Limiting Alkali Aggregate Reaction in Non-Structural Concrete

St. John's, Newfoundland

Client:
Kevin Penny
AMEC, Earth and Environmental Ltd.

Student Group: Cretecon Consulting
Kallan Fitzgerald
Megan Jarvis
Adam Mandville
Vince Kerrivan

Course: Engineering 8700
Senior Civil Design Project

Instructors:
Dr. Steve Bruneau
Dr. Amgad Hussein
Mr. Justin Skinner

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AMEC Earth and Environmental Ltd.
133 Crosbie Road
St. John's, NL
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February 3, 2013

CC: Dr. Steve Bruneau
Dr. Amgad Hussein
Mr. Justin Skinner

Dear Mr. Penney:

Cretecon Consulting is undertaking a study on mitigation of Alkaline Aggregate Reaction in non-structural concrete as requested by AMEC, Earth and Environmental Division.

The enclosed project plan will give a general description of the project, methodology, associated tasks, schedule with gantt chart, costs, risks and deliverables. The plan provides a comprehensive list of the required activities as well as their deadlines to ensure successful completion of the study.

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

Best Regards,

Cretecon Consulting

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1.0 Project Description

This project was requested by AMEC Earth and Environmental Division to research and test methods of reducing Alkali Aggregate Reaction (AAR) in non-structural concrete. The project investigates the uses of various replacement materials for portland cement as well as non-reactive aggregates.

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. By substituting a portion of portland cement with fine siliceous materials, the excess alkalinity of the cement is neutralized thus reducing AAR.

There has been some prior research on the Alkali Aggregate Reaction in concrete. Therefore, a thorough literature review is necessary to determine the optimal cement replacement materials and their proportions. In order to reduce testing time and sample size, the design of experiments method will be used. The design of experiments method allows manipulation of several factors while producing accurate results. Testing will be accomplished using compression tests, mortar bar tests, slump tests and air tests as well as a comprehensive analysis of the results.

Figure 1 - Characteristic AAR Crack Pattern

2.0 Statement of Project Requirements

The goal of this project will be to research and test concrete mixtures in order to identify a mixture that will be effective in the reduction of the Alkali Aggregate Reaction. Specifically, glass powder will be used as the main cement replacement material to aid in the reduction of AAR. Other cement replacement materials will be silica fume, fly ash, slag and non-reactive aggregates will be tested throughout the project.

The project will be composed of four main sections research, experimental testing, analysis, and recommendations that will be detailed as follows:

Research:

- Literature review of portland cement replacements such as glass powder, fly ash, silica fume, slag and non-reactive aggregate.
- Identify and explain the current concrete practices for AAR reduction in Newfoundland and Labrador.
- Concrete Testing methods
- Proper Design of Experiments.
- Potential implementation methods of glass powder production in Newfoundland.

Experimental Testing:

- Mortar Bar Test: To evaluation the expansion of concrete due to AAR.
- 3, 7, 14, and 28 Compressive Strength Test of concrete.
- Slump Test
- Air Entrainment Test
- Penetration Resistance Test

Analysis:

- Effect of cement replacement materials on Alkali Aggregate Reactivity
- Effect of cement replacement materials on compressive strength of concrete
- In-depth analysis of the results using a full factorial design and second degree polynomial response surface through proper design of experiment procedures.
- Feasibility of glass powder production in Newfoundland.

Recommendations:

- Optimal proportions of cement replacement materials required to reduce AAR.
- Glass powder production method.

3.0 Methodology

3.1 Project Overview

The requirements of this project include a literature review process to familiarize ourselves with previous research into the use of glass powder as an alkali-aggregate reaction (AAR) suppressant. Research will be completed into the use of powdered glass as a replacement for portland cement in concrete mixes as well as into glass recycling and concrete testing standards. After completing this research, a hypothesis will be conceived and an experiment can be designed for testing. The design of experiments approach will be used, including the use of Design Expert 8 software, in order to form a credible experimental procedure as well as to minimize the required number of runs. All testing will be conducted according to CSA Standards.

A partial literature review has already been completed and a hypothesis is being formed. Currently, the project focus will be on the effect of using glass powder as a portland cement replacement, in respect to AAR. Initial testing parameters will be 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.

It is understood that the curing of the concrete test samples will consume a large amount of time. For this reason, testing should be conducted as early as possible. Because of this, early organization will be critical to the project's success. A group email, as well as a cloud file sharing site has been set up for the purposes of communication and document sharing, to aid in project organization.

3.2 Design of Experiments

Design of experiments (DOE) is the organization of a detailed experimental plan in advance of conducting an experiment. The advantages of DOE include a reduction in design costs by speeding up the design process, as well as a reduction in the number of required combination of factors (i.e. the number of batches). A minimum of 5 factors are required for an effective DOE approach. As stated earlier, the factors to be incorporated into the design of this experiment include 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. The ranges of each test factor are displayed in the table below.

Design Of Experiment Factors

Factor	Name	Units	Type	Minimum	Maximum
A	Ratio of Fly Ash to Portland Cement	%	Numeric	0	10
B	Ratio of Silica Fume to Portland Cement	%	Numeric	0	10
C	Ratio of Powdered Glass to Portland Cement	%	Numeric	10	30
D	Ratio of slag to Portland Cement	%	Numeric	0	10
E	Reactive/Non-Reactive Aggregate	N/A	Categoric	Reactive	Non-Reactive

Table 1: Design of Experiment Factors Table

Design Expert 8 software will be used to complete a full factorial design from these factors and a second degree polynomial response surface will be generated. This will limit our number of experimental runs from 2^5 to 2^{5-1} which cuts our requirements in half, from 32 to 16 test batches. The ultimate goal of using the DOE approach is to reduce the number of required test runs and to give credibility to the project by utilizing a proper experimental method.

3.3 Experimental Testing

Tests that will be conducted for this experiment will include:

- Slump Test
- Air Entrainment Test
- Compressive Strength Test
- Penetration Resistance Test
- Mortar Bar Test

Concrete Slump Test

The concrete slump test will be conducted to determine the consistency and workability of the concrete. The slump test will be conducted for every concrete mix, complying with requirements of ASTM Standards C143 / C143M.

Air Entrainment Test

The air entrainment test will be conducted to determine air content of the concrete. The air entrainment test will also be conducted for every concrete mix, complying with the requirements of ASTM Standard C185.

Compressive Strength Test

The compressive strength test will be conducted on 3, 7, 14, and 28 days after the day of batching. Two inch (2”) cubes will be used for testing as opposed to cylinders, allowing for more test samples of each mix and resulting in more accurate results. The compressive strength tests will comply with the requirements of ASTM Standard C109 / C109M.

Penetration Resistance Test

The penetration test will be conducted to determine the setting time for the mortar to reach specified values of resistance to penetration. This test method can also be used to determine the effects of variables, such as water content; brand, type and amount of cementitious material; or admixtures, upon the time of setting of concrete. All penetration resistance tests will comply with the requirements of ASTM Standard C403 / C403M.

Mortar Bar Test

The mortar bar test provides a means of detecting the potential of an aggregate intended for use in concrete undergoing alkali-aggregate reaction resulting in potentially damaging internal expansion. Results will be obtained at the end of the 16-day testing period. All mortar bar tests will comply with the requirements of ASTM Standard C1260.

3.4 Client Role

Meetings between Cretecon Consulting and AMEC will occur on a weekly basis at specified locations. AMEC will be providing all equipment and necessary materials required for the experimental testing. The mixing and curing of all experimental concrete specimens will take place at AMEC’s concrete lab on Pippy Place. The client, as well as conducting all experimental testing, will provide necessary guidance and direction while using the testing facilities.

3.5 Feasibility Study

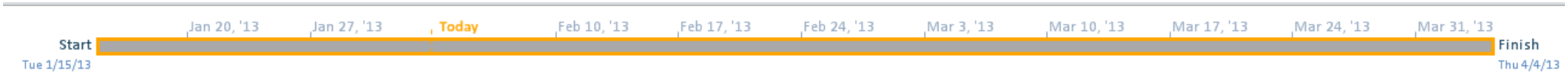
As well as conducting research experiments on materials that limit AAR, Cretecon Consulting will be completing a conceptual feasibility study on recycled powdered glass in St. John's. The focus of this study will be on the costs of different manufacturing methods and plant set up costs across Newfoundland. Consideration will also be given to the practicability of equipping current concrete batch plants with equipment required to produce powdered glass.

4.0 Tasks

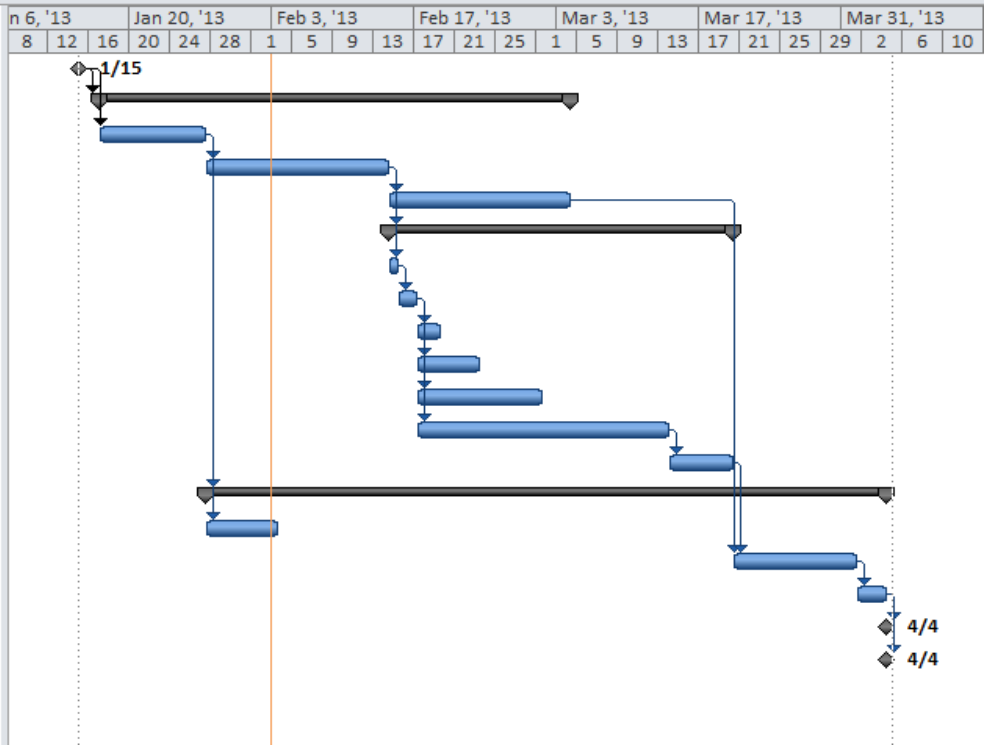
Task Name	Responsibility	Duration	Resource
Research Concrete Mix Designs	M. Jarvis, V. Kerrivan	1 week	ACI, ASTM, CSA, Scholarly Resources
Research powdered glass implementation	K. Fitzgerald, A. Mandville	1 week	ACI, ASTM, CSA, Scholarly Resources
Design Concrete Mixes	All	1 week	Cretecon, K. Penney, J. Skinner, A. Hussein
Mix/Set Concrete	All	1 week	Cretecon, AMEC
Results Analysis	All	2 weeks	Cretecon, AMEC
Report Writing	All	3 weeks	Cretecon, AMEC

Table 2: Task Breakdown

5.0 Schedule



	Task Name	Duration	Start	Finish	Predecessors
1	**Match Night**	0 days	Tue 1/15/13	Tue 1/15/13	
2	**Literature Review**	**52 days**	**Thu 1/17/13**	**Mon 3/4/13**	**1**
3	Previous Project Review	12 days	Thu 1/17/13	Sun 1/27/13	1
4	Concrete Mix Study	20 days	Sun 1/27/13	Thu 2/14/13	3
5	Feasability Study	20 days	Thu 2/14/13	Mon 3/4/13	4
6	**Concrete Testing**	**38 days**	**Thu 2/14/13**	**Wed 3/20/13**	**4**
7	Crushing Recycled Glass	1 day	Thu 2/14/13	Fri 2/15/13	4
8	Batching Concrete Mixes and Setting	2 days	Fri 2/15/13	Sun 2/17/13	7
9	3 Day Testing/AAR Testing	3 days	Sun 2/17/13	Tue 2/19/13	8
10	7 Day Testing/AAR Testing	7 days	Sun 2/17/13	Sat 2/23/13	8
11	14 Day Testing/AAR Testing	14 days	Sun 2/17/13	Fri 3/1/13	8
12	28 Day Testing	28 days	Sun 2/17/13	Wed 3/13/13	8
13	Analysis of Results	7 days	Thu 3/14/13	Wed 3/20/13	12
14	**Report Composition**	**75 days**	**Sun 1/27/13**	**Thu 4/4/13**	**3**
15	Project Plan	8 days	Sun 1/27/13	Sun 2/3/13	3
16	Final Report	14 days	Wed 3/20/13	Mon 4/1/13	5,13
17	Editing and Review	3 days	Mon 4/1/13	Thu 4/4/13	16
18	**Final Deliverable**	0 days	Thu 4/4/13	Thu 4/4/13	17
19	**Final Presentation**	0 days	Thu 4/4/13	Thu 4/4/13	17



6.0 Costs

Direct costs associated with this project include:

- Concrete Mix Materials
- Laboratory Testing Equipment with associated man hours required for testing
- Miscellaneous costs such as printing, binding, stationary, etc.

AMEC will be providing all concrete mix materials and laboratory testing equipment. AMEC and Cretecon will both be using man hours for the required testing. To minimize costs and volume of materials, Cretecon will be testing smaller 2''x2'' concrete cubes instead of concrete cylinders. Miscellaneous costs will be funded by Cretecon.

7.0 Deliverables

The final project report will be submitted to the client via hardcover document and a pdf document containing:

- Full literature review of currently used methods for AAR suppression using cement replacement materials.
- Complete results, analysis, conclusion and recommendations based on concrete tests performed.
- Recommendations on possible glass powder production techniques in Newfoundland.

8.0 Risks

As with any project there will be associated risks. To mitigate any risks throughout the project we will follow the CSA, ASTM standards as well as AMEC safety regulations during batching and testing concrete.

Risks associated with quality of project results are:

- Inclusive results.
- Not being able to obtain cement replacement materials.
- Time limitations due to length of test and fixed project end date.
- Mixing error due to small batch volumes.
- Random testing errors at the AMEC test laboratory.

Risks associated with Health and Safety during the project:

- NaOH can cause burns and irritation with prolonged skin contact.
    - Ensure use of full-face shields, rubber aprons, and gloves impervious to NaOH.
- Ensure safe work practices during all handing of concrete materials.

9.0 References

- Kevin Penney (Client: AMEC)
- Justin Skinner (ENGR 8700 Professor)
- Amgad Hussien (ENGR 8700 Professor)
- Utilization of Recycled Glass in Non-Structural Concrete, 2011, ALPHA Engineering, ENGR 8700 Course Project 2011
- www.astm.org
- www.csa.ca

Appendix A

Statement of Qualifications

Mission Statement

Cretecon Consulting will aim to provide the highest quality of civil related, technical solutions to our client and, ultimately, deliver an efficient design which meets or exceeds all perceived requirements.

Cretecon

the RIGHT experience

Experience

The members of Cretecon have been exposed to many organizations and projects, across Canada, which represent all aspects of the civil engineering field.

Organizations:

- Department of Municipal Affairs (Gov of NL)
- Department of Transportation and Works (Gov of NL)
- HJ O'Connell Construction Ltd.
- Pennecon Heavy Civil
- PCL Construction
- Meridian Engineering Inc. (Formerly Rutter Inc.)
- Syncrude Canada Ltd.
- Kiewit
- Irving Oil Refining
- North American Construction Group
- Terracon

Projects:

- Refinery Structural Maintenance
- Overburden Removal
- Long Harbour Processing Plant (concrete work, scaffolding, and earthworks)
- Haul Road Construction
- Iron Ore Company of Canada
- Newfoundland Ferries Project
- Lower Churchill Project
- Airport Trail Tunnel Project
- Light Rail Transit Platform Extension Project
- Water Treatment Plant Rehabilitation Projects
- Arnold's Cove Wharf Design
- Come-by-Chance/Sunnyside TCH Underpass
- Hurricane Igor Recovery Projects
- T'Railway Provincial Park Hurricane Igor Damage Assessment
- Thin Fine Tailings Return (TFTR) 2.5 Water Transfer System

Locations:

- St. John's
- Long Harbour
- Clarenville
- Grand Falls-Winsor
- Marystown
- Come-By-Chance
- Wabush
- Saint John
- Calgary
- Fort McMurry

Cretecon Consulting

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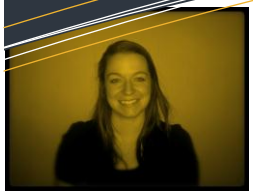
About Us

Cretecon was formed in January of 2013 for the ENGI 8700 – Civil Engineering Project course. The group consists of a group of 4 senior civil engineering students, on the verge of becoming young professionals. The four members of Cretecon have a proven history of group success, having worked together on all civil engineering group projects since 2009. In 2011, the group achieved the winning bid (closest to the actual winning bid in cost and working hours) in the ENGI 6749 – Construction Planning Equipment and Methods term project. Cretecon is eager to undertake any engineering project with the goal of providing quality deliverables and comprehensive design recommendations. The 4 members of Cretecon draw upon a wide range of work experience from across Canada.

Team Members:



Megan Jarvis

Megan Jarvis is a senior Civil Engineering Student at Memorial University of Newfoundland. Her previous experience in the construction industry has included working closely with Project Managers performing project cost estimating, scheduling, coordination, planning and project control duties. Her education and work experience has provided the opportunity for the development of effective communication, leadership, interpersonal and problem-solving as well as the ability to work independently or as an effective team member. Her participation in daily safety inspections of site and the development of safety reports has expanded her knowledge and commitment to safety. She has thoroughly enjoying both field and office related duties during work term placements.

Kallan Fitzgerald

Kallan Fitzgerald is currently completing his final term in the Civil Engineering degree program at Memorial University of Newfoundland. Kallan has gained valuable experience in various fields related to civil engineering throughout his five work terms. His experience has consisted of project management duties, tender document review, daily monitoring of field activities and processing of field collected data. He was heavily involved in Hurricane Igor repair work; completing site inspections, preparing inspection reports, performing quantity takeoffs, preparing cost estimates, completing design work/calculations, and preparing tender documents. Having worked with consultants, government, and contractors, Kallan has gained a broad view of the different corners of civil engineering and brings well developed civil knowledge to the team.

Adam Mandville

Adam Mandville is a senior civil engineering student currently completing academic Term VIII at Memorial University. Through his wide range of work placements he has been involved in a variety of engineering environments including marine infrastructure, construction, mining, and heavy civil. His most recently work placements allowed him gain abundance of project management and field experience, working on projects including water treatment plant rehabilitation, light rail train platform extensions, as well as a cast-in-place concrete tunnel project in Calgary where he was heavily involved in quality control and management of own forces work. Adam draws upon his work term experiences, as well as his strong work ethic and ability to work cohesively as part of a team in order to be a valuable member of Cretecon.

Vince Kerrivan

Vince Kerrivan is currently attending Memorial University as a senior Civil Engineering student. He is a motivated and hardworking individual who enjoys communicating with other people, who is talented and creative. He takes initiative, has a positive attitude and has the ability to work within a team or independently. He has gained valuable experience with geotechnical QA/QC and project coordination while working in the Fort McMurray Oil Sands. At the Long Harbour Processing Plant, he worked as a field engineer and faced a variety of challenges daily. Vince's analytical skills, strong work ethic and desire to work and to learn provide an important contribution to Cretecon Consulting.

Project Management

With experience managing small infrastructure projects, such as culvert installations, Cretecon is capable of ensuring projects are managed in a professional manner.

Design

Cretecon members have experience in designing roads and highways, costal structures, culvert structures, various concrete constructions, as well as various steel formations.

Estimating

A strong, proven ability to accurately estimate project costs, project timelines, and perform quantity take-offs shows that Cretecon has the right experience.

Cretecon Consulting

WITH EXPERIENCE IN ALL CORNERS OF THE CIVIL ENGINEERING FIELD, WE'RE READY FOR ANY CHALLENGE.