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Subject: HVdc TL - Review of Foundation Works - Structure S1-70
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Attachments: [.png](#)
[.png](#)
[Review of Foundation Works - Structure S1-070.pdf](#)
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Good morning All,

We have completed our review of initial foundation works and reinstallation at structure S1-70, and documented our findings.

Attached summarizes our findings for your feedback and comments, if any. We will be appending over 200 pages of documentation to final version.

We would like to use the final version as a template to any other structures that would require the same review.

As there is no technical nature to this document, I believe a through review by management would be beneficial.

Would Keenan be able to provide the review?

Does the document need to be coded for document control and final submittal?

Best,

Nazmi



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You owe it to yourself, and your family, to make it home safely every day. What have you done today so that nobody gets hurt?

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1. Initial Foundation Selection and Installation

Contractor supervisor/foreman:

Zeb Gore (Legs A and D), David Sudworth (Legs B and C)

Foundation selection and installation period:

19-Jan-2015 to 03-Feb-2015

Selected foundation type:

Type 1 (100 kPa Soil) grillage foundations were selected for each leg by AMEC Foster Wheeler (AMEC).

Foundation selection and installation package and associated QC forms: Presented in Appendix A.


Summary of foundation selection and installation activities observed:

Foundation selection and installation activities were undertaken in cold winter conditions, with temperatures ranging from -31 to -3 degree Celsius. Foundation installation was completed with two different foundation crews with inconsistent means and methods. Soils encountered consisted of, in general, root mat/topsoil to 0.3 m depth, underlain by dense gravelly Sand Till deposits in moist to wet conditions, overlying weathered bedrock, ranging from 3.1 to approximately 3.9 m in depth. Soil conditions observed met the allowable bearing capacity of 100 kPa and above design requirements as per appended Engineered AMEC Foundation Selection Reports.

Summary of concerns identified during selection and installation:

Review of Foundation Installation Package and LCP site personnel daily field reports indicated that challenges were experienced due to inadequate surficial water mitigations measures, frost protection for founding base and backfill operations, as well as groundwater control. Inconsistent means and methods were observed between the two foundation crews. As a result, reworks for foreseen deficiencies were undertaken throughout the installation process to meet project requirements. One example would be, during the initial installation, the embedded grillage for Leg C had to be removed and reinstalled. The rework damaged the grillage, exposed the excavation to frost in presence of groundwater at adverse weather condition. Open excavations overnight were also observed, indicative of frost penetrations and may have affected founding base and backfill for the foundations.

Although compaction efforts were in place for founding base and backfill, with the exception of leg A backfill, no compaction tests results were provided. Photographs taken during the backfill operation depicted that lifts from founding to surface level were completed in a trapezoidal cone shape rather than inverted, as per foundation drawings. Backfill source stockpiled at site was not protected from frost. Grading at the surface level was not to the project specifications nor Site Instruction SIN-CT0327001-006 (dated 02-Feb-2015); possibly allowing surficial water and melting snow to compromise the overall integrity of the foundations. This site instruction provided additional mounding due to difficulties to attain proper compaction inside the tetrapod of the grillage footing and was communicated to foundation crews by LCP field personnel. Review of data indicated concerns on whether proper lift thickness was undertaken. A grillage footing founded at 3.5 m below ground surface and mounding of additional minimum 250 mm (3750 mm total backfill) would require 13 backfill lifts at 300 mm maximum lift thickness. Quality control documentations provided noted a total

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of 10 lifts of backfill for Leg A and a total of 9 lifts of backfill for Legs B, C and D.

Due to aforementioned concerns, at the completion of the works and receipt of foundation installation package, deficiencies with overall foundations were inferred and a field monitoring program was initiated by LCP Construction Team.

Select photos (pre-, during and post-selection and installation):



Photo 1: S1-70 Leg A Re-work on base preparation exposed to frost, compaction effort with no verification of test data.



Photo 2: S1-70 Leg B Founding base preparation and compaction effort with no verification of test data.



Photo 3: S1-70 Leg C– Reclaim of grillage during initial installation. Frozen founding base and frozen backfill with oversized boulders.



Photo 4: S1-70 Leg D excavation works with inefficient ground water control.

2. Foundation Investigation

Date of first identification of deficiency:

04-July-2015

Deficiency identified by:

Deficiencies identified during monitoring by LCP Construction Management Team and through internal survey



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verification. However, prior survey data from Valard indicated foundations were out of specification tolerances and were not immediately raised for remedial measures.

Deficiency description:

- Improper grading and no additional mounding as per SIN-CT0327001-006 at the surface level during the initial installation.
- Saturated backfill.
- Inferred frost above, at and below grillage footings.
- Oversized boulders within backfill material over the grillage exceeding specified size.
- The difference in elevations between any two footings exceeded the 6 mm tolerance.
- The centre-to-centre distance between any two adjacent footings exceeded the 6 mm tolerance
- The centre-to-centre distance between any two diagonal footings exceeded the 12 mm tolerance.

Root cause:

- Improper grading performed during the initial installation was further deteriorated with poor surficial runoff measures, saturating foundation backfill and settlement in backfill.
- Lack of site instruction SIN-CT0327001-006 being followed- no additional mounding.
- Lack of effective measures for frost protection during the foundation works.
- Inadequate compaction effort verifications for both base preparation and backfill operations. No compaction test results with the exception of backfill for Leg A.
- Lift thicknesses during backfill operations noted to be above specified thickness of 300 mm maximum.
- Backfill operations completed using a trapezoidal cone shape rather than inverted compromising lateral support to compacted material and possibly allowing migration water into footprint of foundation.
- Excessive reworks for foreseen deficiencies during the initial installation.
- Lack of presence of quality personnel.

Select photos (Investigation):



Photo 5: S1-70, General view looking East, July 5, 2015.



Photo 6: S1-70 Leg A, reclamation of grillage footing.



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Photo 7: S1-70 Leg C, reclamation of grillage footing, saturated founding base and backfill.



Photo 8: S1-70, common excavation, confirmed weathered bedrock below founding depth.

3. Foundation Remediation and/or Reinstallation

Decision to remediate by:

Valard Construction LP (Valard).

Remediation measures:

- Reclamation of grillage foundations installed.
- Removal of saturated backfill and foundation base material.
- Reselection and reinstallation of foundation to project specifications.

Foundation remediation/re installation period:

1-Aug-2015 to 20-Aug-2015

Description of reinstallation (include any differences in technique):

- Improved mitigation measures to control surficial water by surficial trenches to capture surface runoff.
- Improved mitigation measures to control ground water by additional sump pumps and “side pool” and trenching in the excavations.
- Common excavation for all four (4) grillage footings for better control of site challenges.
- Over excavation to confirmed bedrock underlying saturated overburden to 4.3 m depth.
- Preparation of base from bedrock to founding depth with compacted 6 inches minus crushed stone underlying Class A granular compacted and tested to minimum 95% of maximum modified proctor dry density as per project specifications.
- Closer attention to proper lift thicknesses, material suitability and compaction effort verification.
- Proper grading meeting the project requirements, however additional mounding as per SIN- SIN-CT0327001-006 has yet to be completed.



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- Attention to quality of the product with increased presence of quality control personnel.
- Single foundation crew completing the overall reinstallation.

Foundation re-selection and reinstallation package and associated QC forms: Presented in Appendix C.

Select photos (Remediation/Reinstallation):



Photo 9: S1-70, Leg A, Groundwater control, found base preparation and compaction effort verification.




Photo 10: S1-70, Leg A, Grillage Placement on prepared founding base with groundwater control.



Photo 11: S1-70, Leg D, Grillage placement on prepared founding base with groundwater control.



Photo 12: S1-70 completed reinstallation of foundations, general view looking Southeast. Proper grading however no additional mounding.

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4. Conclusions
<p>Review of compiled data indicated that initial installation had constructability challenges due to adverse weather as well as problematic site conditions. However these challenges are expected and could have been mitigated by adequate planning, improved workmanship and with greater presence of quality control personnel. The findings during the reclamation of grillage footings and compromised earthworks supported the deficiencies noted.</p> <p>At time of preparation of this review, only Engineered AMEC Foundation Selection reports have been received. Foundation Reinstallation Package pending receipt. Reinstallation of the foundations observed were undertaken with adequate planning, improved workmanship and with greater presence of quality control personnel. The survey verification by Valard following the reinstallation and prior to tower erection indicated elevation and lateral distances are within the specified tolerances. Provided that additional mounding is completed, it is anticipated that the mitigation measures undertaken during the reworks, were adequate to prevent further remediation works. However, a monitoring program is currently exercised by LCP Construction Team.</p> <p>It should be noted that completed foundations and any mitigation measures at ground surface should not be compromised by any alteration and/or modifications during the above ground works, i.e., tower erection and stringing. Any unavoidable alteration and/or modifications to foundation should be corrected following the above ground works.</p> <p>This review is based on foundation installation packages received from Valard to date, and the review of internal documentations, presented in the appendices.</p>

	TITLE	NAME	SIGNATURE	DATE
Prepared by:	Quality Advisor	Zachary Andrews		
	Geotechnical Engineer	Nazmi Boran, P.Eng		
Reviewed by:				

APPENDICIES:

Appendix A: QC Documentation – Initial Foundation Installation

Appendix B: Daily Construction Reports – Initial Foundation Installation

Appendix C: QC Documentation – Foundation Remediation/Reinstallation

Appendix D: Daily Construction Reports – Foundation Remediation/Reinstallation

Appendix A: QC Documentation – Initial Foundation Installation

Appendix B: Daily Construction Reports – Initial Foundation Installation

Appendix C: QC Documentation – Foundation Remediation/Reinstallation
(Foundation Reinstallation Package pending receipt)

Appendix D: Daily Construction Reports – Foundation Remediation/Reinstallation