8 April 2021

Wood File: BX30653

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Arie & Willemiek Muilwijk
P.O. Box 1628
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Attention: Arie Muilwijk

Re: Supplementary Information
Roller Compacted Concrete for Calf Shelter, Calf/Feeder Pens
NE-10-009-27-W4M, near Fort Macleod, Alberta

As requested, Wood Environment & Infrastructure Solutions (Wood) has prepared this letter to support the use of Roller Compacted Concrete (RCC) as a liner at the above-captioned site, in accordance with the Agricultural Operation Practices Act, AB Reg. 267/2001 (hereinafter referred to as "AOPA").

The use of RCC is gaining widespread popularity and acceptance among producers in the confined feeding industry in Southern Alberta. Since 2018, the local Lethbridge NRCB office has also permitted the construction of at least one feedlot expansion[1] with RCC as the pen base, with consideration of the RCC as the liner material meeting the requirements of the AOPA.

Given the questions surrounding the use of RCC as a liner satisfying the requirements of AOPA, most of the local RCC pen base construction has encompassed the rehabilitation of older 'grandfathered' confined feeding operations or existing permitted facilities as an alternative to the ongoing requirement for imported clay to reconstruct pen bases following manure removal. Wood provided engineering support to one of the first projects associated with the recent onslaught of RCC use as a pen base more than ten years ago. That first project, as well as the associated widespread use of RCC that has developed in the more recent few years, has consistently demonstrated that RCC is robust and performs very well for many years both in terms of animal health and performance of the pen bases during all cycles of pen cleaning activities and animal occupation.

While the NRCB has released a document entitled "Non-Engineered Concrete Liners for Manure Collection and Storage Areas" (Agdex 096-03 dated June 2015), this provides guidance for the use of conventional reinforced plastic concrete, and is not directly applicable to the use of RCC as a liner material. At this time neither Alberta Agriculture nor the NRCB have released an official guidance document to support the use of RCC as a liner material for solid manure storage. Accordingly, this letter is prepared to satisfy the intent of AOPA Section 9(6), which indicates: *"The liner of a manure storage facility and of a manure collection area, if constructed of compacted soil or constructed of concrete, steel, <u>or other synthetic or manufactured materials</u>, must provide equal or greater protection than that provided by compacted soil (c)0.5m in depth with a hydraulic conductivity of not more than 5 x 10^{-7} centimetres per second for a solid manure storage or solid manure collection area."*, by providing engineering rational to support RCC as a liner which satisfies AOPA Section 9(6)c. It is noted that this option for engineering

[1] NRCB permit: LA18053B

rational to support a liner design which differs from convention is also reiterated in the introduction of the previously-referenced Agdex 096-93.

The use of concrete as a liner in past years, even in the case of completely unreinforced concrete, has demonstrated significant longevity, *and generally performs better than compacted soil, HDPE, or steel*. An important advantage of concrete, whether conventional concrete or RCC, is the level to which positive drainage can be maintained in low-slope situations within the pen areas as compared to clay-lined pens. Consequently, RCC pens are generally characterized by much less ponding than for clay pens, and where water is efficiently shed off the RCC mat rather than allowed to pond in the pen, the net result is that the volume of surface water *available* to permeate through the pen base is much less than for RCC pens, resulting in a substantially lower risk of surface water permeating through the liner.

Permeability through RCC

Permeability through RCC and conventional concrete is widely documented. For conventional concrete, the Cement Association of Canada indicates a typical permeability of concrete ranging between about 8×10^{-10} cm/s for a water cement ratio of 0.75, to about 2×10^{-11} cm/s for a water cement ratio of 0.40[2]. For RCC, the permeability has been demonstrated to be somewhat higher than that of conventional concrete. A publication by the Portland Cement Association[3] indicates that typical permeability values through RCC range between 1.5×10^{-10} cm/s to 1.5×10^{-8} cm/s.

It is noted that at the highest (i.e., worst case) permeability value indicated, the level of protection far exceeds the minimum liner requirement for permeability as indicated by Section 9(6)(c) of the AOPA. Particularly, a 150 mm thick RCC liner with a permeability of 1.5×10^{-8} cm/s is the equivalent of 5 m of material having a permeability of 5×10^{-7} cm/s, which is ten times the level of protection required by the AOPA. Assuming an average permeability of 1×10^{-9} cm/s, the level of protection provided by the RCC would be over 100 times the protection required by the AOPA.

Potential for and Prediction of Cracking of RCC

The readily available and previously referenced publication "*Design and Control of Concrete Mixtures*" by the Cement Association of Canada provides a good discourse on volume changes related to concrete. Cracking tendency of concrete can be primarily attributed to slight volume changes in the concrete, particularly in conjunction with tension stresses that develop because of shrinkage. This volume change (or shrinkage) occurs for a variety of reasons. In early concrete stages, chemical shrinkage occurs in conjunction with the reduction in volume of solids and liquids in paste resulting from cement hydration. Autogenous shrinkage occurs at a macroscopic level where there is visible dimensional change of the cement paste resulting from hydration. Subsidence occurs in the form of vertical shrinkage of fresh concrete as bleed water rises to the surface. And plastic shrinkage occurs in the case that rapid evaporation of moisture from the surface of the concrete exceeds the bleeding rate. Following hardening

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[2] Canadian Cement Association *"Design and Control of Concrete Mixtures"* (8th Edition, 2011), Table 18-2.
[3] Wayne S. Adaska *"Roller Compacted Concrete (RCC)"* PCA R&D Serial No. 2975 published 2006. The article indicates a range of permeability of 0.15 to 15×10^{-9} cm/s.

of the concrete, volume changes occur as a result of moisture changes (with shrinkage occurring as a result of moisture loss and expansion during moisture gain), and as a result of temperature changes (with contraction occurring during cold weather, and expansion occurring during warmer weather.

The level of early age volume changes related to roller compacted concrete is generally considered to be *lower* than for conventional (plastic concrete) due to the typical lower water content and water-cement ratio of the concrete, the general absence of bleed water, and the effect of compacting the concrete matrix into place during placement. However, based on Wood's experience, the volume changes of the roller compacted concrete resulting from moisture changes or thermal expansion/contraction appear to be consistent with conventional concrete. Assuming a coefficient of thermal expansion of 8×10^{-6} per degree Celsius for concrete using sand and gravel, the calculated linear change of a concrete pad associated with a temperature variation between -30 °C and +30°C would be up to about 5 mm per 10 m length of concrete.

<u>*Permeability through Potential RCC Cracks*</u>

Invariably, cracks in the RCC mat become infilled with a combination of bedding material, manure, and soil. Theoretically, during the coldest months, these cracks would be the widest in conjunction with the lowest temperatures. Incidentally, the permeability would also be the lowest during this time, as any liquid on or in the RCC or cracks would be frozen, and not permeating through the RCC or cracks. During the warmer months, the material in the cracks would compress as a result of thermal expansion of the RCC, effectively sealing the cracks and reducing permeability through the cracks to a minimum.

While Wood does not know of any studies specifically measuring permeability through infilled cracks of a manure storage pad, some excellent work has been done to measure permeability through the black interface and gleyed zone occurring in conjunction with moderately coarse and moderately fine textured soils in feedlot pen surfaces in Southern Alberta[4]. The intent (in part) of the referenced study was to investigate this black interface layer between the manure pack and underlying stained soils to assess suitability of this material relative to protection of groundwater. The results of the study indicated permeability of this interface layer ranging between about 4×10^{-5} cm/sec and 9×10^{-4} cm/sec (see Note[5]). While the permeability through this black interface zone or (in some cases a gleyed layer) would not directly satisfy the stated AOPA requirements for groundwater protection, the localized higher permeability through these narrow interface zones (i.e., infilled cracks) can be considered in conjunction with the broader relatively impermeable RCC (or concrete) matrix. For the purposes of the current RCC assessment, the permeability of the cracked area has been assumed permeability at 1×10^{-4} cm/sec. This assumed value is consistent with the permeability of "silt", and is considered conservative relative to the application at hand.

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[4] Jim J Miller, Tony Curtis, Francis J. Larney, Tim A. McAllister, and Barry M. Olson: *"Physical and Chemical Properties of Feedlot Pen Surfaces Located on Moderately Coarse- and Moderately Fine-Textured Soils in Southern Alberta"* Journal of Environmental Quality, Volume 37, July-August 2008.

[5] Note: Miller et al reports field-saturated hydraulic conductivity, K_{fs}, of 4.37 to 92.9×10^{-7} m s^{-1} for pen base soils at the three study sites.

Permeability of Subgrade Soils at NE-10-009-27-W4M

At the outset of the proposed permit application for the subject development, a series of four boreholes were advanced at the site by Chilako Drilling Services of Coaldale, Alberta. The soils were logged by Mr. Larry Delong of Chilako Drilling services; the soil logs are appended, for reference. The borehole locations are illustrated on Figure 1, attached.

The four boreholes extended to depths of about 6.2 m below grade. The observations of the drilling indicated the presence of a lacustrine complex of silt, fine sand and clay through the full drilling depths of the boreholes. The static groundwater table was identified at a depth of about 2.7 m to 3.6 m below existing grade.

At the time of the drilling, the estimated permeability of the naturally occurring soils were deemed too high to meet the AOPA requirements for a naturally occurring liner. Accordingly, permeability test wells were not installed at the time of the drilling. Notwithstanding, the presence and permeability of the subgrade soils, though they do not directly meet the AOPA requirement independently, will augment the protection provided by the RCC. The typical permeability of soils relative to grain-size of the material is widely available in the published literature. Based on information published by Craig[6], the average permeability of lacustrine (silt/clay/fine sand) site soils would be in the order of 2 x 10^{-5} cm/s. Accordingly, for purposes of the current assessment, an average permeability of 2 x 10^{-5} cm/s is assumed.

It is noted that a layer of silty clay (SiCL) is noted in the borehole logs, with medium to high plastic descriptors, and thicknesses ranging between 0.5 m and 1.0 m. These plastic clay soils would have a permeability in the order of 1 x 10^{-8} to 1 x 10^{-9} cm/s. While these layers alone would provide protection greater than the protection required by the AOPA, the layers were generally too thin to construct permeability test wells to directly measure the permeability of these layers.

Average Permeability

For comparison of the permeability of the RCC mat to the AOPA requirements, the following unit permeability values and thicknesses have been assumed:

1. RCC Permeability: 1 x 10^{-9} cm/s, minimum thickness of 0.15 m
2. Permeability of In-filled Crack: 1 x 10^{-4} cm/s, minimum thickness of 0.15 m
3. Permeability of Subgrade Lacustrine Soils: 2 x 10^{-5} cm/s, thickness of 3.0 m.

[6] R.F. Craig, *"Soil Mechanics"*, 6th Edition (1997), Table 2.1.

Considering a unit area of RCC measuring 10 m by 10 m having total potential cracking of 10 m long by 15 mm wide, the average permeability can be expressed as follows:

$$k_{ave} = (A_{RCC}(k_{RCC}) + A_{CR}(k_{CR}))/A_{total}$$

where: A_{CR} = tributary area of cracking (m^2) = $0.015m \times 10m = 0.15m^2$
A_{RCC} = tributary area of RCC (m^2) = $10m \times 10m - A_{RCC} = 99.85m^2$
k_{RCC} = permeability of RCC $(1 \times 10^{-9}$ cm/s$)$
k_{CR} = permeability through infilled cracks $(1 \times 10^{-4}$ cm/s$)$
A_{total} = *total unit area* $(10m \times 10m = 100\ m^2)$

Based on the above, the average permeability, k_{AVE}, has been calculated to be 1.5 x 10^{-7} cm/s. This would be the equivalent of 0.5 m of material having a permeability of 5 x 10^{-7} cm/s (the reference standard for compacted clay liner for solid manure storage provided by the AOPA).

With consideration of the solid manure storage mat being frozen for the winter months (i.e., three months per year), the average permeability over the duration of a year would increase by one-third, to 1.13 x 10^{-7} cm/s. This would be the equivalent of about 0.58 m of material having a permeability of 5 x 10^{-7} cm/s.

Finally, a 3.0 m thickness of naturally occurring lacustrine materials having an average permeability of 2 x 10^{-5} cm/s would provide an additional equivalent (calculated) protection of 0.075 m of material having a permeability of 5 x 10^{-7} cm/s.

Based on the above, with consideration of the RCC, up to 15 mm by 10 m of cracking within a 10 m x 10 m unit area, consideration of winter freezing, and consideration of the underlying lacustrine soils, the RCC would provide a total equivalent thickness of approximately 0.65 m of material having a permeability of 5 x 10^{-7} cm/s, which exceeds the required thickness of 0.5 m indicated by Section 9(6)(c) of the AOPA.

Accordingly, it is Wood's opinion that the Roller Compacted Concrete which has been constructed at the subject Muilwijk farm satisfies the requirements for liner material indicated in Section 9(6)c of the AOPA.

This report has been prepared for the exclusive use of Arie & Willemiek Muilwijk for the specific application to the development described in this report, and may be used by the NRCB and its Review Board specifically to support the permit application (and associated board review) by the Muilwijk's for the subject calf shelter and calf/feeder pens as described herein. Any use that another party makes of this report, or any reliance or decisions based on this report are the sole responsibility of those parties. This report has been prepared in accordance with generally accepted soil and materials engineering practices. No other warranty, express or implied, is made.

We trust this satisfies your present requirements. If you have questions or require further information or clarification, please do not hesitate to contact the undersigned.

Respectfully submitted,

Wood Environment and Infrastructure Solutions,
A Division of Wood Canada Limited

8 April 2021

PROFESSIONAL ENGINEER
JOHN LOBBEZOO
ALBERTA

PERMIT TO PRACTICE
Wood Environment & Infrastructure Solutions
Signature
Date 8 April 2021
PERMIT NUMBER: P-04546
The Association of Professional Engineers and Geoscientists of Alberta

John Lobbezoo, P.Eng.
Associate Engineer, Geotechnical
Lethbridge Geotechnical & Materials Testing Lead

Reviewed by:
Adam Johnson, C.E.T.
Field & Laboratory Services Manager

Attachments: Figure 1 – Borehole Locations
Soil Profile and Parent Material Description (Chilako Drilling Services)


Borehole Locations
Pen & Catch Basin Permitting
Arie Muilwijk
Wood File: BX30653
April, 2021
Legend
Feature 1
AM2-19
Covered Shelter Area
AM1-19
Subject Pen
Subject Pen
AM3-19
AM4-19
Subject Pen Area
Proposed Catch Basin Area
Google Earth
Image S. Alberta MD s and Counties
©2018 Google
N
80 m

CHILAKO DRILLING SERVICES LTD

Box 942 Coaldale, Alberta, T1M 1M8
(403) 345-3710

SOIL PROFILE AND PARENT MATERIAL DESCRIPTION

Site Location: Arie Muilwijk Date: 9-Aug-19

Hole #	Location	Depth	Texture	Moisture	Geological	Sample	Remarks
AM1-19	0314346	0-2.1	VFSL	SM	Lac		Silty
	5511364	2.1-3.5	VFSCL	VM	Lac		
		3.5-5.1	VFSL	VM-Sat	Lac		
		5.1-5.9	SiCL	M	Lac		V. firm, med-high plastic, yellow brown
		5.9-6.2	FSCL	VM	Lac		Slough @ 3.3m
AM2-19	0314354	0-2.9	VFSL	SM	Lac		Silty
	5511400	2.9-3.6	SiCL	VM	Lac		Sandy
		3.6-5.6	VFSL	Sat	Lac		Soft, olive brown, silty, free water
		5.6-6.2	SiCL	M	Lac		V. firm, med-high plastic, olive brown
							slough @ 3.9m
AM3-19	0314364	0-1.8	VFSL	M	Lac		Loose, olive brown, silty
	5511294	1.8-2.3	VFSCL	VM	Lac		Low plastic, olive brown, silty
		2.3-3.0	VFSL	VM	Lac		Silty
		3.0-4.1	VFSL	Sat	Lac		Silty, free water, VFSL sand lenses
		4.1-4.6	SiCL	M	Lac		Stiff, med plastic, olive brown
		4.6-5.0	VFSCL	VM	Lac		Soft, low plastic, olive brown
		5.0-6.2	SiCL	VM	Lac		Firm, low plastic, olive brown
AM4-19	0314411	0-1.0	SiCL	M	Lac		
	5511281	1.0-2.7	VFSL	M	Lac		
		2.7-4.4	VFSL	Sat	Lac		Soft
		4.4-6.2	C-SC	M	Till		Stiff, low plastic, trace gravel

Legend:

L	Loam
C	Clay
S	Sand
Gr.	Gravel
Si	Silt
F	Fine (sand)
VF	Very Fine (sand)

Eg. VFSCL = Very Fine Sandy Clay Loam