PAYMENT DATE	BEGINNING BALANCE	SCHEDULED PAYMENT	EXTRA PAYMENT	TOTAL PAYMENT	PRINCIPAL	INTEREST	ENDING BALANCE	CUMULATIVE INTEREST
31	12/1/2015	$4,960,824.88	$32,885.62	$0.00	$32,885.62	$16,349.54	$16,536.08	$4,944,475.34	$537,083.54
32	1/1/2016	$4,944,475.34	$32,885.62	$0.00	$32,885.62	$16,404.03	$16,481.58	$4,928,071.31	$553,565.12
33	2/1/2016	$4,928,071.31	$32,885.62	$0.00	$32,885.62	$16,458.71	$16,426.90	$4,911,612.59	$569,992.03
34	3/1/2016	$4,911,612.59	$32,885.62	$0.00	$32,885.62	$16,513.58	$16,372.04	$4,895,099.01	$586,364.07
35	4/1/2016	$4,895,099.01	$32,885.62	$0.00	$32,885.62	$16,568.62	$16,317.00	$4,878,530.39	$602,681.07
36	5/1/2016	$4,878,530.39	$32,885.62	$0.00	$32,885.62	$16,623.85	$16,261.77	$4,861,906.54	$618,942.83
37	6/1/2016	$4,861,906.54	$32,885.62	$0.00	$32,885.62	$16,679.26	$16,206.36	$4,845,227.28	$635,149.19
38	7/1/2016	$4,845,227.28	$32,885.62	$0.00	$32,885.62	$16,734.86	$16,150.76	$4,828,492.41	$651,299.95
39	8/1/2016	$4,828,492.41	$32,885.62	$0.00	$32,885.62	$16,790.64	$16,094.97	$4,811,701.77	$667,394.92
40	9/1/2016	$4,811,701.77	$32,885.62	$0.00	$32,885.62	$16,846.61	$16,039.01	$4,794,855.16	$683,433.93
41	10/1/2016	$4,794,855.16	$32,885.62	$0.00	$32,885.62	$16,902.77	$15,982.85	$4,777,952.39	$699,416.78
42	11/1/2016	$4,777,952.39	$32,885.62	$0.00	$32,885.62	$16,959.11	$15,926.51	$4,760,993.28	$715,343.29
43	12/1/2016	$4,760,993.28	$32,885.62	$0.00	$32,885.62	$17,015.64	$15,869.98	$4,743,977.64	$731,213.26
44	1/1/2017	$4,743,977.64	$32,885.62	$0.00	$32,885.62	$17,072.36	$15,813.26	$4,726,905.27	$747,026.52
45	2/1/2017	$4,726,905.27	$32,885.62	$0.00	$32,885.62	$17,129.27	$15,756.35	$4,709,776.01	$762,782.87
46	3/1/2017	$4,709,776.01	$32,885.62	$0.00	$32,885.62	$17,186.37	$15,699.25	$4,692,589.64	$778,482.13
47	4/1/2017	$4,692,589.64	$32,885.62	$0.00	$32,885.62	$17,243.65	$15,641.97	$4,675,345.99	$794,124.09
48	5/1/2017	$4,675,345.99	$32,885.62	$0.00	$32,885.62	$17,301.13	$15,584.49	$4,658,044.85	$809,708.58
49	6/1/2017	$4,658,044.85	$32,885.62	$0.00	$32,885.62	$17,358.80	$15,526.82	$4,640,686.05	$825,235.39
50	7/1/2017	$4,640,686.05	$32,885.62	$0.00	$32,885.62	$17,416.67	$15,468.95	$4,623,269.39	$840,704.35
51	8/1/2017	$4,623,269.39	$32,885.62	$0.00	$32,885.62	$17,474.72	$15,410.90	$4,605,794.66	$856,115.25
52	9/1/2017	$4,605,794.66	$32,885.62	$0.00	$32,885.62	$17,532.97	$15,352.65	$4,588,261.69	$871,467.90
53	10/1/2017	$4,588,261.69	$32,885.62	$0.00	$32,885.62	$17,591.41	$15,294.21	$4,570,670.28	$886,762.10
54	11/1/2017	$4,570,670.28	$32,885.62	$0.00	$32,885.62	$17,650.05	$15,235.57	$4,553,020.23	$901,997.67
55	12/1/2017	$4,553,020.23	$32,885.62	$0.00	$32,885.62	$17,708.89	$15,176.73	$4,535,311.34	$917,174.40
56	1/1/2018	$4,535,311.34	$32,885.62	$0.00	$32,885.62	$17,767.91	$15,117.70	$4,517,543.43	$932,292.11
57	2/1/2018	$4,517,543.43	$32,885.62	$0.00	$32,885.62	$17,827.14	$15,058.48	$4,499,716.29	$947,350.59
58	3/1/2018	$4,499,716.29	$32,885.62	$0.00	$32,885.62	$17,886.56	$14,999.05	$4,481,829.72	$962,349.64
59	4/1/2018	$4,481,829.72	$32,885.62	$0.00	$32,885.62	$17,946.19	$14,939.43	$4,463,883.54	$977,289.07
60	5/1/2018	$4,463,883.54	$32,885.62	$0.00	$32,885.62	$18,006.01	$14,879.61	$4,445,877.53	$992,168.68
61	6/1/2018	$4,445,877.53	$32,885.62	$0.00	$32,885.62	$18,066.03	$14,819.59	$4,427,811.50	$1,006,988.28
62	7/1/2018	$4,427,811.50	$32,885.62	$0.00	$32,885.62	$18,126.25	$14,759.37	$4,409,685.25	$1,021,747.65
63	8/1/2018	$4,409,685.25	$32,885.62	$0.00	$32,885.62	$18,186.67	$14,698.95	$4,391,498.58	$1,036,446.60
64	9/1/2018	$4,391,498.58	$32,885.62	$0.00	$32,885.62	$18,247.29	$14,638.33	$4,373,251.29	$1,051,084.93
65	10/1/2018	$4,373,251.29	$32,885.62	$0.00	$32,885.62	$18,308.11	$14,577.50	$4,354,943.18	$1,065,662.43
66	11/1/2018	$4,354,943.18	$32,885.62	$0.00	$32,885.62	$18,369.14	$14,516.48	$4,336,574.04	$1,080,178.91
67	12/1/2018	$4,336,574.04	$32,885.62	$0.00	$32,885.62	$18,430.37	$14,455.25	$4,318,143.66	$1,094,634.15
68	1/1/2019	$4,318,143.66	$32,885.62	$0.00	$32,885.62	$18,491.81	$14,393.81	$4,299,651.86	$1,109,027.97
69	2/1/2019	$4,299,651.86	$32,885.62	$0.00	$32,885.62	$18,553.45	$14,332.17	$4,281,098.41	$1,123,360.14
70	3/1/2019	$4,281,098.41	$32,885.62	$0.00	$32,885.62	$18,615.29	$14,270.33	$4,262,483.12	$1,137,630.47
71	4/1/2019	$4,262,483.12	$32,885.62	$0.00	$32,885.62	$18,677.34	$14,208.28	$4,243,805.78	$1,151,838.75
72	5/1/2019	$4,243,805.78	$32,885.62	$0.00	$32,885.62	$18,739.60	$14,146.02	$4,225,066.18	$1,165,984.76

PMT NO	PAYMENT DATE	BEGINNING BALANCE	SCHEDULED PAYMENT	EXTRA PAYMENT	TOTAL PAYMENT	PRINCIPAL	INTEREST	ENDING BALANCE	CUMULATIVE INTEREST
73	6/1/2019	$4,225,066.18	$32,885.62	$0.00	$32,885.62	$18,802.07	$14,083.55	$4,206,264.11	$1,180,068.32
74	7/1/2019	$4,206,264.11	$32,885.62	$0.00	$32,885.62	$18,864.74	$14,020.88	$4,187,399.37	$1,194,089.20
75	8/1/2019	$4,187,399.37	$32,885.62	$0.00	$32,885.62	$18,927.62	$13,958.00	$4,168,471.75	$1,208,047.20
76	9/1/2019	$4,168,471.75	$32,885.62	$0.00	$32,885.62	$18,990.71	$13,894.91	$4,149,481.04	$1,221,942.10
77	10/1/2019	$4,149,481.04	$32,885.62	$0.00	$32,885.62	$19,054.02	$13,831.60	$4,130,427.02	$1,235,773.71
78	11/1/2019	$4,130,427.02	$32,885.62	$0.00	$32,885.62	$19,117.53	$13,768.09	$4,111,309.49	$1,249,541.80
79	12/1/2019	$4,111,309.49	$32,885.62	$0.00	$32,885.62	$19,181.25	$13,704.36	$4,092,128.24	$1,263,246.16
80	1/1/2020	$4,092,128.24	$32,885.62	$0.00	$32,885.62	$19,245.19	$13,640.43	$4,072,883.05	$1,276,886.59
81	2/1/2020	$4,072,883.05	$32,885.62	$0.00	$32,885.62	$19,309.34	$13,576.28	$4,053,573.70	$1,290,462.87
82	3/1/2020	$4,053,573.70	$32,885.62	$0.00	$32,885.62	$19,373.71	$13,511.91	$4,034,200.00	$1,303,974.78
83	4/1/2020	$4,034,200.00	$32,885.62	$0.00	$32,885.62	$19,438.29	$13,447.33	$4,014,761.71	$1,317,422.11
84	5/1/2020	$4,014,761.71	$32,885.62	$0.00	$32,885.62	$19,503.08	$13,382.54	$3,995,258.63	$1,330,804.65
85	6/1/2020	$3,995,258.63	$32,885.62	$0.00	$32,885.62	$19,568.09	$13,317.53	$3,975,690.54	$1,344,122.18
86	7/1/2020	$3,975,690.54	$32,885.62	$0.00	$32,885.62	$19,633.32	$13,252.30	$3,956,057.22	$1,357,374.48
87	8/1/2020	$3,956,057.22	$32,885.62	$0.00	$32,885.62	$19,698.76	$13,186.86	$3,936,358.46	$1,370,561.34
88	9/1/2020	$3,936,358.46	$32,885.62	$0.00	$32,885.62	$19,764.42	$13,121.19	$3,916,594.04	$1,383,682.53
89	10/1/2020	$3,916,594.04	$32,885.62	$0.00	$32,885.62	$19,830.31	$13,055.31	$3,896,763.73	$1,396,737.85
90	11/1/2020	$3,896,763.73	$32,885.62	$0.00	$32,885.62	$19,896.41	$12,989.21	$3,876,867.33	$1,409,727.06
91	12/1/2020	$3,876,867.33	$32,885.62	$0.00	$32,885.62	$19,962.73	$12,922.89	$3,856,904.60	$1,422,649.95
92	1/1/2021	$3,856,904.60	$32,885.62	$0.00	$32,885.62	$20,029.27	$12,856.35	$3,836,875.33	$1,435,506.30
93	2/1/2021	$3,836,875.33	$32,885.62	$0.00	$32,885.62	$20,096.03	$12,789.58	$3,816,779.29	$1,448,295.88
94	3/1/2021	$3,816,779.29	$32,885.62	$0.00	$32,885.62	$20,163.02	$12,722.60	$3,796,616.27	$1,461,018.48
95	4/1/2021	$3,796,616.27	$32,885.62	$0.00	$32,885.62	$20,230.23	$12,655.39	$3,776,386.04	$1,473,673.87
96	5/1/2021	$3,776,386.04	$32,885.62	$0.00	$32,885.62	$20,297.67	$12,587.95	$3,756,088.37	$1,486,261.82
97	6/1/2021	$3,756,088.37	$32,885.62	$0.00	$32,885.62	$20,365.32	$12,520.29	$3,735,723.05	$1,498,782.12
98	7/1/2021	$3,735,723.05	$32,885.62	$0.00	$32,885.62	$20,433.21	$12,452.41	$3,715,289.84	$1,511,234.53
99	8/1/2021	$3,715,289.84	$32,885.62	$0.00	$32,885.62	$20,501.32	$12,384.30	$3,694,788.52	$1,523,618.83
100	9/1/2021	$3,694,788.52	$32,885.62	$0.00	$32,885.62	$20,569.66	$12,315.96	$3,674,218.86	$1,535,934.79
101	10/1/2021	$3,674,218.86	$32,885.62	$0.00	$32,885.62	$20,638.22	$12,247.40	$3,653,580.64	$1,548,182.18
102	11/1/2021	$3,653,580.64	$32,885.62	$0.00	$32,885.62	$20,707.02	$12,178.60	$3,632,873.62	$1,560,360.79
103	12/1/2021	$3,632,873.62	$32,885.62	$0.00	$32,885.62	$20,776.04	$12,109.58	$3,612,097.58	$1,572,470.36
104	1/1/2022	$3,612,097.58	$32,885.62	$0.00	$32,885.62	$20,845.29	$12,040.33	$3,591,252.29	$1,584,510.69
105	2/1/2022	$3,591,252.29	$32,885.62	$0.00	$32,885.62	$20,914.78	$11,970.84	$3,570,337.51	$1,596,481.53
106	3/1/2022	$3,570,337.51	$32,885.62	$0.00	$32,885.62	$20,984.49	$11,901.13	$3,549,353.01	$1,608,382.66
107	4/1/2022	$3,549,353.01	$32,885.62	$0.00	$32,885.62	$21,054.44	$11,831.18	$3,528,298.57	$1,620,213.83
108	5/1/2022	$3,528,298.57	$32,885.62	$0.00	$32,885.62	$21,124.62	$11,761.00	$3,507,173.95	$1,631,974.83
109	6/1/2022	$3,507,173.95	$32,885.62	$0.00	$32,885.62	$21,195.04	$11,690.58	$3,485,978.91	$1,643,665.41
110	7/1/2022	$3,485,978.91	$32,885.62	$0.00	$32,885.62	$21,265.69	$11,619.93	$3,464,713.22	$1,655,285.34
111	8/1/2022	$3,464,713.22	$32,885.62	$0.00	$32,885.62	$21,336.58	$11,549.04	$3,443,376.64	$1,666,834.38
112	9/1/2022	$3,443,376.64	$32,885.62	$0.00	$32,885.62	$21,407.70	$11,477.92	$3,421,968.95	$1,678,312.30
113	10/1/2022	$3,421,968.95	$32,885.62	$0.00	$32,885.62	$21,479.06	$11,406.56	$3,400,489.89	$1,689,718.87
114	11/1/2022	$3,400,489.89	$32,885.62	$0.00	$32,885.62	$21,550.65	$11,334.97	$3,378,939.24	$1,701,053.83

PMT NO	PAYMENT DATE	BEGINNING BALANCE	SCHEDULED PAYMENT	EXTRA PAYMENT	TOTAL PAYMENT	PRINCIPAL	INTEREST	ENDING BALANCE	CUMULATIVE INTEREST
115	12/1/2022	$3,378,939.24	$32,885.62	$0.00	$32,885.62	$21,622.49	$11,263.13	$3,357,316.75	$1,712,316.96
116	1/1/2023	$3,357,316.75	$32,885.62	$0.00	$32,885.62	$21,694.56	$11,191.06	$3,335,622.19	$1,723,508.02
117	2/1/2023	$3,335,622.19	$32,885.62	$0.00	$32,885.62	$21,766.88	$11,118.74	$3,313,855.31	$1,734,626.76
118	3/1/2023	$3,313,855.31	$32,885.62	$0.00	$32,885.62	$21,839.43	$11,046.18	$3,292,015.87	$1,745,672.94
119	4/1/2023	$3,292,015.87	$32,885.62	$0.00	$32,885.62	$21,912.23	$10,973.39	$3,270,103.64	$1,756,646.33
120	5/1/2023	$3,270,103.64	$32,885.62	$0.00	$32,885.62	$21,985.27	$10,900.35	$3,248,118.36	$1,767,546.68
121	6/1/2023	$3,248,118.36	$32,885.62	$0.00	$32,885.62	$22,058.56	$10,827.06	$3,226,059.81	$1,778,373.74
122	7/1/2023	$3,226,059.81	$32,885.62	$0.00	$32,885.62	$22,132.09	$10,753.53	$3,203,927.72	$1,789,127.27
123	8/1/2023	$3,203,927.72	$32,885.62	$0.00	$32,885.62	$22,205.86	$10,679.76	$3,181,721.86	$1,799,807.03
124	9/1/2023	$3,181,721.86	$32,885.62	$0.00	$32,885.62	$22,279.88	$10,605.74	$3,159,441.98	$1,810,412.77
125	10/1/2023	$3,159,441.98	$32,885.62	$0.00	$32,885.62	$22,354.15	$10,531.47	$3,137,087.83	$1,820,944.24
126	11/1/2023	$3,137,087.83	$32,885.62	$0.00	$32,885.62	$22,428.66	$10,456.96	$3,114,659.17	$1,831,401.20
127	12/1/2023	$3,114,659.17	$32,885.62	$0.00	$32,885.62	$22,503.42	$10,382.20	$3,092,155.75	$1,841,783.40
128	1/1/2024	$3,092,155.75	$32,885.62	$0.00	$32,885.62	$22,578.43	$10,307.19	$3,069,577.32	$1,852,090.58
129	2/1/2024	$3,069,577.32	$32,885.62	$0.00	$32,885.62	$22,653.69	$10,231.92	$3,046,923.62	$1,862,322.51
130	3/1/2024	$3,046,923.62	$32,885.62	$0.00	$32,885.62	$22,729.21	$10,156.41	$3,024,194.42	$1,872,478.92
131	4/1/2024	$3,024,194.42	$32,885.62	$0.00	$32,885.62	$22,804.97	$10,080.65	$3,001,389.45	$1,882,559.57
132	5/1/2024	$3,001,389.45	$32,885.62	$0.00	$32,885.62	$22,880.99	$10,004.63	$2,978,508.46	$1,892,564.20
133	6/1/2024	$2,978,508.46	$32,885.62	$0.00	$32,885.62	$22,957.26	$9,928.36	$2,955,551.20	$1,902,492.56
134	7/1/2024	$2,955,551.20	$32,885.62	$0.00	$32,885.62	$23,033.78	$9,851.84	$2,932,517.42	$1,912,344.40
135	8/1/2024	$2,932,517.42	$32,885.62	$0.00	$32,885.62	$23,110.56	$9,775.06	$2,909,406.86	$1,922,119.46
136	9/1/2024	$2,909,406.86	$32,885.62	$0.00	$32,885.62	$23,187.60	$9,698.02	$2,886,219.26	$1,931,817.48
137	10/1/2024	$2,886,219.26	$32,885.62	$0.00	$32,885.62	$23,264.89	$9,620.73	$2,862,954.37	$1,941,438.21
138	11/1/2024	$2,862,954.37	$32,885.62	$0.00	$32,885.62	$23,342.44	$9,543.18	$2,839,611.93	$1,950,981.39
139	12/1/2024	$2,839,611.93	$32,885.62	$0.00	$32,885.62	$23,420.25	$9,465.37	$2,816,191.69	$1,960,446.77
140	1/1/2025	$2,816,191.69	$32,885.62	$0.00	$32,885.62	$23,498.31	$9,387.31	$2,792,693.37	$1,969,834.07
141	2/1/2025	$2,792,693.37	$32,885.62	$0.00	$32,885.62	$23,576.64	$9,308.98	$2,769,116.73	$1,979,143.05
142	3/1/2025	$2,769,116.73	$32,885.62	$0.00	$32,885.62	$23,655.23	$9,230.39	$2,745,461.50	$1,988,373.44
143	4/1/2025	$2,745,461.50	$32,885.62	$0.00	$32,885.62	$23,734.08	$9,151.54	$2,721,727.42	$1,997,524.98
144	5/1/2025	$2,721,727.42	$32,885.62	$0.00	$32,885.62	$23,813.19	$9,072.42	$2,697,914.23	$2,006,597.40
145	6/1/2025	$2,697,914.23	$32,885.62	$0.00	$32,885.62	$23,892.57	$8,993.05	$2,674,021.66	$2,015,590.45
146	7/1/2025	$2,674,021.66	$32,885.62	$0.00	$32,885.62	$23,972.21	$8,913.41	$2,650,049.44	$2,024,503.85
147	8/1/2025	$2,650,049.44	$32,885.62	$0.00	$32,885.62	$24,052.12	$8,833.50	$2,625,997.32	$2,033,337.35
148	9/1/2025	$2,625,997.32	$32,885.62	$0.00	$32,885.62	$24,132.29	$8,753.32	$2,601,865.03	$2,042,090.68
149	10/1/2025	$2,601,865.03	$32,885.62	$0.00	$32,885.62	$24,212.74	$8,672.88	$2,577,652.29	$2,050,763.56
150	11/1/2025	$2,577,652.29	$32,885.62	$0.00	$32,885.62	$24,293.44	$8,592.17	$2,553,358.85	$2,059,355.73
151	12/1/2025	$2,553,358.85	$32,885.62	$0.00	$32,885.62	$24,374.42	$8,511.20	$2,528,984.42	$2,067,866.93
152	1/1/2026	$2,528,984.42	$32,885.62	$0.00	$32,885.62	$24,455.67	$8,429.95	$2,504,528.75	$2,076,296.88
153	2/1/2026	$2,504,528.75	$32,885.62	$0.00	$32,885.62	$24,537.19	$8,348.43	$2,479,991.56	$2,084,645.31
154	3/1/2026	$2,479,991.56	$32,885.62	$0.00	$32,885.62	$24,618.98	$8,266.64	$2,455,372.58	$2,092,911.95
155	4/1/2026	$2,455,372.58	$32,885.62	$0.00	$32,885.62	$24,701.04	$8,184.58	$2,430,671.54	$2,101,096.52
156	5/1/2026	$2,430,671.54	$32,885.62	$0.00	$32,885.62	$24,783.38	$8,102.24	$2,405,888.16	$2,109,198.76

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157	6/1/2026	$2,405,888.16	$32,885.62	$0.00	$32,885.62	$24,865.99	$8,019.63	$2,381,022.16	$2,117,218.39
158	7/1/2026	$2,381,022.16	$32,885.62	$0.00	$32,885.62	$24,948.88	$7,936.74	$2,356,073.28	$2,125,155.13
159	8/1/2026	$2,356,073.28	$32,885.62	$0.00	$32,885.62	$25,032.04	$7,853.58	$2,331,041.24	$2,133,008.71
160	9/1/2026	$2,331,041.24	$32,885.62	$0.00	$32,885.62	$25,115.48	$7,770.14	$2,305,925.76	$2,140,778.84
161	10/1/2026	$2,305,925.76	$32,885.62	$0.00	$32,885.62	$25,199.20	$7,686.42	$2,280,726.56	$2,148,465.26
162	11/1/2026	$2,280,726.56	$32,885.62	$0.00	$32,885.62	$25,283.20	$7,602.42	$2,255,443.36	$2,156,067.68
163	12/1/2026	$2,255,443.36	$32,885.62	$0.00	$32,885.62	$25,367.47	$7,518.14	$2,230,075.89	$2,163,585.83
164	1/1/2027	$2,230,075.89	$32,885.62	$0.00	$32,885.62	$25,452.03	$7,433.59	$2,204,623.86	$2,171,019.41
165	2/1/2027	$2,204,623.86	$32,885.62	$0.00	$32,885.62	$25,536.87	$7,348.75	$2,179,086.98	$2,178,368.16
166	3/1/2027	$2,179,086.98	$32,885.62	$0.00	$32,885.62	$25,622.00	$7,263.62	$2,153,464.99	$2,185,631.78
167	4/1/2027	$2,153,464.99	$32,885.62	$0.00	$32,885.62	$25,707.40	$7,178.22	$2,127,757.58	$2,192,810.00
168	5/1/2027	$2,127,757.58	$32,885.62	$0.00	$32,885.62	$25,793.09	$7,092.53	$2,101,964.49	$2,199,902.53
169	6/1/2027	$2,101,964.49	$32,885.62	$0.00	$32,885.62	$25,879.07	$7,006.55	$2,076,085.42	$2,206,909.07
170	7/1/2027	$2,076,085.42	$32,885.62	$0.00	$32,885.62	$25,965.33	$6,920.28	$2,050,120.08	$2,213,829.36
171	8/1/2027	$2,050,120.08	$32,885.62	$0.00	$32,885.62	$26,051.89	$6,833.73	$2,024,068.20	$2,220,663.09
172	9/1/2027	$2,024,068.20	$32,885.62	$0.00	$32,885.62	$26,138.73	$6,746.89	$1,997,929.47	$2,227,409.99
173	10/1/2027	$1,997,929.47	$32,885.62	$0.00	$32,885.62	$26,225.85	$6,659.76	$1,971,703.62	$2,234,069.75
174	11/1/2027	$1,971,703.62	$32,885.62	$0.00	$32,885.62	$26,313.27	$6,572.35	$1,945,390.35	$2,240,642.10
175	12/1/2027	$1,945,390.35	$32,885.62	$0.00	$32,885.62	$26,400.98	$6,484.63	$1,918,989.36	$2,247,126.73
176	1/1/2028	$1,918,989.36	$32,885.62	$0.00	$32,885.62	$26,488.99	$6,396.63	$1,892,500.37	$2,253,523.36
177	2/1/2028	$1,892,500.37	$32,885.62	$0.00	$32,885.62	$26,577.28	$6,308.33	$1,865,923.09	$2,259,831.70
178	3/1/2028	$1,865,923.09	$32,885.62	$0.00	$32,885.62	$26,665.88	$6,219.74	$1,839,257.21	$2,266,051.44
179	4/1/2028	$1,839,257.21	$32,885.62	$0.00	$32,885.62	$26,754.76	$6,130.86	$1,812,502.45	$2,272,182.30
180	5/1/2028	$1,812,502.45	$32,885.62	$0.00	$32,885.62	$26,843.94	$6,041.67	$1,785,658.51	$2,278,223.97
181	6/1/2028	$1,785,658.51	$32,885.62	$0.00	$32,885.62	$26,933.42	$5,952.20	$1,758,725.08	$2,284,176.17
182	7/1/2028	$1,758,725.08	$32,885.62	$0.00	$32,885.62	$27,023.20	$5,862.42	$1,731,701.88	$2,290,038.59
183	8/1/2028	$1,731,701.88	$32,885.62	$0.00	$32,885.62	$27,113.28	$5,772.34	$1,704,588.60	$2,295,810.92
184	9/1/2028	$1,704,588.60	$32,885.62	$0.00	$32,885.62	$27,203.66	$5,681.96	$1,677,384.94	$2,301,492.89
185	10/1/2028	$1,677,384.94	$32,885.62	$0.00	$32,885.62	$27,294.34	$5,591.28	$1,650,090.61	$2,307,084.17
186	11/1/2028	$1,650,090.61	$32,885.62	$0.00	$32,885.62	$27,385.32	$5,500.30	$1,622,705.29	$2,312,584.47
187	12/1/2028	$1,622,705.29	$32,885.62	$0.00	$32,885.62	$27,476.60	$5,409.02	$1,595,228.69	$2,317,993.49
188	1/1/2029	$1,595,228.69	$32,885.62	$0.00	$32,885.62	$27,568.19	$5,317.43	$1,567,660.50	$2,323,310.92
189	2/1/2029	$1,567,660.50	$32,885.62	$0.00	$32,885.62	$27,660.08	$5,225.53	$1,540,000.41	$2,328,536.45
190	3/1/2029	$1,540,000.41	$32,885.62	$0.00	$32,885.62	$27,752.28	$5,133.33	$1,512,248.13	$2,333,669.79
191	4/1/2029	$1,512,248.13	$32,885.62	$0.00	$32,885.62	$27,844.79	$5,040.83	$1,484,403.34	$2,338,710.62
192	5/1/2029	$1,484,403.34	$32,885.62	$0.00	$32,885.62	$27,937.61	$4,948.01	$1,456,465.73	$2,343,658.63
193	6/1/2029	$1,456,465.73	$32,885.62	$0.00	$32,885.62	$28,030.73	$4,854.89	$1,428,434.99	$2,348,513.51
194	7/1/2029	$1,428,434.99	$32,885.62	$0.00	$32,885.62	$28,124.17	$4,761.45	$1,400,310.83	$2,353,274.96
195	8/1/2029	$1,400,310.83	$32,885.62	$0.00	$32,885.62	$28,217.92	$4,667.70	$1,372,092.91	$2,357,942.66
196	9/1/2029	$1,372,092.91	$32,885.62	$0.00	$32,885.62	$28,311.98	$4,573.64	$1,343,780.93	$2,362,516.31
197	10/1/2029	$1,343,780.93	$32,885.62	$0.00	$32,885.62	$28,406.35	$4,479.27	$1,315,374.58	$2,366,995.58
198	11/1/2029	$1,315,374.58	$32,885.62	$0.00	$32,885.62	$28,501.04	$4,384.58	$1,286,873.55	$2,371,380.16

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199	12/1/2029	$1,286,873.55	$32,885.62	$0.00	$32,885.62	$28,596.04	$4,289.58	$1,258,277.51	$2,375,669.74
200	1/1/2030	$1,258,277.51	$32,885.62	$0.00	$32,885.62	$28,691.36	$4,194.26	$1,229,586.14	$2,379,864.00
201	2/1/2030	$1,229,586.14	$32,885.62	$0.00	$32,885.62	$28,787.00	$4,098.62	$1,200,799.15	$2,383,962.62
202	3/1/2030	$1,200,799.15	$32,885.62	$0.00	$32,885.62	$28,882.96	$4,002.66	$1,171,916.19	$2,387,965.28
203	4/1/2030	$1,171,916.19	$32,885.62	$0.00	$32,885.62	$28,979.23	$3,906.39	$1,142,936.96	$2,391,871.67
204	5/1/2030	$1,142,936.96	$32,885.62	$0.00	$32,885.62	$29,075.83	$3,809.79	$1,113,861.13	$2,395,681.46
205	6/1/2030	$1,113,861.13	$32,885.62	$0.00	$32,885.62	$29,172.75	$3,712.87	$1,084,688.38	$2,399,394.33
206	7/1/2030	$1,084,688.38	$32,885.62	$0.00	$32,885.62	$29,269.99	$3,615.63	$1,055,418.39	$2,403,009.96
207	8/1/2030	$1,055,418.39	$32,885.62	$0.00	$32,885.62	$29,367.56	$3,518.06	$1,026,050.83	$2,406,528.02
208	9/1/2030	$1,026,050.83	$32,885.62	$0.00	$32,885.62	$29,465.45	$3,420.17	$996,585.38	$2,409,948.19
209	10/1/2030	$996,585.38	$32,885.62	$0.00	$32,885.62	$29,563.67	$3,321.95	$967,021.71	$2,413,270.14
210	11/1/2030	$967,021.71	$32,885.62	$0.00	$32,885.62	$29,662.21	$3,223.41	$937,359.50	$2,416,493.54
211	12/1/2030	$937,359.50	$32,885.62	$0.00	$32,885.62	$29,761.09	$3,124.53	$907,598.41	$2,419,618.08
212	1/1/2031	$907,598.41	$32,885.62	$0.00	$32,885.62	$29,860.29	$3,025.33	$877,738.12	$2,422,643.40
213	2/1/2031	$877,738.12	$32,885.62	$0.00	$32,885.62	$29,959.83	$2,925.79	$847,778.29	$2,425,569.20
214	3/1/2031	$847,778.29	$32,885.62	$0.00	$32,885.62	$30,059.69	$2,825.93	$817,718.60	$2,428,395.13
215	4/1/2031	$817,718.60	$32,885.62	$0.00	$32,885.62	$30,159.89	$2,725.73	$787,558.71	$2,431,120.85
216	5/1/2031	$787,558.71	$32,885.62	$0.00	$32,885.62	$30,260.42	$2,625.20	$757,298.29	$2,433,746.05
217	6/1/2031	$757,298.29	$32,885.62	$0.00	$32,885.62	$30,361.29	$2,524.33	$726,937.00	$2,436,270.38
218	7/1/2031	$726,937.00	$32,885.62	$0.00	$32,885.62	$30,462.50	$2,423.12	$696,474.50	$2,438,693.50
219	8/1/2031	$696,474.50	$32,885.62	$0.00	$32,885.62	$30,564.04	$2,321.58	$665,910.46	$2,441,015.08
220	9/1/2031	$665,910.46	$32,885.62	$0.00	$32,885.62	$30,665.92	$2,219.70	$635,244.55	$2,443,234.78
221	10/1/2031	$635,244.55	$32,885.62	$0.00	$32,885.62	$30,768.14	$2,117.48	$604,476.41	$2,445,352.27
222	11/1/2031	$604,476.41	$32,885.62	$0.00	$32,885.62	$30,870.70	$2,014.92	$573,605.71	$2,447,367.19
223	12/1/2031	$573,605.71	$32,885.62	$0.00	$32,885.62	$30,973.60	$1,912.02	$542,632.11	$2,449,279.21
224	1/1/2032	$542,632.11	$32,885.62	$0.00	$32,885.62	$31,076.85	$1,808.77	$511,555.27	$2,451,087.98
225	2/1/2032	$511,555.27	$32,885.62	$0.00	$32,885.62	$31,180.44	$1,705.18	$480,374.83	$2,452,793.16
226	3/1/2032	$480,374.83	$32,885.62	$0.00	$32,885.62	$31,284.37	$1,601.25	$449,090.46	$2,454,394.41
227	4/1/2032	$449,090.46	$32,885.62	$0.00	$32,885.62	$31,388.65	$1,496.97	$417,701.81	$2,455,891.38
228	5/1/2032	$417,701.81	$32,885.62	$0.00	$32,885.62	$31,493.28	$1,392.34	$386,208.53	$2,457,283.72
229	6/1/2032	$386,208.53	$32,885.62	$0.00	$32,885.62	$31,598.26	$1,287.36	$354,610.27	$2,458,571.08
230	7/1/2032	$354,610.27	$32,885.62	$0.00	$32,885.62	$31,703.59	$1,182.03	$322,906.69	$2,459,753.12
231	8/1/2032	$322,906.69	$32,885.62	$0.00	$32,885.62	$31,809.26	$1,076.36	$291,097.42	$2,460,829.47
232	9/1/2032	$291,097.42	$32,885.62	$0.00	$32,885.62	$31,915.29	$970.32	$259,182.13	$2,461,799.80
233	10/1/2032	$259,182.13	$32,885.62	$0.00	$32,885.62	$32,021.68	$863.94	$227,160.45	$2,462,663.74
234	11/1/2032	$227,160.45	$32,885.62	$0.00	$32,885.62	$32,128.42	$757.20	$195,032.03	$2,463,420.94
235	12/1/2032	$195,032.03	$32,885.62	$0.00	$32,885.62	$32,235.51	$650.11	$162,796.52	$2,464,071.05
236	1/1/2033	$162,796.52	$32,885.62	$0.00	$32,885.62	$32,342.96	$542.66	$130,453.56	$2,464,613.70
237	2/1/2033	$130,453.56	$32,885.62	$0.00	$32,885.62	$32,450.77	$434.85	$98,002.78	$2,465,048.55
238	3/1/2033	$98,002.78	$32,885.62	$0.00	$32,885.62	$32,558.94	$326.68	$65,443.84	$2,465,375.22
239	4/1/2033	$65,443.84	$32,885.62	$0.00	$32,885.62	$32,667.47	$218.15	$32,776.36	$2,465,593.37
240	5/1/2033	$32,776.36	$32,885.62	$0.00	$32,776.36	$32,667.11	$109.25	$0.00	$2,465,702.62

APPENDIX E

Mortar Bar Data Sheets

amec

MORTAR BAR WORKSHEET

CSA A23.2-25A

Client and Project No.:
Source of Aggregate:
Lab ID.:

Date Sample Rec'd:
Date Mixed:
Start Mixing:
Finish Mixing:
Finish Casting:
Time Demoulded:

Room Temp.
Room Humidity

Natural ☐
Crushed ☐
Method of Crushing:

Cement (Lab #):
Cement Sieved: ☐

Temp. of oven
Temp. of solution

Batched By:
Cast By:

Total Aggregate weight	990.0
Cement weight	440.0
Natural Sand - Water (0.44)	193.6
Crushed Agg - Water (0.50)	220.0

Comments/Obs.

Aggregate weight by sieve size:
2.5mm
1.25mm
630 µm
315 µm
160 µm

Initial Gauge Length:

Grading Requirements
Sieve Size

Passing	**Retained**	**Mass %**	**Mass grams**
5 mm	2.5 mm	10	99.0
2.5 mm	1.25 mm	25	247.5
1.25 mm	630 um	25	247.5
630 um	315 um	25	247.5
315 um	160 um	15	148.5
		Total	**990.0**

Cretecon2013@gmail.com

20% GP

ACCELERATED DETECTION OF POTENTIALLY DELETERIOUS ALKALI-SILICA REACTIVE AGGREGATE BY EXPANSION OF MORTAR BARS

CSA A23.2 - 25A

		Wednesday Mar 6	Thursday Mar 7	Friday Mar 8	Mar 9th	20% GP 10th	Monday 11th	Tuesday 12th	Wednesday 13th	Thrus 14th	Friday 15th	16th	17th	Monday 18th	Tuesday 19th	Wednesday 20th
	Initial	Zero	1 Day	2 Day	3 Day	4 Day	5 day	6 Day	7 day	8 Day	9 Day	10 Day	11 day	12 Day	13 Day	14 day
Readings																
Air Temp.	19.0	21	19.8	20.1°C			20.1	18.8°C	20.4°C	20.0°C	20.3			18.9°C		20.6
Solution Temp		79.6	80	79.7			81.0	81.1	80.5°C	80.4	81.0			81.0°C		78.0
Time Taken	12:36	11:00	1:16	11:50			11:45	12:44	11:19	11:42	11:30			11:36		11:16
Reference Bar	-.12	-.96	-0.066	-0.070			-.076	-0.082	-0.114	-0.096	-0.066			-0.086		-0.066
A	~~-.78~~	~~-.48~~														
B	.240	.392	0.406	0.414			0.444	0.456	0.462	0.472	0.494			0.532		0.542
C	.176	.326	0.352	0.352			0.386	0.392	0.396	0.410	0.428			0.458		0.466
Reference Bar	.000	0.002	0.006	0.002			0.000	0.000	0.002	0.000	0.004			0.002		0.000

Expansion %	Initial	Zero	1 Day	2 Day	3 Day	4 Day	5 day	6 Day	7 day	8 Day	9 Day	10 Day	11 day	12 Day	13 Day	14 day
Mortars																
A																
B																
C																
Average																

(20%)GP + FA(10%)

amec

ACCELERATED DETECTION OF POTENTIALLY DELETERIOUS ALKALI-SILICA REACTIVE AGGREGATE BY EXPANSION OF MORTAR BARS

CSA A23.2 - 25A

		Wednesday Mar 6	Thru Mar 7	Fri Mar 8	Sat Mar 9	Sun 10th	GP + FA 11th	Tues 12th	Wedn 13th	thurs 14th	Frid 15th	Sat 16th	Sun 17th	Mon 18th	Tues 19th	Wednes 20th
	Initial	Zero	1 Day	2 Day	3 Day	4 Day	5 day	6 Day	7 day	8 Day	9 Day	10 Day	11 day	12 Day	13 Day	14 day
Readings																
Air Temp.	18.9	21.0	20.0°C	20.0°C			20.0	18.9	20.3°C	20.6	20.2			18.9°C		20.5
Solution Temp		80°C	79.7	78.3			79.0	80.0	80.0°C	81.0	80.5			81.0°C		80.5
Time Taken	12:30	11:10	1:30	11:47			11:41	12:48	11:18	11:45	11:30			11:39		11:15
Reference Bar	-.12	-.052	-0.068	-0.072			-0.108	-0.116	-0.076	-0.072	-0.076			-0.082		-0.066
A	.254	0.406	0.408	0.400			0.416	0.434	0.416	0.434	0.444			0.462		0.446
B	.194	0.334	0.346	0.336			0.356	0.386	0.358	0.368	0.392			0.400		0.390
C	.002	0.154	0.172	0.148			0.176	0.200	0.182	0.180	0.208			0.226		0.226
Reference Bar	.000	0.004	0.000	0.002			0.004	0.002	0.002	0.000	0.002			0.002		0.002
Expansion %	Initial	Zero	1 Day	2 Day	3 Day	4 Day	5 day	6 Day	7 day	8 Day	9 Day	10 Day	11 day	12 Day	13 Day	14 day
Mortars																
A																
B																
C																
Average																

Mun Term Project cretecon2013@gmail.com

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ACCELERATED DETECTION OF POTENTIALLY DELETERIOUS ALKALI-SILICA REACTIVE AGGREGATE BY EXPANSION OF MORTAR BARS

CSA A23.2 - 25A

10% Silica fume

	Tue	wed	Thur	Fri	Sat	Sun	Mon	Tue	wed	Thur	Fri	Sat	Sun	Mon	Tue	wed
	Initial	Zero	1 Day	2 Day	3 Day	4 Day	5 day	6 Day	7 day	8 Day	9 Day	10 Day	11 day	12 Day	13 Day	14 day
Readings	Feb 26	Feb 27	Feb 28	mar 1	mar 2	mar 3	mar 4	mar 5	mar 6	mar 7	mar 8	mar 9	mar 10	mar 11	mar 12	mar 13
Air Temp.	17.5	18.7°C	19.2°C	20.0°C			21.4°C		21.0		19.9			20.1	19.0°C	20.5°C
Solution Temp	—	78.0°C	78.02	79.8			80.0°C		80.4		79.8			11:50	80.8	78.0°C
Time Taken	12:42	1:00	12:30	12:45			12:18		11:15		11:45			81.0	12:51	11:34
Reference Bar	-.152	-.134	-0.118	-0.180			-.058		-0.054		-0.068			-0.114	-0.114	-0.110
A	.172	.330	0.344	0.346			0.386		0.406		0.418			0.438	0.430	0.434
B	.108	.268	0.278	0.286			0.330		0.344		0.334			0.368	0.352	0.360
C	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Reference Bar	-.002	.000	0.002	0.000			0.000		0.000		0.002			0.000	0.002	0.002

Expansion %	Initial	Zero	1 Day	2 Day	3 Day	4 Day	5 day	6 Day	7 day	8 Day	9 Day	10 Day	11 day	12 Day	13 Day	14 day
Mortars																
A																
B																
C																
Average																

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ACCELERATED DETECTION OF POTENTIALLY DELETERIOUS ALKALI-SILICA REACTIVE AGGREGATE BY EXPANSION OF MORTAR BARS

CSA A23.2 - 25A

	Tues	wed	Thurs	Fri	Sat	Sun	GU Mon	Tues	wed	Thurs	Fri	Sat	Sun	Mon	Tues	wed
	Initial	Zero	1 Day	2 Day	3 Day	4 Day	5 day	6 Day	7 day	8 Day	9 Day	10 Day	11 day	12 Day	13 Day	14 day
Readings	Feb19	Feb 20	Feb 21	Feb 22	Feb 23	Feb 24	Feb 25	Feb 26	Feb 27	Feb 28	Mar 1	Mar 2	mar 3	mar 4	mar 5	mar 6
Air Temp.	18.6	17.2	17.4	17.1			17.1°C		18.6°C		19.5			21.7		21.9
Solution Temp	—	78.4	78.5	78.3			79.2°C		80.5°C		78.6			80.0		80.6
Time Taken	13:40	12:49	12.40	12:50			12:30				13:50			12:30		11,00
Reference Bar	-.152	-.146	-0.192	-.156			-0.156		-0.170		-0.144			-0.052		-,060
A	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
B	-.142	0.136	-0.16	-.148			0.016	-	0.312		0.512			0.782		,914
C	.106	0.266	0.278	.288			0.642		0.928		1,148			1.416		1,548
Reference Bar	,002	0.002	0.004	,000			0.004		0.000		0.002			0.000		0.002

Expansion %	Initial	Zero	1 Day	2 Day	3 Day	4 Day	5 day	6 Day	7 day	8 Day	9 Day	10 Day	11 day	12 Day	13 Day	14 day
Mortars																
A																
B		.006														
C		.160														
Average																

AMEC Environment & Infrastructure
36 Pippy Place
St. John's, NL CANADA A1C 3X2

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ACCELERATED DETECTION OF POTENTIALLY DELETERIOUS ALKALI-SILICA REACTIVE AGGREGATE BY EXPANSION OF MORTAR BARS

CSA A23.2 - 25A

Terc 3

	Initial	Zero	1 Day	2 Day	3 Day	4 Day	5 day	6 Day	7 day	8 Day	9 Day	10 Day	11 day	12 Day	13 Day	14 day
	Tues	wed	Thurs	Fri	Sat	Sun	mon	Tue	wed	Thurs	Fri	Sat	Sun	Mon	Tue	wed
Readings	Feb 19	Feb20	Feb 21	Feb 22	Feb23	Feb24	Feb 25	Feb 26	Feb27	Feb28	Mar 1	mar 2	mar 3	mar 4	mar 5	mar 6
Air Temp.	18.6	16.8	17.6	17.1			17.1		18.6°C		19.6			21.6		
Solution Temp	—	80.3	80.2	80.0			79.6		81.2°C		79.3			80.2		81.4
Time Taken	13:45	12:40	12:40	12:30			12:30				12:55			12:34		11:00
Reference Bar	-.156	-.152	-0.146	-.148			-0.154		-0.176		-0.144			-.052		-0.078
A	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
B	0.138	0.302	0.292	.292			0.312		.306		0.322			0.330		0.370
C	.114	.286	0.268	.268			0.294		.270		0.286			0.294		0.[illegible] .296
Reference Bar	0.000	0.000	0.000	.002			0.002		.006		0.01			0.000		0.000

Expansion %	Initial	Zero	1 Day	2 Day	3 Day	4 Day	5 day	6 Day	7 day	8 Day	9 Day	10 Day	11 day	12 Day	13 Day	14 day
Mortars																
A																
B		.164														
C		.172														
Average																

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ACCELERATED DETECTION OF POTENTIALLY DELETERIOUS ALKALI-SILICA REACTIVE AGGREGATE BY EXPANSION OF MORTAR BARS

CSA A23.2 - 25A

25% Fly Ash

	Tues	wed	Thur	Fri	Sat	Sun	mon	Tue
	Initial	Zero	1 Day	2 Day	3 Day	4 Day	5 day	6 Day
Readings	Feb26	Feb27	Feb28	mar 1	mar 2	mar 3	mar 4	mar 5
Air Temp.	17.5	18.8°C	19.2°C	19.1			21.6°C	
Solution Temp	—	78.4°C	79.0°C	79.0			80.2°C	
Time Taken	12:40		12:30	12:45			12:20	
Reference Bar	-.156	-0.124	-0.128	-.184			-0.092	
A	0.120	0.276	0.270	0.264			0.296	
B	0.214	0.370	0.352	0.342			0.390	
C	—	—	—	—	—	—	—	—
Reference Bar	.000	0.002	0.006	0.000			-0.002	
Expansion %	Initial	Zero	1 Day	2 Day	3 Day	4 Day	5 day	6 Day
Mortars								
A								
B								
C								
Average								

	wed	Thur	Fri	Sat	Sun	mon	Tue	wed
	7 day	8 Day	9 Day	10 Day	11 day	12 Day	13 Day	14 day
Readings	mar 6	mar 7	mar 8	mar 9	mar 10	mar 11	mar 12	mar 13
Air Temp.	21.0		19.9			20.1	19.2	20.4°C
Solution Temp	81.2		80°C			80	80.0°C	78.0°C
Time Taken	11:00		11:40			11:50	12:50	11:30
Reference Bar	-0.58		-0.076			-.068	-0.108	-0.114
A	0.304		0.304			0.308	0.342	0.304
B	0.388		0.386			0.392	0.420	0.392
C	—	—	—	—	—	—	—	—
Reference Bar	0.00[illegible]		-0.002			0.000		0.000
Expansion %	7 day	8 Day	9 Day	10 Day	11 day	12 Day	13 Day	14 day
Mortars								
A								
B								
C								
Average								

10% GP/10% FA.

amec

ACCELERATED DETECTION OF POTENTIALLY DELETERIOUS ALKALI-SILICA REACTIVE AGGREGATE BY EXPANSION OF MORTAR BARS

CSA A23.2 - 25A

	Mar.13 Wed		14 Th	15 Fr	16 Sat	17 Sun	18 Mon	19 Tu	20 Wed	21 Th	22 Fr	23 Sat	24 Sun	25 Mon	26 Tu	27 Wed.
	Initial	Zero	1 Day	2 Day	3 Day	4 Day	5 day	6 Day	7 day	8 Day	9 Day	10 Day	11 day	12 Day	13 Day	14 day
Readings																
Air Temp.	19.4°C	20.1°C	20.1	20.3			20.4°C		20.4		21.3			80.2	~~20.5~~	20.5
Solution Temp	~~4~~ —	80.0°C	77.3	79			78.6°C		78.0		76.2			21.2	~~79.4~~	79.4
Time Taken	1.15	11:16	11:50	11:30			11:40		11:05 ~~10:05~~		1150			11:10	~~11:30~~	11:30
Reference Bar	-0.070	-0.100	-0.106	-0.078			-0.120		-0.05		-0.096			-0.062	-~~.104~~	-.104
A	0.212	0.362	0.344	0.370			0.408		0.386		0.416			.436	/	.440
B	0.288	0.446	0.436	0.444			0.468		0.484		0.474			.508	/	.494
C	—	—	—	—			—		—		—			—	—	—
Reference Bar	0.000	0.000	0.000	0.000			0.000		0.000		0.00			.002	/	.000

Expansion %	Initial	Zero	1 Day	2 Day	3 Day	4 Day	5 day	6 Day	7 day	8 Day	9 Day	10 Day	11 day	12 Day	13 Day	14 day
Mortars																
A																
B																
C																
Average																

10% GP

amec

ACCELERATED DETECTION OF POTENTIALLY DELETERIOUS ALKALI-SILICA REACTIVE AGGREGATE BY EXPANSION OF MORTAR BARS

CSA A23.2 - 25A

		13 Wed	14 Thur	15 Fri	16 Sat	17 Sun	18 Mon	19 Tues	20 Wed	21 Thur	22 Frid	23 Sat	24 Sun	25 Mon	26 Tue	27 Wed
	Initial	Zero	1 Day	2 Day	3 Day	4 Day	5 day	6 Day	7 day	8 Day	9 Day	10 Day	11 day	12 Day	13 Day	14 day
Readings																
Air Temp.	19.4°C	20.0°C	20.1	20.4			20.9°C		20.4		21.3			21.2		20.7
Solution Temp	—	78.5°C	77.5	78.5			78.0°C		78.0		76.4			80.4		80.3
Time Taken	1:14	11:15	11:50	11:30			11:42		11:12		1:50			11:12		11:32
Reference Bar	-0.078	-0.068	-0.070	-0.68			-0.114		-0.060		-0.058			-.076		-0.068
A	0.294	0.444	0.468	0.480			0.634		0.756		0.886			1.060		1.172
B	0.160	0.316	0.322	0.324			0.482		0.606		0.722			.898		.992
C	0.352	0.510	0.514	0.518			0.674		0.812		0.946			1.122		1.236
Reference Bar	0.000	0.004	[illegible].002	0.002			0.002		0.002		0.002			0.000		0.000

Expansion %	Initial	Zero	1 Day	2 Day	3 Day	4 Day	5 day	6 Day	7 day	8 Day	9 Day	10 Day	11 day	12 Day	13 Day	14 day
Mortars																
A																
B																
C																
Average																

APPENDIX F

Compressive Strength Data Sheets

GROUT CUBE COMPRESSIVE STRENGTH TEST REPORT

PROJECT NO: TF12 Mun

REPORT NO: 4

PROJECT: Mun Term Project

DATE CAST: Feb 20, 2013

CLIENT:

10% Silica Fume

LABORATORY TEST DATA

RoL	CYLINDER NUMBER	SIZE (mm)	DATE TESTED	AGE AT TEST (Days)	STRENGTH (MPa)	Time *5000 Lb
0.29	9734 A	51.08 x 51.96	Feb 27	7	19110 / 32.1	29.06 sec
	B	51.54 x 52.86	Mar 6	14	26120 / 42.8	
0.29	C	51.44 x 51.41	Mar 20	28	32416 / 54.1	
0.29	D	52.03 x 51.18	Mar 20	28	30966 / 51.9	
	E			Hold		
	F			Hold		

Grout (g):

Sand (g):

Water (g):

W/C Ratio:

Mix Time:

Time Cast:

Testing: Water

Temperature (°C):

Initial Curing: Open plastic bag in Curing Room

REMARKS: *Testing was preformed at AMEC, St. John's Laboratory, 36 Pippy Place, St. John's, NL*

Tested By: ____________

Reviewed By: ____________

We certify the testing procedures performed by this laboratory are in accordance with CSA A23.2-8A-09

GROUT CUBE COMPRESSIVE STRENGTH TEST REPORT

PROJECT NO: TF12 Mun

PROJECT: Mun Term Project

CLIENT:

REPORT NO: 3

DATE CAST: Feb 20, 2013

25% Fly Ash

LABORATORY TEST DATA

RoL	CYLINDER NUMBER	SIZE (mm)	DATE TESTED	AGE AT TEST (Days)	STRENGTH (MPa)	Time 10000 lb
0.26	9733 A	50.54 x 50.31	Feb 27	7	12502 / 21.9	*674 sec
	B	50.95 x 50.07	Mar 6	14	16567 / 29.0	
0.29	C	50.23 x 51.01	Mar 20	28	20400 / 35.5	
0.30	D	51.25 x 50.06	Mar 20	28	20704 / 36.0	
	G			Hold		
	F			Hold		

Grout (g):
Sand (g):
Water (g):
W/C Ratio:
Mix Time:
Time Cast:

Testing: Water
Temperature (°C):
Initial Curing: Open plastic bag in Curing Room

REMARKS: *Testing was preformed at AMEC, St. John's Laboratory, 36 Pippy Place, St. John's, NL*

Tested By: ______________

Reviewed By: ______________

We certify the testing procedures performed by this laboratory are in accordance with CSA A23.2-8A-09

amec

GROUT CUBE COMPRESSIVE STRENGTH TEST REPORT

PROJECT NO: TA12Mun
PROJECT: Term Project
CLIENT:

REPORT NO: 1
DATE CAST: Feb 18, 2013

GU

LABORATORY TEST DATA

CYLINDER NUMBER	SIZE (mm)	DATE TESTED	AGE AT TEST (Days)	STRENGTH (MPa)
9725 A	51.07 x 50.90	Feb 25	7	20199 / 34.6
B	51.10 x 53.09	Mar 4	14	20220 / 33.2
0.30 C	51.1 X 51.2	Mar 18	28	26946 / 45.9
0.29 D	51.2 X 51.2	Mar 18	28	28154 / 47.9
E		Hold		
F		Hold		

Grout (g):
Sand (g):
Water (g):
W/C Ratio:
Mix Time:
Time Cast:

Testing: Water
Temperature (°C):
Initial Curing: Open plastic bag in Curing Room

REMARKS: *Testing was preformed at AMEC, St. John's Laboratory, 36 Pippy Place, St. John's, NL*

Tested By: ______________

Reviewed By: ______________

We certify the testing procedures performed by this laboratory are in accordance with CSA A23.2-8A-09

amec

GROUT CUBE COMPRESSIVE STRENGTH TEST REPORT

PROJECT NO: TF12Mun

REPORT NO: 1

PROJECT:

DATE CAST: Feb 18, 2013

CLIENT:

TerC3

LABORATORY TEST DATA

0.30

0.28

CYLINDER NUMBER	SIZE (mm)	DATE TESTED	AGE AT TEST (Days)	STRENGTH (MPa)
9726 A	51.55 x 51.28	Feb 25	7	13297/22.4
B	50.75 x 50.10	Mar 4	14	18342/32.2
C	52.8 X 51.3	Mar 18	28	24021/39.5
D	52.6 X 51.3	Mar 18	28	22825/37.7
G		Hold		
F		Hold		

Grout (g):

Sand (g):

Water (g):

W/C Ratio:

Mix Time:

Time Cast:

Testing: Water

Temperature (°C):

Initial Curing: Open plastic bag in Curing Room

REMARKS: *Testing was preformed at AMEC, St. John's Laboratory, 36 Pippy Place, St. John's, NL*

Tested By: ____________

Reviewed By: ____________

We certify the testing procedures performed by this laboratory are in accordance with CSA A23.2-8A-09

GROUT CUBE COMPRESSIVE STRENGTH TEST REPORT

PROJECT NO: TP17Mun
PROJECT: Mun Term Project
CLIENT:

REPORT NO:
DATE CAST: Mar. 11th, 2013

10% GP

LABORATORY TEST DATA

	CYLINDER NUMBER	SIZE (mm)	DATE TESTED	AGE AT TEST (Days)	STRENGTH (MPa)
0.27	9773 A	50.5X50.6	Mar 18/13	7	14818 / 25.9
0.31	B	50.6 x 49.93	Mar 25/13	14	16399 / 28.9
0.30	C	50.5X50.8	Apr 1/13	28	18513 / 32.2
0.29	D	50.0X50.8	Apr 1/13	28	18447/32.4
	G			Hold	
	F			Hold	

Grout (g):
Sand (g):
Water (g):
W/C Ratio:
Mix Time:
Time Cast:

Testing: Water
Temperature (°C):
Initial Curing: Open plastic bag in Curing Room

REMARKS: *Testing was preformed at AMEC, St. John's Laboratory, 36 Pippy Place, St. John's, NL*

Tested By: ______________

Reviewed By: ______________

We certify the testing procedures performed by this laboratory are in accordance with CSA A23.2-8A-09

amec

GROUT CUBE COMPRESSIVE STRENGTH TEST REPORT

PROJECT NO: TF12Mun
PROJECT: Mun Term Project
CLIENT:

REPORT NO:
DATE CAST: Mar, 11st, 2013

10%GP/10% FA

LABORATORY TEST DATA

	CYLINDER NUMBER	SIZE (mm)	DATE TESTED	AGE AT TEST (Days)	STRENGTH (MPa)
0.26	9794 A	52.1 X 51.3	Mar 18/13	7	11751/12.6
0.27	B	51.2 x 51.7	Mar 25/13	14	12524/21.1
0.28	C	51.9 X 51.0	Apr 1/13	28	15467/26.1
0.31	D	51.5X52.5	Apr 1/13	28	16666/27.5
	G			Hold	
	F			Hold	

Grout (g):
Sand (g):
Water (g):
W/C Ratio:
Mix Time:
Time Cast:

Testing: Water
Temperature (°C):
Initial Curing: Open plastic bag in Curing Room

REMARKS: *Testing was preformed at AMEC, St. John's Laboratory, 36 Pippy Place, St. John's, NL*

Tested By: ______________

Reviewed By: ______________

We certify the testing procedures performed by this laboratory are in accordance with CSA A23.2-8A-09

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GROUT CUBE COMPRESSIVE STRENGTH TEST REPORT

PROJECT NO: TF12 Mun
PROJECT:
CLIENT:

REPORT NO:
DATE CAST:

Rol

LABORATORY TEST DATA

20% Glass Powder to 10% Fly Ash

	CYLINDER NUMBER	SIZE (mm)	DATE TESTED	AGE AT TEST (Days)	STRENGTH (MPa)
0.28	~~9756~~ A	2635 mm²	Mar 11	7	9018 / 15.3
0.31	9757 B	2683 mm²	Mar 18	14	11781 / 19.6
0.28	C	2663 mm².	Apr 1	28	16113 / 27.0
0.29	D	2699 mm²	Apr 1	28	15712 / 26.0
	E			Hold	
	F			Hold	

Grout (g):
Sand (g):
Water (g):
W/C Ratio:
Mix Time:
Time Cast:

Testing: Water
Temperature (°C):
Initial Curing: Open plastic bag in Curing Room

REMARKS: *Testing was preformed at AMEC, St. John's Laboratory, 36 Pippy Place, St. John's, NL*

Tested By: ____________

Reviewed By: ____________

We certify the testing procedures performed by this laboratory are in accordance with CSA A23.2-8A-09

amec

GROUT CUBE COMPRESSIVE STRENGTH TEST REPORT

PROJECT NO: TF12 Mcn
REPORT NO:
PROJECT:
DATE CAST:
CLIENT:

20% Glass Powder

Rol

0.26
0.28

LABORATORY TEST DATA

CYLINDER NUMBER	SIZE (mm)	DATE TESTED	AGE AT TEST (Days)	STRENGTH (MPa)
~~9755~~ A	2534mm²	Mar 11	7	9960 / 17.5
9756 B	2616mm²	Mar 18	14	13815/23.5
C	2555mm²	Apr 1	28	15873/27.7
D	2627mm²	Apr 1	28	16103/27.3
E			Hold	
F			Hold	

Grout (g):		Testing:	Water
Sand (g):		Temperature (°C):	
Water (g):		Initial Curing:	Open plastic bag in Curing Room
W/C Ratio:			
Mix Time:			
Time Cast:			

REMARKS: *Testing was preformed at AMEC, St. John's Laboratory, 36 Pippy Place, St. John's, NL*

Tested By: ____________

Reviewed By: ____________

We certify the testing procedures performed by this laboratory are in accordance with CSA A23.2-8A-09

APPENDIX G

AAR Graphical Results

Test Method for Detection of Alkali- Silica Reactivity of Aggregate by Accelerated Expansion of Mortar Bars, CSA A23.2-25A

1. Aggregate

CLIENT:
SOURCE:

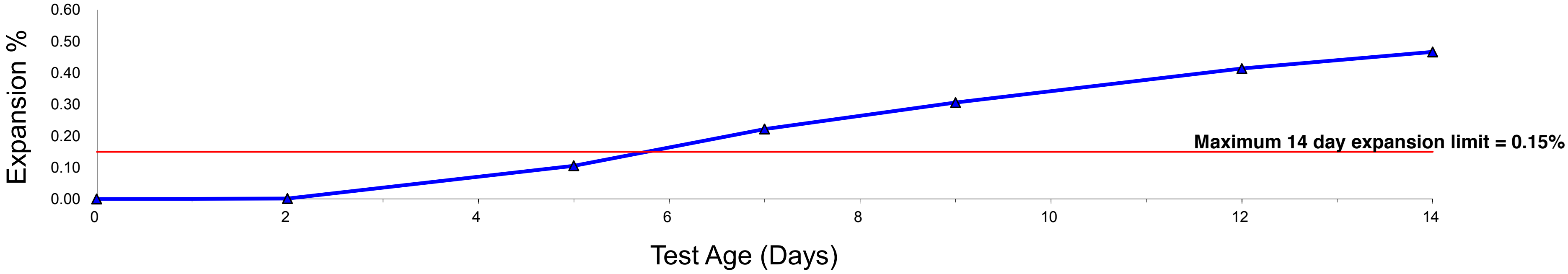
SAMPLE TYPE:
DATE RECEIVED:
DATE TESTED:

2. Cement

SOURCE: GU
TYPE:
ALKALI CONTENT: -
TOTAL ALKALI AS
SODIUM OXIDE EQUIV.:
WATER / CEMENT RATIO:

Mortar Bar No.	**EXPANSION %**					
	2 Day	**5 day**	**7 day**	**9 day**	**12 day**	**14 day**
A	0.000	0.000	0.000	0.000	0.000	0.000
B	-0.005	0.061	0.179	0.259	0.367	0.420
C	0.009	0.150	0.265	0.353	0.460	0.513
Average Expansion	**0.002**	**0.106**	**0.222**	**0.306**	**0.414**	**0.466**

COMMENT:

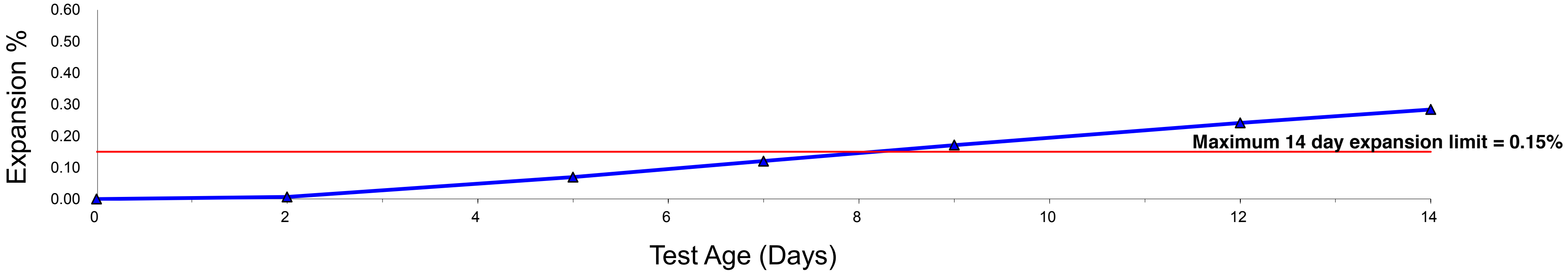


Test Method for Detection of Alkali- Silica Reactivity of Aggregate by Accelerated Expansion of Mortar Bars, CSA A23.2-25A

1. Aggregate		**2. Cement**	
CLIENT:		**SOURCE:**	**10% GP**
SOURCE:		**TYPE:**	
		ALKALI CONTENT:	**-**
SAMPLE TYPE:		**TOTAL ALKALI AS**	
DATE RECEIVED:		**SODIUM OXIDE EQUIV.:**	
DATE TESTED:		**WATER / CEMENT RATIO:**	

Mortar Bar No.	EXPANSION %					
	2 Day	5 day	7 day	9 day	12 day	14 day
A	0.014	0.076	0.125	0.177	0.246	0.291
B	0.003	0.066	0.116	0.162	0.233	0.270
C	0.003	0.066	0.121	0.174	0.245	0.290
Average Expansion	**0.007**	**0.069**	**0.121**	**0.171**	**0.241**	**0.284**

COMMENT:

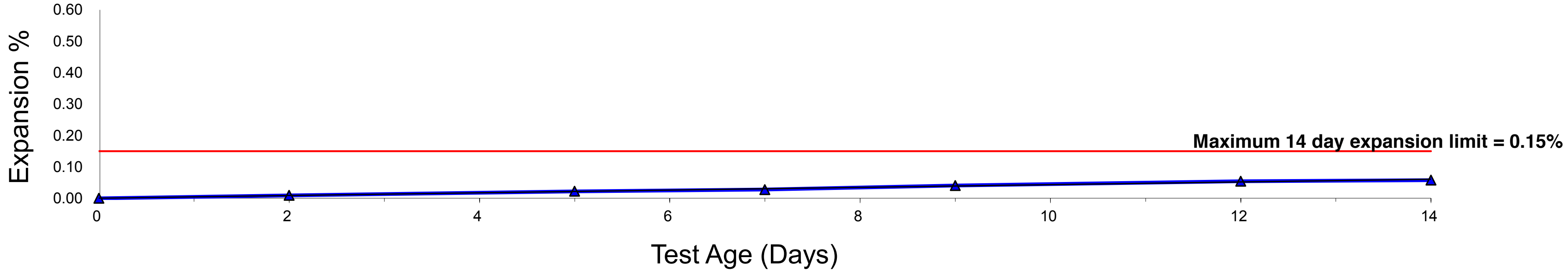


Test Method for Detection of Alkali- Silica Reactivity of Aggregate by Accelerated Expansion of Mortar Bars, CSA A23.2-25A

1. Aggregate		**2. Cement**	
CLIENT:		**SOURCE:**	**20% GP**
SOURCE:		**TYPE:**	
		ALKALI CONTENT:	**-**
SAMPLE TYPE:		**TOTAL ALKALI AS**	
DATE RECEIVED:		**SODIUM OXIDE EQUIV.:**	
DATE TESTED:		**WATER / CEMENT RATIO:**	

Mortar Bar No.	**EXPANSION %**					
	2 Day	**5 day**	**7 day**	**9 day**	**12 day**	**14 day**
A	0.009	0.021	0.028	0.041	0.056	0.060
B	0.010	0.024	0.028	0.041	0.053	0.056
C	0.000	0.000	0.000	0.000	0.000	0.000
Average Expansion	**0.010**	**0.022**	**0.028**	**0.041**	**0.054**	**0.058**

COMMENT:



Test Method for Detection of Alkali- Silica Reactivity of Aggregate by Accelerated Expansion of Mortar Bars, CSA A23.2-25A

1. Aggregate

CLIENT:

SOURCE:

SAMPLE TYPE:

DATE RECEIVED:

DATE TESTED:

2. Cement

SOURCE: **10% Silica Fume**

TYPE:

ALKALI CONTENT: **-**

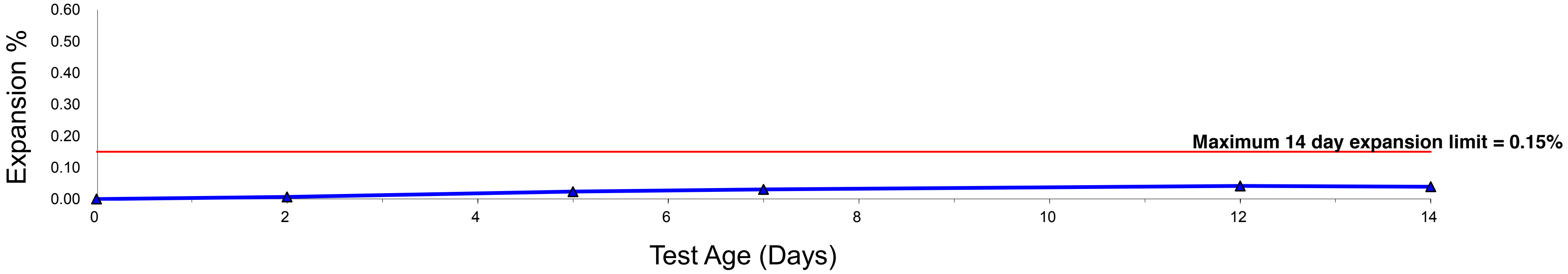
TOTAL ALKALI AS

SODIUM OXIDE EQUIV.:

WATER / CEMENT RATIO:

Mortar Bar No.	**EXPANSION %**					
	2 Day	**5 day**	**7 day**	**9 day**	**12 day**	**14 day**
A	0.006	0.022	0.030	0.035	0.043	0.042
B	0.007	0.025	0.030	0.026	0.040	0.037
C	0.000	0.000	0.000	0.000	0.000	0.000
Average Expansion	**0.007**	**0.024**	**0.030**	**0.031**	**0.042**	**0.039**

COMMENT:



Test Method for Detection of Alkali- Silica Reactivity of Aggregate by Accelerated Expansion of Mortar Bars, CSA A23.2-25A

1. Aggregate

CLIENT:

SOURCE:

SAMPLE TYPE:

DATE RECEIVED:

DATE TESTED:

2. Cement

SOURCE: **20% GP + 10% FA**

TYPE:

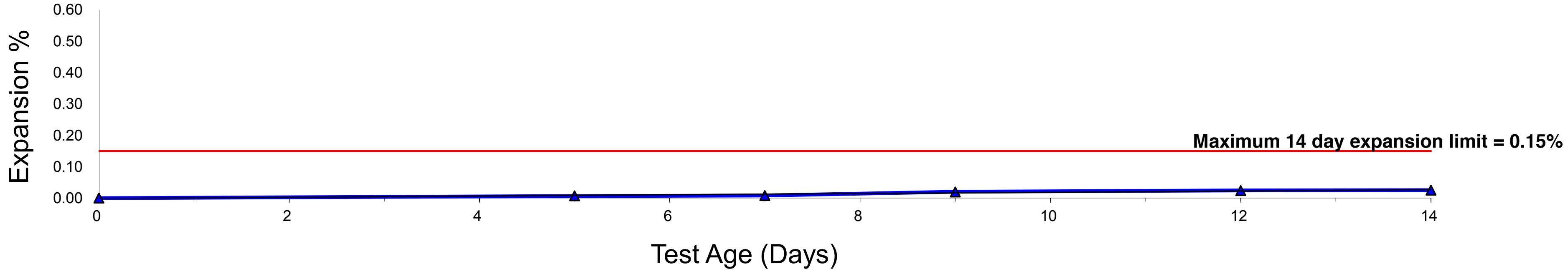
ALKALI CONTENT: **-**

TOTAL ALKALI AS
SODIUM OXIDE EQUIV.:

WATER / CEMENT RATIO:

Mortar Bar No.	**EXPANSION %**					
	2 Day	**5 day**	**7 day**	**9 day**	**12 day**	**14 day**
A	-0.002	0.004	0.004	0.015	0.022	0.016
B	0.001	0.009	0.010	0.023	0.026	0.022
C	-0.002	0.009	0.011	0.022	0.029	0.029
Average Expansion	**-0.001**	**0.007**	**0.008**	**0.020**	**0.024**	**0.026**

COMMENT:



Test Method for Detection of Alkali- Silica Reactivity of Aggregate by Accelerated Expansion of Mortar Bars, CSA A23.2-25A

1. Aggregate

CLIENT:

SOURCE:

SAMPLE TYPE:

DATE RECEIVED:

DATE TESTED:

2. Cement

SOURCE: **10% GP / 10% FA**

TYPE:

ALKALI CONTENT: **-**

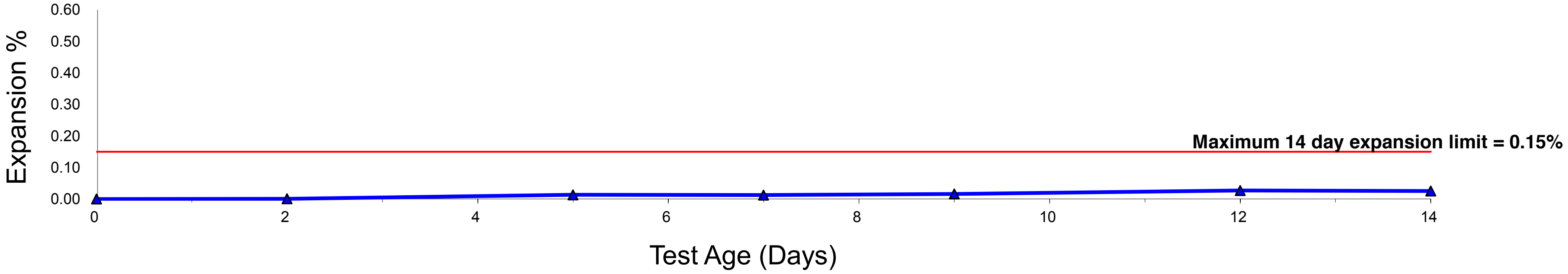
TOTAL ALKALI AS

SODIUM OXIDE EQUIV.:

WATER / CEMENT RATIO:

Mortar Bar No.	**EXPANSION %**					
	2 Day	**5 day**	**7 day**	**9 day**	**12 day**	**14 day**
A	0.003	0.018	0.010	0.022	0.030	0.031
B	-0.001	0.009	0.015	0.011	0.025	0.019
C	0.000	0.000	0.000	0.000	0.000	0.000
Average Expansion	**0.001**	**0.014**	**0.012**	**0.016**	**0.027**	**0.025**

COMMENT:



Test Method for Detection of Alkali- Silica Reactivity of Aggregate by Accelerated Expansion of Mortar Bars, CSA A23.2-25A

1. Aggregate

CLIENT:

SOURCE:

SAMPLE TYPE:

DATE RECEIVED:

DATE TESTED:

2. Cement

SOURCE: **25% FlyAsh**

TYPE:

ALKALI CONTENT: -

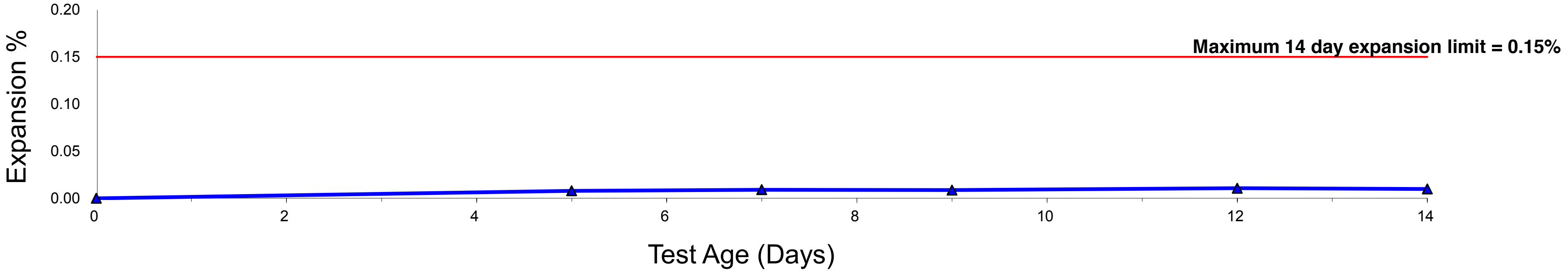
TOTAL ALKALI AS

SODIUM OXIDE EQUIV.:

WATER / CEMENT RATIO:

Mortar Bar No.	EXPANSION %					
	2 Day	5 day	7 day	9 day	12 day	14 day
A	-0.005	0.008	0.011	0.011	0.013	0.011
B	-0.011	0.008	0.007	0.006	0.009	0.009
C	0.000	0.000	0.000	0.000	0.000	0.000
Average Expansion	**-0.008**	**0.008**	**0.009**	**0.009**	**0.011**	**0.010**

COMMENT:



Test Method for Detection of Alkali- Silica Reactivity of Aggregate by Accelerated Expansion of Mortar Bars, CSA A23.2-25A

1. Aggregate

CLIENT:
SOURCE:

SAMPLE TYPE:
DATE RECEIVED:
DATE TESTED:

2. Cement

SOURCE: TERC3
TYPE:
ALKALI CONTENT: -
TOTAL ALKALI AS
SODIUM OXIDE EQUIV.:
WATER / CEMENT RATIO:

Mortar Bar No.	EXPANSION %					
	2 Day	5 day	7 day	9 day	12 day	14 day
A	0.000	0.000	0.000	0.000	0.000	0.000
B	-0.004	0.004	0.002	0.008	0.011	0.011
C	-0.007	0.003	-0.006	0.000	0.003	0.004
Average Expansion	**-0.006**	**0.004**	**-0.002**	**0.004**	**0.007**	**0.008**

COMMENT: