



LOWER CHURCHILL PROJECT
MUSKRAT FALLS,
CD0502

ROOT CAUSE ANALYSIS (RCA)

MUSKRAT **FALLS GIS** BUILDING CONCRETE POURING ISSUES

Document Number RCA-MFA-502-CW-0019 Rev.02

Reference NCR #: MFA-502-CW-0019

Prepared:	Approved by
RCA—Team	Thierry Martin
<u>Refer Page 2</u>	LCP Project Director
03-May-2016:	03-May,2016



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Schedule of revisions

REV	DATE	MODIFICATION CONTENTS	PAGE / SECTION
01	23-Apr-2016	Original Issue	1-6
02	03-May-2016	Updated as per company comments: Referenced the GE-Alstom root cause and problem solving methodology, RCA team names, Reinforced the action plan.	2, 5, 7.



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INTRODUCTION

The purpose of this root cause analysis (RCA) is to determine the causes that contributed to the recent major deficiencies observed for the concrete pour of the GIS building at Muskrat Falls.

To conduct the root cause analysis it was used the GE-AG's 8D Problem Solving Process.

RCA Participants:

- Andre Lambert, Project Manager (GE)
- Walter Feletto, Construction Manager (GE)
- Joe Martino, P.Eng (Sostratus)
- Francois Richer, P.Eng (GE)
- Thierry Martin
- Driss Abdellahi
- Andrei Topa

DESCRIPTION OF THE ISSUE

Between Tuesday, Dec 8th 2015 and Thursday Dec 10th 2015, the GIS Building elevated slab and columns were scheduled for concrete pours.

The slab was to be poured in three sections, monolithically with the last section of the columns (which were previously poured in two sections).

Form removal commenced on January 11th. Following removal, missing concrete was discovered in columns C15, C16 and A16, large voids and honeycombing were found on grid 10 columns and beams, and segregation and honeycombing was further observed in the concrete of columns C13 and C14. The second section pour led to minimal honeycombing discovered in the columns and beams while the third section pour showed large voids and segregation on grids 1 and 4. The Company installed safety tape around the structure and instructed that nobody be allowed in the area and all works were to stop. Shoring was installed immediately in order to support the structure and to mitigate against any concerns of possible deflection that could have occurred.

At the beginning of March 2016 a deviation from drawings and specification requirements,



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regarding the elevations and flatness of the elevated slab was also identified.

CHRONOLOGY OF EVENTS

- **Monday Dec 7th 2015**
Inspections of the slab rebar and formwork was completed as per ITP and release for concrete pour was given to CWC.
- **Tuesday Dec 8th 2015**
First section of the slab and columns (grid 10 to 16) were poured as per description presented in the previous section and finishing continued late into the evening.
- **Wednesday Dec 9th 2015**
Second section of the slab and columns (grid 6 to 10) was poured and finishing continued late into the evening.
- **Thursday Dec 10th 2015**
Third section of slab and columns (grid 1 to 6) was poured and finishing continued into the morning of the following day (Friday Dec 11th 2015).
- **11th January 2016 — 9th February 2016**
Stripping of the slab and columns commenced from grid 16 till grid 1. Hollow columns and concrete deficiencies were discovered in C15, C16 and A16, large voids and honeycombing were found on grid 10 columns and beams, and some segregation and honeycombing was observed in columns C13 and C14. All other columns did not exhibit these deficiencies



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FINDINGS

SPECIFICATION AND WORK PLAN

The requirements for concreting are defined in the Specification Common-Building and Yard-Concrete- Construction ILK-AS-SD-8000-CV-F01-0001-01- C2.

The Civil Work Contractor (CWC) prepared the Concrete Work Plan 504-MFA-000-P0M-005-003-QA defining the concrete activities and referring to the above specification.

The CWE's representative on site revised the Concrete Work Plan 504-MFA-000-P0M-005-003-QA. The status of this review was level "4 — revise and resubmit, work may proceed subject to resolution of indicated comment". A specific comment was made in Clause 5.1 to "Follow Specification Clause 4.4 for placing the concrete".

The code in question has been applicable to all concrete pours with no major deficiencies observed prior to the damages incurred in the GIS Building. At the time of GIS slab pour, a relapse of concentration or complacency by CWC workforce and supervision had occurred and failed to isolate the issue at the time. As illustrated in the sequence of events in the previous page, the pour had occurred in 3 days prior to concrete plant shutting down which contributed to improper execution of the work.

Attention is drawn to the following detail requirements in the Specification Common Building and Yard Concrete- Construction ILK-AS-SD-8000-CV-F01-0001-01- C2 Clause 4.4

- Concrete will not be poured through closely laid reinforcement bar, as this may cause segregation of large aggregates. In such cases, a flexible chute or other means will be used. The maximum free drop height of the concrete will not exceed 1.5 meters, as prescribed in the CSA A23.1. (page 31)
- The concrete will be compacted with mechanical vibrators and in accordance with CSA A23.1 recommendations. The vibrator will be of closed type and always be in sufficient numbers and power to adequately vibrate all the concrete. (page 31)
- The vibrator will be inserted as much as possible in a vertical manner, with the head inserted into the concrete under the effect of its own weight. Vibration will be performed as deep as possible to ensure good bonding between two superposed layers of concrete. (page 31)
- The duration of the concrete vibration will be limited to what is required to adequately compact the concrete without segregation, as prescribed in the CSA A23.1. Mechanical vibrators, formwork vibrators, or surface vibrators will not be used for moving or spreading the concrete.



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FINDINGS: COLUMNS OF THE GIS BUILDING (GRID 14T016.C10&013)

It is noted that the design and procedures are common to all Columns and Beams and the Quality Control Concrete Checklists confirm that the formwork and rebar has been implemented as designed prior to the Concrete pours taking place. The results of the pours vary from installed as designed through to the Quality issues described.

Based on the investigation conducted, the team has determined several probable likely causes, or contributory factors, regarding this event:

- 1) Deficient concrete consolidation
- 2) Minimal supervision of the workforce by subcontractor and CWC.
- 3) Lack of experience and competence of the workforce.
- 4) Work Plan review should be revised to exclude the condition that works can proceed subject to resolution of the indicated comments. The plan should have incorporated Clause 4.4 directly rather than relying on a reference.

The CWC also identified items 1, 2, 3 and 4 within his own review of the Root Causes.

FINDINGS: SLAB

The finishing method required in the specification is category C in compliance with standard CSA A23.1. (Spec ILK-AS-SD-8000-CV-F01-0001-01 C2 Page 32), Concrete Work Plan 504-MFA-000-P0M-005-00-QA does not indicate the method that will be implemented to meet the Specification requirement.

Based on the investigation conducted, the team has determined several probable likely causes, or contributory factors, regarding this event:

- 1) Lack of survey by CWC during concrete pour to ensure the conformity of the slab elevations;
- 2) Lack of supervision of the workforce by subcontractor;
- 3) Lack of supervision of the subcontractors by CWC;
- 4) Lack of experience and competence of the workforce (Laborers & Cement Finishers);
- 5) Finishing method used by the contractor was not adequate to ensure the category C required by the Spec.



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ROOT CAUSE

Considering the above findings, the following three factors are identified as root causes of the issue:

1. Workforce Otibiffitalidfl Lack of experience and competence of the workforce considering the complexity of the requested pouring methods and provided level of details in the CWC's Work Plan.
2. Supervision of subcontractorG. The supervision of subcontractors by CWC during the execution of the pouring work was inadequate considering the low level of details provided in the CWC's Work Plan. Furthermore, the slab pour date was pushed till first week of December few days prior to concrete plant shutdown which created stress for CWC and for OWE in the completion of the work.
3. CWC Work Plan. Important elements of the specification were not transferred properly in to the CWC's Work Plan.

CORRECTIVE ACTIONS

Please refer the consolidated Corrective Actions Plan CAP-LTR-CD0501-LILLP-AG-0252. The corrective action plan presented in the Revision 01 of the current RCA has been reinforced with additional actions and consolidated with the actions that have been developed in response to Company's Letter LTR-CD0501-LILLP-AG-0252 LTR-CD0502-LTCLILLP-AG-0232.

Annexes:

Annex 1 Concrete Pouring Work Plan

Annex 2 Civil Work Inspection and Test Plan



ROOT CAUSE ANALYSIS

Doc* NCR-001 -MFAA.C-005 Date: 2016 - 04 - 29 Investigator Antony Charnoun
 YYYY-MM-DD

Problem Description:

After stripping walls formwork at Valve hall pole 1, we found 3 piers that have concrete deficiency as well at the door opening.

Directions: Use the following questions as a guide when investigating the Root Cause for a Corrective or Preventive action. Mark "Yes" or "No" for each item and indicate any notes as needed.

The following questions apply to any organization	YES	NO	NOTES
1. What was the initial problem reported?			Honeycorribs
2. <u>Is this a recurring issue?</u>		X	First pour
3. What circumstances led up to the problem? Ask why several times?			Lack of vibration, inadequate consolidation, stiff concrete bad concreting placement
4. What process allowed this circumstance to occur?			<u>Workers inexperienced with basic concrete placement methods</u>
5. Is that process documented in the form of a procedure, work instruction, form, checklist, etc?	X		Concrete work plan
6. Does everyone responsible understand the process?	X		
7. Does everyone responsible have the required skills?	X	X	Labourers, cement finishers
8. Are there steps in the process that are difficult to do correctly?	X		Lack of space for the vibrator
9. Do employees commonly have to work around the "official" process to get the job done?		X	
10. Are there steps in the process that are easily done wrong?	X		Vibration
11. If the process is being followed, are there changes needed in the documented process?	X		Teach workers the various types of vibration methods
12. <u>Is needed information incomplete or missing?</u>		X	Different types of vibration
13. Are there previous corrective actions related to the problem?		X	

Effective Date:

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ROOT CAUSE ANALYSIS

Root Cause Summary *(The Root Cause Summary cannot be a restatement of the Problem Summary):*

Not enough space between rebar and formwork. to vibrate the concrete (R.e,bar, steel angle, openings, anchor bolts)

The concrete deficiencies are repaired.

Preventive activy It has been decided that before the pours a meeting will be held to study the situation and explain well for the workers how we are going to pour the concrete. Dining the pour a Quality representative and a supervisor will be present at all time to make sure that they are pouring and vibrating well.

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