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Wood File: BX30653

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Attention: Arie Muilwijk

Re: Compliance Report – 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 provided engineering support services in conjunction with the recently constructed calf shelter and feeder pens at the above-captioned site. It is understood that the NRBC permitting for this expansion was not quite finalized at the time of construction of the subject shelter and pens, and in the time since construction, several issues have been raised by the NRCB which have to this point encumbered the permitting of the facility. The purpose of this letter is to provide an engineering basis for the design of the shelter and pen base relative to the Agricultural Operation Practices Act, AB Reg. 267/2001 (hereinafter referred to as "AOPA"), to support NRCB permitting of the new facility.

In general, the subject floor of the shelter and base of three pens were constructed using Roller Compacted Concrete (RCC). The RCC mat was constructed with a minimum targeted thickness of 150 mm, and the nominal targeted compressive strength of the concrete was 25 MPa. The RCC was placed in November, 2019.

Construction Review of the RCC Mat

The calf shelter RCC mat encompasses an area of about 15 m wide by 80 m long, and is located directly east of the residence and north of the barns (see Figure 1). The new feedlot pens encompass an area of about 37 m wide by 97 m long, and are located just southeast of the calf shelter building (see Figure 1). At the time of Wood's field review, the catch basin had been formed, but the liner was not installed. The catch basin excavation measured roughly 20 m wide by 30 m long by 1.8 m deep, with side slopes of approximately 3 horizontal to 1 vertical (i.e., 3H:1V).

To assess the RCC mat, Wood reviewed records of construction, the concrete mix, and carried out testing and field review of the completed RCC mat. The site review by Wood was carried out on June 9, 2020, and included coring, non-destructive compressive strength testing, and a visual review of both mats to the extent possible. The following comments, observations, and test results by Wood relative to the recently placed RCC mat are provided as follows:

1. The sizes and locations of the calf shelter, pens, and catch basin are generally consistent with the details provided in the NRCB Permit Application (LA19036).
2. Photographs provided depicted the subgrade prior to placement of the RCC and showed that the subgrade had been levelled and compacted prior to RCC placement.

3. The RCC was placed using GPS based survey-controlled equipment to provide a uniform placement thickness of RCC and positive sloping of the pens. Based on coring of several locations in the RCC, the thickness of RCC ranged between 155 mm and 205 mm, with an average thickness of 173 mm for eight cores.
4. Photographs provided depicted the RCC being compacted around existing fence posts, waterers, and bunk aprons, using a walk-behind plate compactor, while a large vibrating ride-on compactor was used to compact the majority of the RCC.
5. Further photographs provided depicted a layer of straw over the RCC following placement to promote curing of the RCC and to provide crack control related to early-stage curing of the RCC.
6. Laboratory density testing was carried out on core samples recovered from the RCC mat, and indicated in-place densities ranging between 2,395 kg/m^3 and 2,420 kg/m^3, generally representing optimal compaction of the RCC mix, with densities ranging between 99 percent and 101 percent of the target mix density of 2,400 kg/m^3.
7. During Wood's June 9, 2020 site visit, a Schmidt hammer was utilized to estimate the compressive strength of the RCC. The results of the rebound testing indicated compressive strengths of the RCC ranging between about 25 MPa and 40 MPa.
8. At the time of Wood's site review, the catch basin had also been roughly formed, and dimensions were found to be in general accordance with those provided in the application for permit. No accumulation of water or evidence of groundwater was observed in the catch basin excavation. Some accumulation of sand and silt was observed, which would require removal prior to placement of a liner. It is understood that an HDPE liner is proposed for this catch basin.

Roller Compacted Concrete (RCC) as a Liner

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 a 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.

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[1] NRCB permit: LA18053B

While the NRCB has released a document entitled "Non-Engineered Concrete Liners for Manure Collection and Storage Areas" (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, or other synthetic or manufactured materials, 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.

Firstly, it is underscored that for solid manure storage and solid manure collection areas, each of the conventional liner materials have limitations and drawbacks. The AOPA generally only speaks to standards at the time of construction, and does not specifically provide guidance on liner repair, rebuilding, maintenance, or the testing required to support repair or maintenance. For instance, compacted clay is routinely compromised during wet climate periods (including spring thaw and major rainfall events), and often significantly impacted during pen cleaning operations. While the intent is that the clay bases are routinely rehabilitated as necessary to satisfy the liner requirements outlined by AOPA, this may not consistently be happening. Rather pen bases are often reconstructed with material that is readily available, which may include materials other than low-permeable clay. Occasional feedlots reportedly even use sand and gravel to reconstruct pen bases when/where necessary. For synthetic liners (such as HDPE, though not widely used for solid manure storage or collection), these are continuously susceptible to damage by equipment (or even cattle), or degradation and associated shortened life expectancy as a result of UV exposure. The use of steel as a liner (though again, not widely used by solid manure storage or collection), rusts and deteriorates.

For concrete, whether conventional (plastic) or roller compacted concrete, the main challenge pertains to cracking and deterioration along cracks. The NRCB has provided some guidance to help control cracking of conventional (plastic) concrete using steel reinforcing for non-engineered liners; however, even the inclusion of steel reinforcing will not stop cracking, though steel reinforcement (where properly designed and placed) does help to even out crack spacing and reduce the propagation or widening of discrete cracks. In the case of steel exposure to manure within cracks, the long-term performance of small-diameter steel bars to control cracking may also be called into question. Notwithstanding, 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*.

Another important advantage of concrete, whether conventional concrete or RCC, is the level to which positive drainage can be maintained within the pen areas as compared to clay-lined pens. Particularly, RCC pens are generally characterized by much less ponding than for clay pens, and where water is efficiently shed off the 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. The more efficient shedding of water from the pen area also helps to mitigate the freeze/thaw effects on the soil subgrade or compacted clay liner, which is a major contributor to soft clay pen base conditions during spring months.

The readily available publication "*Design and Control of Concrete Mixtures*" by the Cement Association of Canada provides a good discourse on volume changes related to concrete. Cracking 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 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 *somewhat 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 about 5 mm per 10 m length of concrete. Assuming a similar reduction in volume during early age curing, and an additional 10 mm of further propagation of these cracks after a series of seasonal cycles, it would be reasonable to assume typical long-term potential crack propagation to 20 mm per 10 m length of RCC at the subject site. This is generally consistent with Wood's observations of older RCC mats, though it is noted that after one year no readily observable cracking was noted in the RCC mats at the subject Muilwijk operation.

Invariably, the cracks in the RCC mat become infilled with a combination of bedding material, manure, and soil. 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[2]. 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

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[2] 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.

suitability of this material relative to protection of groundwater. The results of the study indicated permeability of this interface layer ranging between about 4 x 10^{-5} cm/sec and 9 x 10^{-4} cm/sec (see Note[3]). 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.

Permeability through RCC and typical hardened concrete is widely documented, and generally below 1 x 10^{-9} cm/sec. Considering a 10 m by 10 m section of RCC mat containing one 20 mm wide crack in both directions (the cracked area having an assumed permeability of 1 x 10^{-4} cm/sec), and a conservative estimate of 1 x 10-9 cm/sec for RCC, the average calculated permeability through the 150 mm thick RCC mat would be 9.0 x 10^{-8} cm/sec. This represents the equivalent of approximately 0.8 m of compacted soil having a hydraulic conductivity of 5 x 10^{-7} cm/sec, which is more than the minimum 0.5 m of compacted soil having a hydraulic conductivity of 5 x 10^{-7} cm/sec indicated by Section 9(6)c for solid manure storage or solid manure collection. It is noted that both the hydraulic conductivity of the RCC and interface zone (cracks) indicated above would be considered conservative estimates of hydraulic conductivity.

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

Closing Comment

In general, the review of the RCC associated with the subject calf shelter and pens indicated that construction of the RCC mat was consistent with good construction practice. Further, the results of density and compressive strength testing of the finished mat indicate that the RCC is competent and suitable for its intended purpose.

Finally, as demonstrated in the discussion provided above it is Wood's opinion that the Roller Compacted Concrete (including with the consideration of potential cracking as outlined herein) 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 specifically to support the permit application by the Muilwijk's for the subject calf shelter and calf/feeder pens as described herein. Any use that a third 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

PROFESSIONAL ENGINEER ALBERTA
JOHN LOBBEZOO

29 Oct 2020.

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Permit to Practice No. P-4546

Attachment: Figure 1 – Site Plan