


**Document Front Sheet**



<b>NE-LCP Contractor/Supplier</b>	Contract or Purchase Number and Description: CH0007-001 – Intake & Powerhouse, Spillway & Transition Dams		Contractor/Supplier Name: ASTALDI CANADA INC.	
	Document Title: MUSKRAT FALLS - DRAFT TUBE UNIT 2 OUTLET - CIVIL GENERAL REPORT - MAN BASKET INSPECTION		Total Number of Pages Incl. Front Sheet 22	
	Contractor Document Number: A-DT000-NA-CV-D31-200-01		Revision Number: 0	
	Supplier Document Number:		Revision Number:	
	NE-LCP Document Number: MFA-AT-SD-331A-EN-A99-0002-01		NE-LCP Issue Number: B1	
	Approver's Signature: Giuseppe Mazzucco 		Date (dd-mmm-yyyy): 21-Jun-2016	Review Class:
<u>Comments:</u>			Equipment Tag or Model Number:	

<b>NE-LCP</b>	REVIEW DOES NOT CONSTITUTE APPROVAL OF DESIGN DETAILS, CALCULATIONS, TEST METHODS OR MATERIAL DEVELOPED AND/OR SELECTED BY THE CONTRACTOR, NOR DOES IT RELIEVE THE CONTRACTOR FROM FULL COMPLIANCE WITH CONTRACTUAL OR OTHER OBLIGATIONS. <input type="checkbox"/> 01 – REVIEWED AND ACCEPTED – NO COMMENTS <input checked="" type="checkbox"/> 02 – REVIEWED – INCORPORATE COMMENTS, REVISE AND RESUBMIT <input type="checkbox"/> 03 – REVIEWED - NOT ACCEPTED <input type="checkbox"/> 04 – INFORMATION ONLY <input type="checkbox"/> 05 – NOT REVIEWED			
	This document has been reviewed & coded electronically via Aconex.			
	Lead Reviewer: Stephen Nicholas	Date (dd-mmm-yyyy): 12-Jul-2016	Project Manager:	Date (dd-mmm-yyyy):
	NE-LCP Management:	Date (dd-mmm-yyyy):		
<u>General Comments:</u>				



**DOCUMENT REVIEW  
Comment Sheet**

<b>Completed by LCP Representative</b>				<b>Completed by LCPDCC</b>	
Document Title:				Record Number:	
MUSKRAT FALLS – DRAFT TUBE UNIT 2 OUTLET – CIVIL GENERAL REPORT – MAN BASKET INSPECTION					
NE-LCP Document Number:	Revision:	3 <sup>RD</sup> Party Document Number:	Revision:	Transmittal Number:	
MFA-AT-SD-331A-EN-A99-0002-01	B1	A-DT000-NA-CV-D31-200-01	0		
LCP Department of Origin:		Purchase Order/Contract Number:		Transmittal Date:	
Project Delivery Team		CH0007 – Construction of Intake and Powerhouse, Spillway and Transition Dams			
Distribute Comment Sheet to:		Date returned to LCPDCC			

**Comments:**

LCP Representatives: Stephen Nicholas, John Mulcahy, Ed Bush (consultant), Sean Dingley (aDB Engineering)			Lead Reviewer: Stephen Nicholas		
Item No.	Section/Paragraph /Page/Sheet	Comment	Response	Status	
1	General	LCP is returning this document code 02. Please revise and resubmit.			
2	Figure 1 and Figure 2	Figure 1 indicates major damage to formwork elements on the north side including towers B1 and B2, while figure 2 does not indicate damage to the towers in this area. It is not clear if it was possible to see the status of those northern towers during the inspection.			
3	General	Since release of this report, it is understood further inspection has taken place on the north side from inside the draft tube. Will this report be updated with this information or will this be captured elsewhere?			
4	Damaged Formwork Elements	“Formwork and shoring element that are repaired and/or reused should be inspected by a qualified person to ensure...” This statement appears to be outside the scope of this document?			



**DOCUMENT REVIEW  
Comment Sheet (Cont'd)**

**Comments:**

Item No.	Section/Paragraph /Page/Sheet	Comment	Response	Status
5	Coil Rod, pg 8 and 9	Higher resolution photos of the coil rod anchors and holes should be provided. Suggest comparing number of tie rods that can be visually confirmed with design. Should discuss presence of spalled concrete. Please include observations about holes that filled with concrete, it appears the bottom are filled while the upper are empty?		
6	Figure 13	Please identify these ties, are they the lower or upper level?		
7	Built-in-place formwork pg 15	Is there any evidence to indicate how the ties for the bulkhead were installed?		
8	Conclusion	"The coil rods tying panel A29 to pour D2USB-02 appear to have been in place at the time of the failure." No basis for this statement based on evidence presented in this report. It appears that some tie rods were installed but others will require a more detailed investigation to confirm. A full investigation of this area shall be performed once concrete can be cleaned off during remediation.		

NE-LCP Lead Reviewer: Stephen Nicholas

Date: 12-Jul-2016

For Contractor: \_\_\_\_\_

Date: \_\_\_\_\_



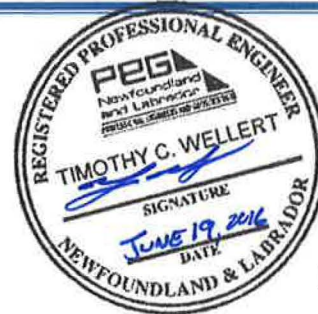
**ILF CONSULTANTS, INC.**

400 112<sup>th</sup> Ave NE #205  
Bellevue WA 98004  
U.S.A.

Telephone: (425)209-4989  
Homepage: www.ilf-usa.com

**Eng. Giuseppe Mazzucco**

Technical Manager – Muskrat Falls Project - Astaldi  
114 Hamilton River Road, HV-GB  
NL, Canada. A0P 1C0  
P.O. Box 177 Station C.



PEGNL Co. No.  
NO 796

Date: June 19, 2016

**LOWER CHURCHILL PROJECT**

**GENERAL REPORT – MAN BASKET INSPECTION OF UNIT 2 FORMWORK FAILURE**

**Purpose of Document:**

This document provides summary observations from visual inspection by man basket on June 4<sup>th</sup> and June 11<sup>th</sup>, 2016 in the Draft Tube 2 formwork/falsework incident area. The purpose of the inspection was to document the extent of the collapse, identify damage to main structural members and note any deficiencies or deviations in the fabrication and construction process.

**Overview:**

On May 29, 2016, 11:58pm, at the Muskrat Falls Hydroelectric Project, Happy Valley – Goose Bay, Labrador, the wooden formwork supporting Draft Tube 2 failed nearing completion of the 530 m<sup>3</sup> pour, resulting in collapse of the freshly poured concrete.

A man basket was used for the inspection of Draft Tube Elbow Unit 2 as it was determined to be the safest means of visually accessing the damage.

**Summary of Findings:**

The determining cause of the failure was not evident at the time of visual inspection but we have the following comments:

The failure of formwork/falsework supporting pour D2ESB-03 was catastrophic, damaging nearly all shoring towers and ribs under fresh concrete and in some cases, beyond. Some formwork members supporting prior draft tube wall pours were damaged by collapsing elements. Fresh concrete supported by cured the D2ESA-02 concrete flowed into the draft tube after the D2ESB-03 formwork failed, resulting in non-conforming concrete above D2ESA-02.

There is no sign of formwork or shoring members in the south outlet, indicating the failure progressed to the north and/or upstream. Inspection of the distortion of upstream damaged towers indicates the failure caused these members to rotate or “rack” to the north.

Concrete from the failed pour flowed into Draft Tube 2 south outlet, damaging Doka shoring towers and engulfing many shoring lower legs in (now) hardened concrete. Weathering was evident in wooden shoring tower elements and there is some indication of inadequate nailing in some wooden tower members.

GENERAL REPORT – MAN BASKET INSPECTION OF UNIT 2 FORMWORK FAILURE

**Damaged Formwork Elements:**

The formwork and shoring underneath the panels outlined in Figures 1 and 2 were identified as damaged. Items outlined in red were destroyed in the collapse and must be replaced, items outlined in orange were damaged and may be repairable in the field. Failed tie rods are indicated in green. Formwork and shoring elements that are repaired and/or reused should be inspected by a qualified person to ensure they are fit for use prior to supporting fresh concrete.

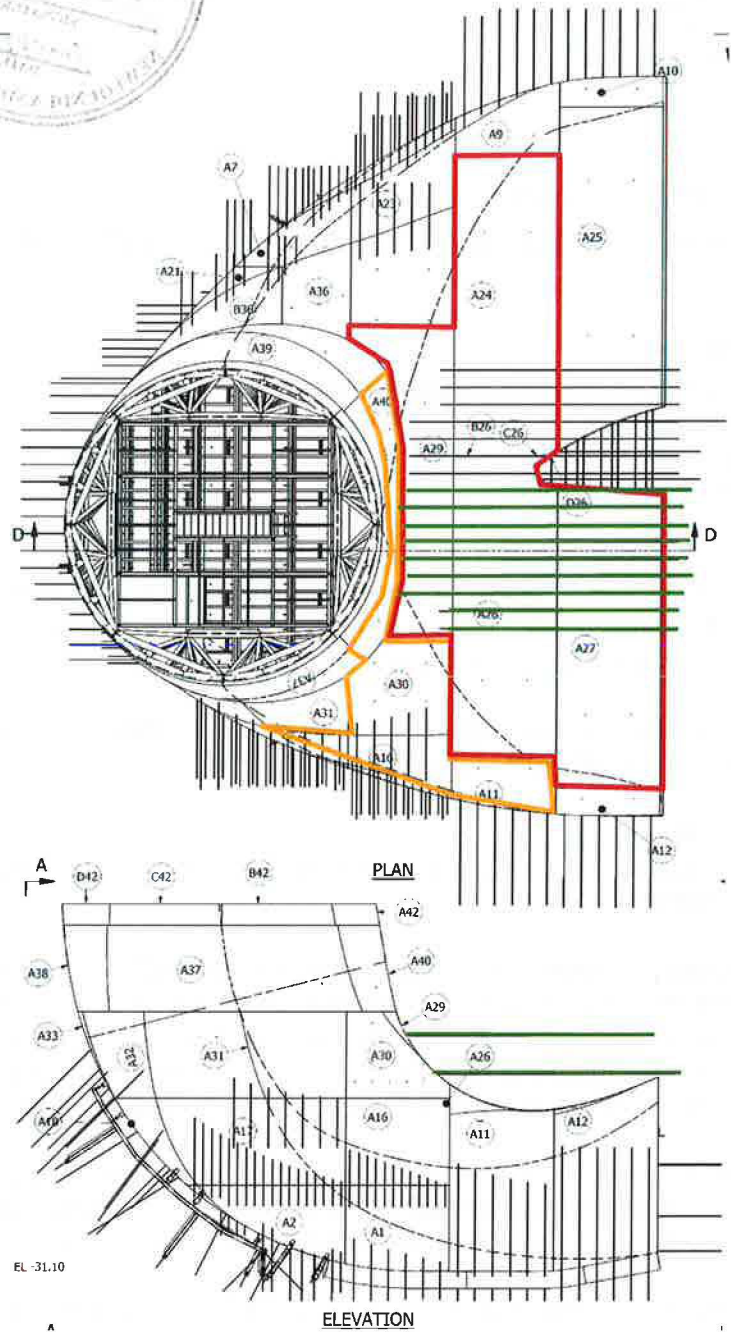
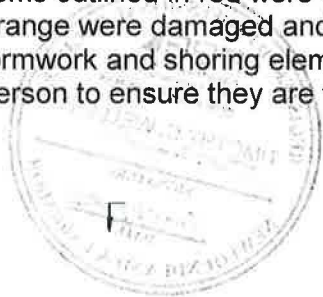


Figure 1: Major CEI formwork elements damaged in the collapse.

GENERAL REPORT – MAN BASKET INSPECTION OF UNIT 2 FORMWORK FAILURE

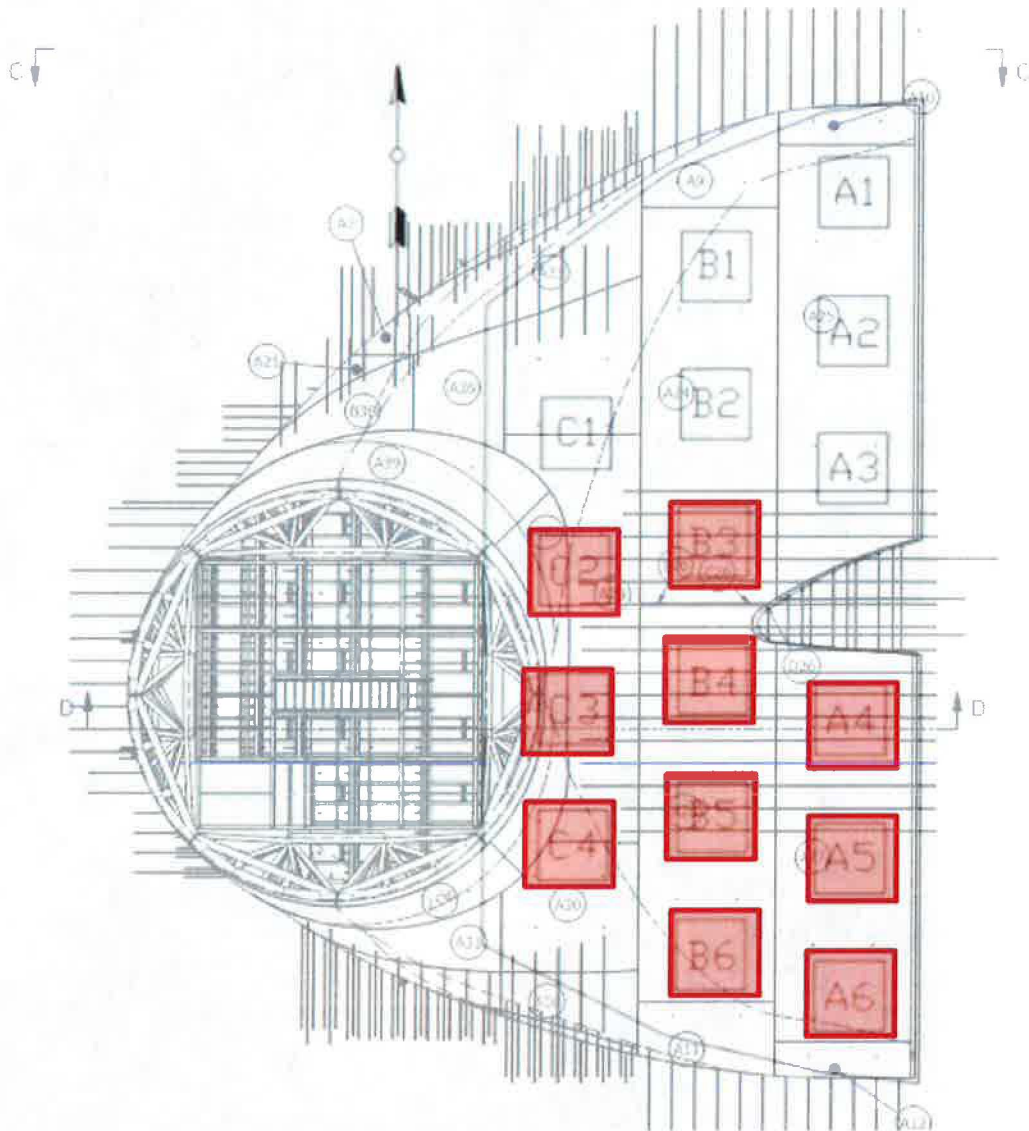
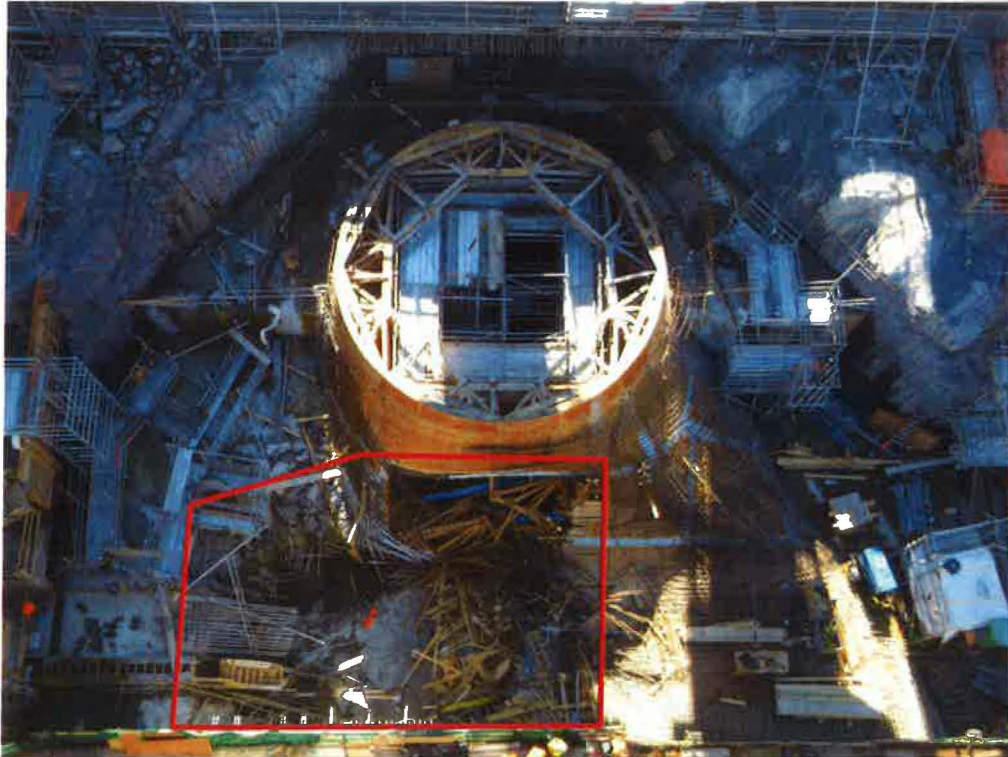


Figure 2: CEI Wooden shoring towers damaged in the collapse

GENERAL REPORT – MAN BASKET INSPECTION OF UNIT 2 FORMWORK FAILURE



**Figure 3: General view of the collapsed area taken from above**



**Figure 4: General view of the collapsed area taken from downstream.**

## GENERAL REPORT – MAN BASKET INSPECTION OF UNIT 2 FORMWORK FAILURE



**Figure 5: General view of the collapsed area taken from North**

### **Shoring towers**

The collapsed CEI shoring towers were buried beneath the pile of debris and concrete. Portions of the upstream tower legs were visible, most have indications of failure and/or damage.

Visible tower leg members have indication of weathering, in form of grey appearance. This is easily seen in Figure 7, with a suspended portion of tower leg clearly grey in color, compared to adjacent formwork lumber.

Several of the upstream (west) legs of towers C3 and C4 have potential indication of inadequate nailing of the 2x10's forming the legs. In some instances, the plys are separated, in others, pieces of leg members are missing. Tower C4 gusset plates pulled free of the tower legs in the NW corner, as shown in Figure 8.

Tower frames have indication of a north-progressing failure due to frames being "racked" to the north. See Figures 8 and 9 for examples.

There was some indication that the bearing surface on top of the shoring towers was not uniform. This is evident in Figure 6 where some of the column members end grain is compressed, and others is not.



GENERAL REPORT – MAN BASKET INSPECTION OF UNIT 2 FORMWORK FAILURE



Figure 6: Shoring Tower C3, SW leg. Note compressed end grain in portions of leg.

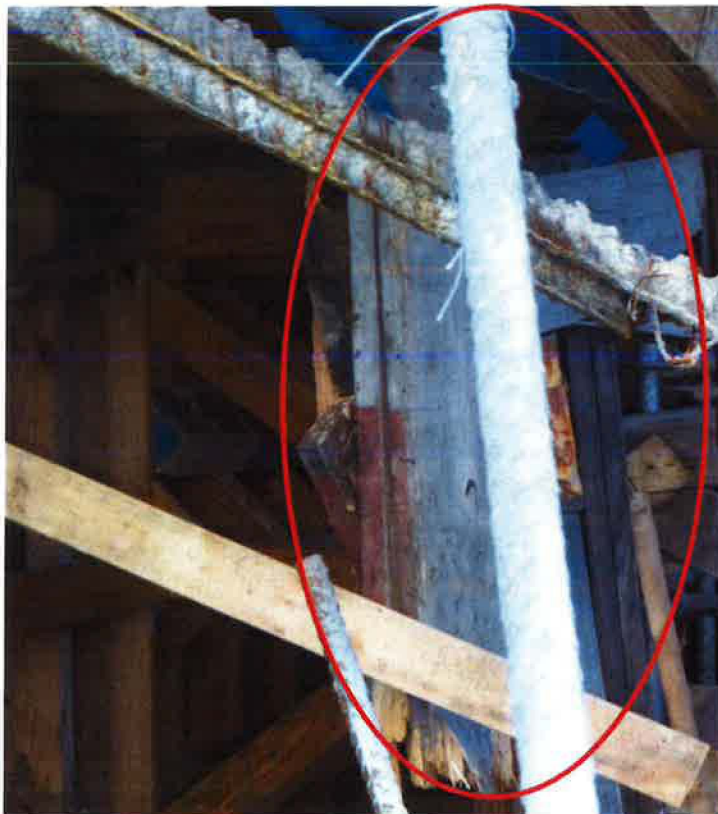


Figure 7: Shoring Tower C4, southern legs (behind rebar). Note weathered wood.

GENERAL REPORT – MAN BASKET INSPECTION OF UNIT 2 FORMWORK FAILURE

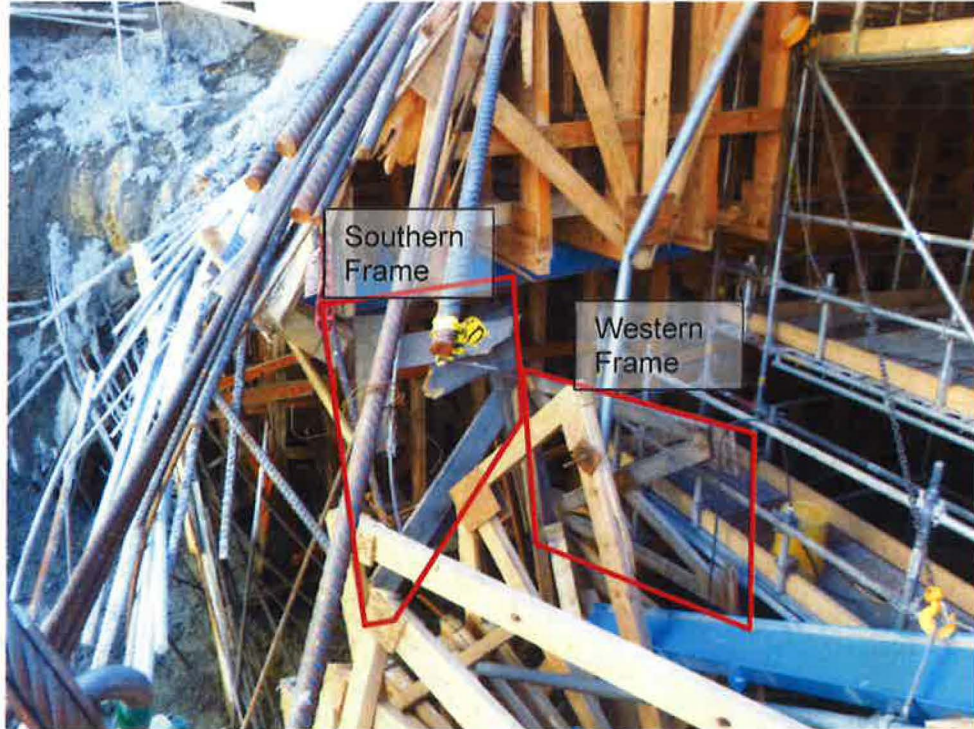


Figure 8: Shoring Tower C4, southern frame and western frame. Tower members outlined in red.

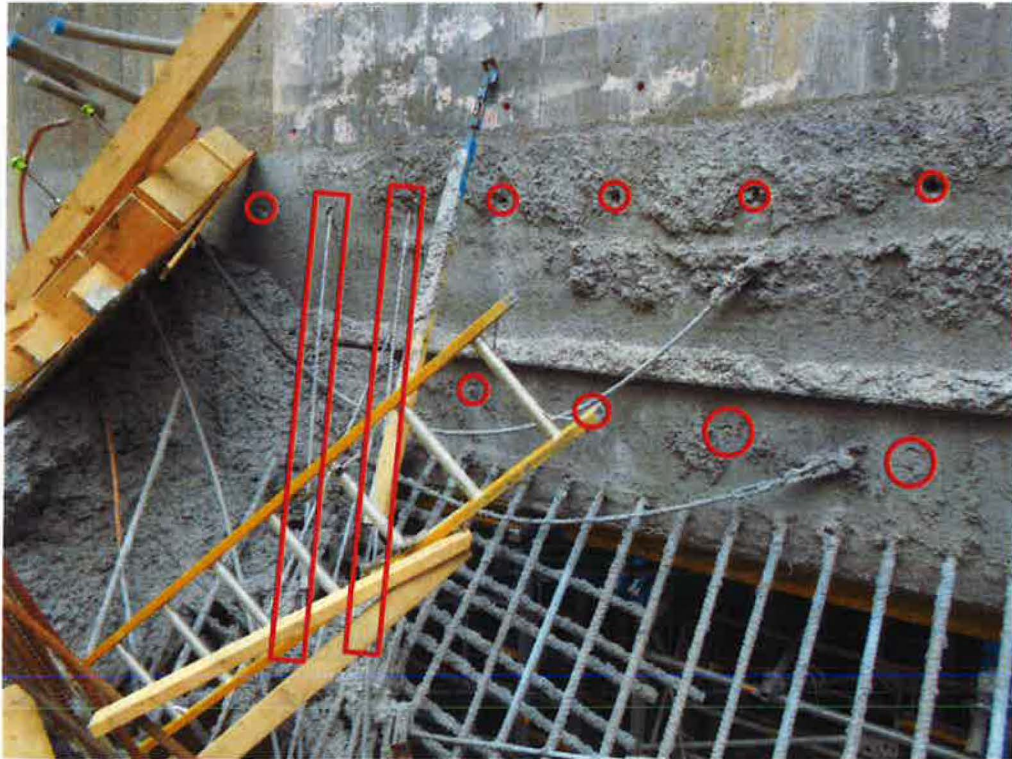


Figure 9: Tower C3 NW leg. Note separation of plies and missing elements

## GENERAL REPORT – MAN BASKET INSPECTION OF UNIT 2 FORMWORK FAILURE

**Coil Rod**

The original formwork configuration includes coil rod connecting element A29 to the Draft Tube Outlet 2 to carry the horizontal loads generated by the pouring of concrete. The coil rod connecting trusses inside formwork panel A39 to the concrete pours D2USB-02 were pulled out or sheared out under the weight of falling concrete and debris. This is shown in Figure 10.



**Figure 10: Upstream face of pour D2USB-02 with the two rows of holes from failed ties**

GENERAL REPORT – MAN BASKET INSPECTION OF UNIT 2 FORMWORK FAILURE



Figure 11: Ties remaining in the upstream face of pour D2USB-02

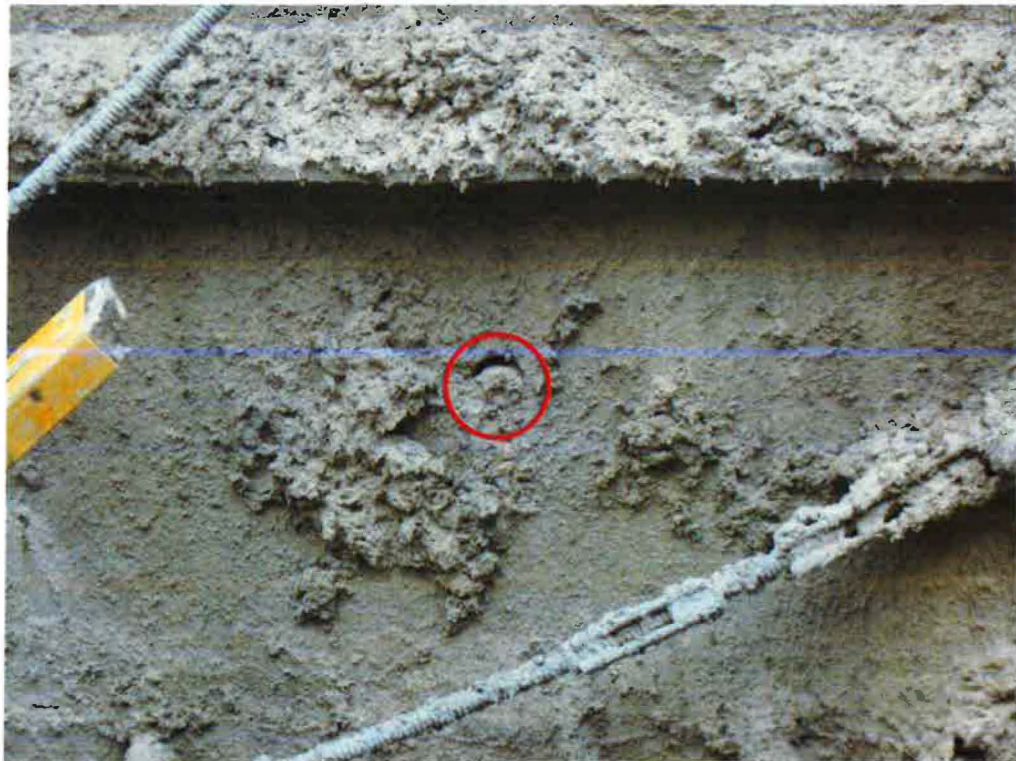


Figure 12: Holes from failure lower row of ties filled with concrete

## GENERAL REPORT – MAN BASKET INSPECTION OF UNIT 2 FORMWORK FAILURE



**Figure 13: Ties penetrating the formwork (for upcoming pour D2ENB-03)**

**Timber elements conditions**

Timber elements forming the skin and supporting ribs of formwork panels are visible in the debris. CEI formwork panels A40 and A43 are unsupported and must be removed or re-shored. Further inspection of damaged formwork elements should be made prior to allowing access to these areas.



**Figure 14: View from downstream of the hole left by the collapse of shoring towers supporting A29**

GENERAL REPORT – MAN BASKET INSPECTION OF UNIT 2 FORMWORK FAILURE



Figure 15: View from above of the hole left by the collapse of shoring towers supporting A29



Figure 16: View of element A30 on the South side of collapsed A29

GENERAL REPORT – MAN BASKET INSPECTION OF UNIT 2 FORMWORK FAILURE



**Figure 17: View of the North portion of Panel A29**



**Figure 18: Timber structure of element A16**

GENERAL REPORT – MAN BASKET INSPECTION OF UNIT 2 FORMWORK FAILURE



**Figure 19: Timber structure of element A16**



**Figure 20: Timber structure of element A16**



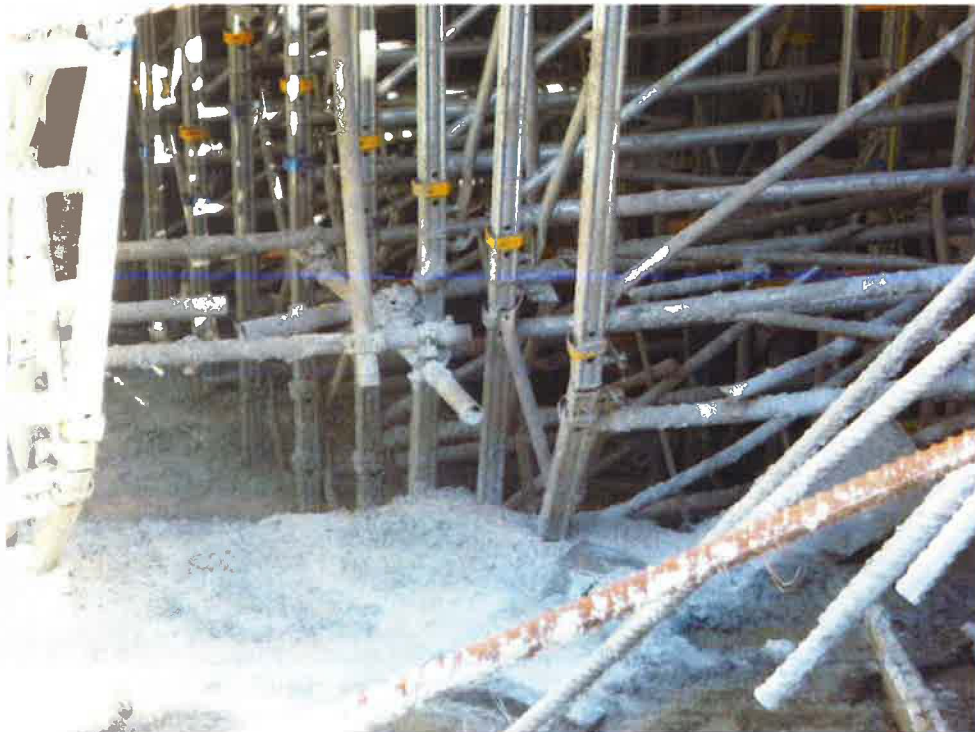
## GENERAL REPORT – MAN BASKET INSPECTION OF UNIT 2 FORMWORK FAILURE

**Damages on Doka Shoring Towers**

Concrete and limited debris bent and displaced the bottom row of Doka tower legs (see Figure 21 and Figure 22). It was observed that the first 2 towers had significant damage and the first 7 towers legs are covered in concrete.



**Figure 21: View of the Doka shoring towers from the Elbow**



**Figure 22: Detail of damaged Doka tower legs; bent and encased in concrete**

## GENERAL REPORT – MAN BASKET INSPECTION OF UNIT 2 FORMWORK FAILURE

**Built-in-place Formwork**

Built in place formwork for the bulkhead separating the failed D2ESB-03 from the D2ENB-03 pour collapsed on top of the formwork debris in Draft Tube 2. Portions of the formwork are still connected to tie rods.

The block-out for drainage trench is also on top of debris in Draft Tube 2 and portions are suspended above the opening in the failed formwork/shoring.

Suspended materials should be lowered prior to allowing access in the area.



**Figure 23: Whalers and ties from Built-in-place bulkhead separating D2ENB-02 and D2ENB-03**

GENERAL REPORT – MAN BASKET INSPECTION OF UNIT 2 FORMWORK FAILURE



Figure 24: Suspended formwork, rebar, and concrete, looking SE



Figure 25: Debris, looking west.

## GENERAL REPORT – MAN BASKET INSPECTION OF UNIT 2 FORMWORK FAILURE

**Non-Conforming concrete and damaged rebar**

Fresh concrete supported by the cured D2ESA-02 concrete flowed into the draft tube after the D2ESB-03 formwork failed, resulting in non-conforming concrete above D2ESA-02.

The majority of the failed formwork/shoring area has loose/suspended rebar. This material should be removed prior to allowing access in the area.

35M rebar penetrating from the outlet roof into Draft Tube 2 were bent down during the May 30 failure. See Figure 28. These bar do not pose an immediate safety hazard but will have to be addressed with the powerhouse engineer of record.



**Figure 26: Non-conforming concrete circled in red.**

GENERAL REPORT – MAN BASKET INSPECTION OF UNIT 2 FORMWORK FAILURE



Figure 27: Approximate extents of non-conforming concrete, in red.

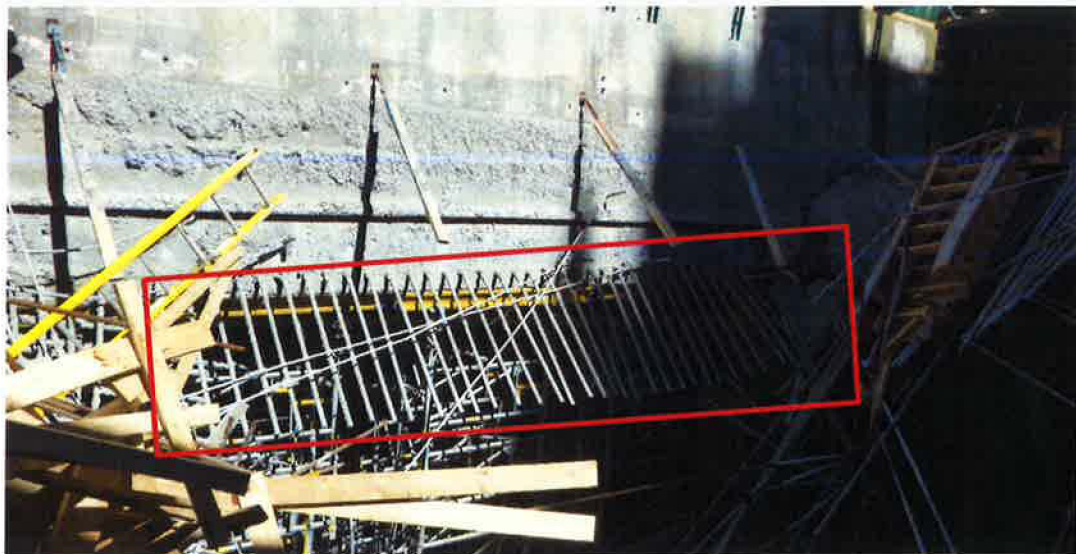


Figure 28: DT02 South Outlet Rebar yielded by failure.

## GENERAL REPORT – MAN BASKET INSPECTION OF UNIT 2 FORMWORK FAILURE

**Conclusion:**

Due to the extent of damage to the formwork, an inspection with a man basket was determined to be the safest initial course of action. During this inspection, a number of observations were made. It was noted that the majority of wooden shoring towers were buried in concrete and debris from the formwork/shoring failure. Portions of the wooden tower legs should be retrieved during removal of debris and to undergo destructive testing.

The coil rods tying panel A29 to pour D2USB-02 appear to have been in place at the time of the failure. Due to poor lighting conditions, we were not able to visually inspect the failed material in order to identify mode of failure. Additional man basket photos are proposed using artificial lighting to illuminate the failed coil rod and/or coil rod tie. Inspection of recovered coil rod in the debris should also be made.

The observations made of the damaged Doka towers in Draft Tube 2 South outlet were used to develop a remediation plan for the removal of the towers and formwork panels in this area. Details are outlined in the Phase 3B Report.

Remediation of non-conforming concrete and yielded rebar will be required.

A remediation plan to remove debris from the affected area should be developed based on the photos and observations made during the man basket investigation.