Technical Reference Document for Liquid Manure Storage Structures

CONCRETE MANURE STORAGE STRUCTURES

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SECTION 1 - PURPOSE AND SCOPE

1.1. Purpose of the Technical Reference Document – This Technical Reference Document for *Concrete Manure Storage Structures* defines the engineering requirements for designing concrete manure storage structures and provides additional references to assist with the structural analysis and design for the conditions of Manitoba.

1.1.1. In Manitoba, the regulatory agency is Manitoba Conservation.

1.1.2. The general information that is required by the regulatory agency for obtaining a construction permit for a concrete manure storage is specified or referenced herein.

1.2. Objective of the Design – Concrete manure storage structures are a practical alternative for long-term storage of manure in a manner that meets environmental and regulatory requirements. The primary objective of a concrete manure storage design is the construction of an economical and structurally sound manure storage structure.

SECTION 2 - RESPONSIBILITIES OF THE ENGINEER

2.1. Qualifications – The Engineer responsible for the design, inspection and certification of the concrete manure storage structure shall be licensed to practice engineering by the Association of Professional Engineers and Geoscientists of the Province of Manitoba.

2.2. Role and Responsibilities – The above Engineer shall comply with the Technical Reference Document *Role and Responsibilities of the Engineer (RRoE)*.

2.2.1. Notwithstanding the requirements outlined in this Technical Reference Document, the Engineer must ensure that the design meets any other standards or documents of the Technical Reference Manual for Liquid Manure Storage Structures that apply.

2.2.2. It is the responsibility of the client and the developer, where applicable, to ensure that the contract between the developer and the Engineer is adequately covering the design, supervision and construction requirements set out herein and any other standards or document in the Technical Reference Manual for Liquid Manure Storage Structures that apply.

2.3. Completeness of Design – The Engineer whose professional seal appears on the design drawings, is responsible for both the completeness of data acquired and the design of the concrete manure storage foundations, floors, walls, partitions and covers (if utilized). Where applicable, the Engineer is also responsible for the design of the transfer piping from the source of the liquid manure to the storage, solid/liquid separators, access ramps or pads for portable pumps and agitators, the soil drainage system, safety fencing and any system for detecting pollution or leaks.

2.4. Other Acts and Regulations – The Engineer is responsible for complying with all of the relevant Acts and regulations in force in Manitoba.

2.5. Other Standards – Provincial, national and international standards and their respective abbreviations are listed in Section 10. In all cases, the most current edition of the referenced standard is implied. Additional relevant documents are also referenced in Section 10.

SECTION 3 - INFORMATION REQUIREMENTS

3.1. Submissions – For the purpose of evaluating an application for a new, expanded or modified livestock manure storage structure, the Engineer shall submit to the regulatory agency information including, but not limited to the following details of the storage structure design and site characteristics:

3.1.1. Site plan showing the location of the manure storage and distances to:

- property lines;
- closest residence not associated with the operation;
- closest community;
- public roads;
- manure source (barn);
- known water wells, sinkholes and surface water features;
- location of abandoned wells
- bore holes for soil and site evaluation;
- proposed system for detecting pollution or leaks (if applicable);
- layout of any underground pipelines from the storage structure to remote field locations, inclusive of cleanout locations, and
- underground utilities.

3.1.2. Detailed construction drawings, drawn to scale, signed and sealed by the Engineer including, but not limited to:

- the manure storage facility;
- piping for manure transfer and handling;
- any associated structures;
- location and details of inlet, outlets and agitation facilities;
- material specifications, including backfill material;
- location and details of any underground pipelines;
- location and details of monitoring wells;
- construction notes; and
- site specific operational notes (if the design is dependent on specific operation and management factors).

Concrete storage structure with permanent plastic forms

3.1.3. A design summary including, but not limited to:

- storage wall load profile (empty);
- storage wall load profile (full);
- load combinations considered;
- storage top load profile (where applicable);
- transportation patterns, vehicular loading and any limitations to vehicular traffic;
- foundation design criteria; and
- statement of full compliance with the codes and standards and Technical Reference Document for Liquid Manure Storage Structure cited in this document.

3.1.4. Geotechnical information including, but not limited to:

- bore hole logs for proposed location of storage structure;
- depth to seasonal high ground water;
- description of soil testing and analyses;
- all applicable soil test results; and
- requirements for construction.

3.1.5. Design assumptions regarding the storage capacity estimate including, but not limited to;

- storage period;
- livestock manure production over the storage period;
- allowance for accumulation of solids;
- additional waste water;
- precipitation over the storage period (less evaporation); and
- freeboard.

3.1.6. Recommendations for regular inspection, maintenance and repair including, but not limited to:

- the frequency of inspection, critical features to inspect and method of inspection (visual, monitoring data etc.);
- procedures for regular maintenance and preventative repairs; and
- contingency plans which include procedures for the repair of damaged features.

Inspection, maintenance and preventative repair recommendations shall include but are not limited to:

3.1.6.1. Liquid manure levels – To protect against overflow, liquid manure levels should be verified on a weekly basis beginning when the stored liquid manure is estimated to reach 80 % of the design volume.

3.1.6.2. Annual inspections – Annual inspections by a qualified professional are necessary to ensure the integrity of the concrete manure storage structure is maintained. The inspections should include:

- walls and foundations for erosion, cracking or spalling;
- subsurface drains or secondary containment systems for accumulation of leachate; and
- signage for adequacy and visibility.

3.1.6.3. Repairs – The operator must contact the regulatory agency to determine if a permit is required for performing repairs on a liquid manure storage facility.

3.1.7. Frost Protection – Special precautions may be required for a concrete manure storage structure that is left empty over the winter and is susceptible to frost heaving and damage (see Section 4.6.2).

SECTION 4 - DESIGN CRITERIA

4.1. Types of Concrete Manure Storage Structures – There are various types of concrete manure storages including:

4.1.1. Circular, open-top, cast-in-place storage structures are typically 30 to 80 m in diameter and up to 6 m deep.

4.1.2. Precast storages are typically circular in design with post-tensioning steel ties and gasketed wall joints and cast-in-place floors and footings. Precast concrete structures require special attention to joint sealing and detailing between the walls and floor as well as between wall elements. The floor connection of these may demand a flexible slip joint that accommodates expansion of the walls under full load.

4.1.3. Rectangular concrete storage structures – Rectangular concrete storage structures can either be open top or covered cast-in-place. The walls may be cantilevered, one-way or two-way spanning structures depending on the location of supporting walls and floor, and buttresses if used.

Pre-cast panels for circular concrete storage structures

Rectangular concrete storage structures with solid tops are used where the application requires in-barn storage, or the storage is otherwise integrated into the livestock production facility. Rectangular storages tend to be smaller and limited to these special applications.

4.2. General Design Criteria – The two most critical aspects of concrete manure storage design are:

- provision for adequate and appropriate reinforcement to prevent cracks due to either shrinkage or load forces; and
- water-tight construction through proper sealing and design of joints between the walls and base or between wall panels or sections while accommodating any structural movement anticipated by the design.

Water-tightness of a concrete structure is reasonably assured if:

- the concrete mix is properly proportioned, placed and consolidated;
- crack width is minimized
- joints are properly placed, designed and constructed; and
- adequate reinforcing steel is provided.

4.3. Structural Design – The structural design for concrete manure storage structures shall comply with the CSA A23.3, *Design of Concrete Structures,* which requires that the specified strength of all components shall equal or exceed all factored loads.

4.3.1. For manure handling facilities, the Engineer shall follow CSA A23.3, which provides the detailed requirements for reinforcing, joints and crack control and appropriate construction standards and, where applicable, the ACI 350. Although the ACI 350 refers to two design methods, only the method described in CSA A23.3 shall be used.

4.4. Load Combinations and Modifications – Concrete manure storage structures shall be designed to withstand all loads. The CSA Standard A23.3 and the NFBC, contains provisions that are relevant to the load combinations and load modification factors for Limit States Design. Concrete manure storage structures design shall follow the Limit States Design approach.

4.4.1. The NFBC also allows for the application of the "low importance" factor, $\gamma = 0.8$, for farm structures. Due to the environmental and human health risks, the low importance factor shall not be used. A γ factor value of 1.0 shall be used for concrete liquid manure storage structures.

Earth loads and traffic must be considered for in-ground designs

4.4.2. Loads due to liquid contents shall be regarded as "Dead Loads" for purpose of applying load modification factors because these loads can be accurately calculated, whereas external forces due to earth pressure shall be regarded as "live loads".

4.5. Internal Loads

4.5.1. The weight of the manure on the footing and/or floor shall be based on a manure density of 10 kN/m^3.

4.5.2. The design outward horizontal liquid pressure from the manure shall be based on a fluid density of 10 kN/m^3 (NFBC), and shall assume that the concrete manure storage will fill to the top of the wall unless there is a positive overflow device to prevent this from occurring. Internal partitions that result in separate compartments shall be designed for full depth loading on one side with the other side empty.

4.5.3. Ice Loads – Ice loading due to freezing of the surface can exert significant pressure from a limited area of ice thickness. This layer also moves as the storage fills. The design of the concrete manure storage shall reflect the forces that result from ice formation. Appendix A of the NFBC provides some guidance for ice loads on liquid manure storage tanks. It should be noted that although hydrostatic pressure is maximum at the bottom of the storage, the ice force is acting on a ring at the surface of the liquid manure.

4.5.3.1. Ice can also adhere to the side of liquid manure storage structures, resulting in loads that could cause structural failure if the storage is completely or partially emptied in this condition. The design shall ensure sufficient storage capacity to avoid having to empty the liquid manure storage structure during the winter.

4.6. External Loads

4.6.1. Soil Pressure – Appendix A-2.2.1.13 of the NFBC provides recommended design values for earth loads on underground structures. If backfill in excess of 1.5 m is to be part of the design, investigative soil testing shall be conducted to determine the external soil pressure. To avoid uneven pressure, exterior soil

elevation shall be kept even during construction and long-term operation.

4.6.1.1. For the purpose of structural design analysis, the wall shall be designed for soil pressure on one side and an empty storage structure condition on the other side.

4.6.2. Frost Action on Footings or Floor – Adequate protection from frost action shall be provided. Under normal operation, damage to internal components such as floors and footings from frost action is not a concern because the storage normally contains unfrozen manure of sufficient depth to prevent freezing. However, if the storage is left unused over the winter, special precautions to prevent frost heaving and damage (such as covering the floor with straw) may be required.

4.6.3. Temperature Induced Stress – The concrete manure storage structure design shall account for temperature induced stress. Values for temperature induced stress are provided by the MWPS and in the ACI 350.

4.6.3.1. Extreme variations in temperature cause differential movement and regions of high stress in concrete walls. The above-ground portion of a tank may expand or contract more than that below the ground, which can result in horizontal cracks if counteracting reinforcing is not provided. Temperature induced stress is most serious for concrete storage structures which are partially below ground.

4.6.3.2. High thermal stress occurs in above-ground concrete manure storage structures which are fully exposed to severe cold. To minimize temperature effects, backfilling concrete storage tanks to near the top is recommended. Without backfilling, extra vertical reinforcing is required. Soil pressure may preclude backfilling for large concrete storage tanks for which the diameter of the tank does not have sufficient circular arch resistance.

4.6.4. Vehicle Traffic at Walls and on Covers– Exterior walls shall be designed for surcharge loading from anticipated wheel traffic such as manure tankers and tractors. Manure storage tops that will be exposed to vehicular traffic or used as livestock floors, shall be designed to withstand these loads.

4.6.4.1. Design values for vehicle traffic are provided in the NFBC and the ASAE Standard EP393.2.

4.6.5. Climate Loads

4.6.5.1. Wind Load – The specified external pressure or suction due to wind on part or all of a surface of a concrete manure storage wall shall be calculated according to the NFBC. ASCE7 is a complimentary reference with information pertaining to wind loads on open top circular structures.

4.6.5.2. Snow and Rain Loads on Covers – If the concrete manure storage is covered, it shall be designed for uniform snow and rain loads. Snow and rain loads will depend on geographical location (Appendix C of NBC). The cover design shall consider the dead load (plus snow loads) or dead load plus 2.0 kPa, whichever is greater (NFBC).

4.6.6. Load Combinations – When designing a concrete manure storage wall, the following live load combinations shall be considered:

4.6.6.1. Ice pressure shall be added to the outward pressure of the manure on the wall.

4.6.6.2. When applicable, other loads such as dead loads, live load reactions on the wall from a possible storage cover, temperature variations in the structure and structural components, creep and shrinkage of the concrete or steel shall be considered.

4.7. Serviceability of Concrete Storage Structures – The cracking of concrete structures shall be controlled through the use of the "z" factor, as detailed in CSA A23.3. The choice and spacing of reinforcing shall be such as to have a "z" factor less than 20 kN/mm. Where the storage structure is constructed in environmentally sensitive areas, the "z" factor shall not exceed 17 kN/mm.

4.8. Volumes and Freeboard – Concrete manure storage structures shall be designed to contain the total amount of

The design of the storage must account for pump equipment

manure estimated to be produced over the required storage period plus precipitation over the storage period (less evaporation), accumulation of solids, any additional liquids to be stored (such as milkhouse wash water) and an allowance for freeboard. Estimated manure production and the required storage period shall be based on published provincial data or statistics from operations using similar livestock production systems. It is the responsibility of the Engineer to ensure that the concrete manure storage structure is designed for adequate capacity.

4.8.1. Guidance on calculating manure storage volumes is available from Manitoba Agriculture, Food and Rural Initiatives – Regional Offices and Livestock Industry Branch.

4.8.2. Freeboard – The storage shall have a reserve capacity to contain a major rainstorm without overflowing. The freeboard is the unfilled capacity below the top of the manure storage structure and the maximum operating level. The level of liquid in the storage should not rise above the maximum operating level except in the event of a major storm.

4.8.2.1. The minimum acceptable vertical distance between the maximum operating level and the top of the storage shall be no less than 30 cm.

4.8.2.2. The maximum operating level shall be clearly marked to assist the operator in maintaining the freeboard.

4.9. Loading, Agitation and Unloading – The concrete manure storage design shall contain appropriate provision for loading, agitation and unloading of manure. Liquid manure can be loaded into the storage from either floor level or from the top. The manure storage designs shall include the following with respect to loading and agitation:

- water stops where pipes penetrate the floor or walls;
- secondary safety shut-off valves for bottom loading inlet pipes; and
- an adequate agitation system to facilitate suspension of settled solids and emptying.

4.10. Valves and Connections – All pipes, valves and connections shall be resistant to corrosion.

4.10.1. Unless otherwise approved by the regulatory authority, PVC pipe and compatible fittings shall be used.

4.10.2. All valve outlets or outflow pipes connected or mounted on a liquid manure storage structure shall provide for means of locking them in closed position. Valves outlets or outflow pipes shall be locked at all times when not in use for emptying the storage structure.

4.11. Secondary Containment – A secondary containment system may be required when concrete liquid manure storage structures are located above very permeable soils such as coarse sands or gravel, or close to sensitive groundwater areas.

4.11.1. The secondary containment system can consist of a polyethylene membrane or other suitable impermeable material of a minimum thickness of 250 μm (10 mil). This membrane shall be installed as a seamed sheet between the sub grade and compacted granular base. The membrane shall be protected from punctures, rips, or tears during construction by placing a layer of fine sand above and below it.

4.11.2. Membranes shall be continuous under the liquid manure storage floor and footings and shall extend up around the outside of the storage structure beyond the foundation and be brought up to a level equal with the top of the storage floor.

4.12. Leakage Detection – The regulatory authority may require a leakage detection system for sensitive sites.

4.13. Quality of Concrete – Quality of concrete is critical to water-tight construction, durability, corrosion resistance and protection for reinforcement.

4.13.1. All concrete shall be delivered from a plant certified by the Manitoba Ready Mix Concrete Association.

4.13.2. Except where concrete is to be placed in contact with soils having a known sulphate content (common in southern Manitoba), Normal Portland cement (Type GU) shall be used. Such concrete shall be classed as an A2 exposure, air entrained with a maximum water/cementitous ratio of 0.45 and a minimum compressive strength at 28 days of 32 MPa. This is essential for corrosive manure environments exposed to freeze-thaw action.

4.13.3. Where concrete in service will be exposed to sulphate in soils or ground water, an S1 exposure class shall be assumed. This requires the use of Type HS cement, a maximum water/cementitous ratio of 0.40 and a minimum compressive strength at 56 days of 35 MPa.

4.13.4. In all mixes, especially those in S1 exposure, other products for concrete enhancement, such as flyash, slag and/or special admixtures such as high-range plasticizers may be used to improve mix performance or concrete placement.

4.13.5. Slump for all placements shall, in accordance with CSA A23.1, be selected appropriate to the placement procedure.

SECTION 5 - FOUNDATIONS AND FLOORS

5.1. Soil Bearing Capacity and Uniformity of Base – The Engineer shall ensure that the soil bearing strength and uniformity of base materials is appropriate for the anticipated loads and construction method.

5.1.1. Maximum Load – The maximum estimated load shall not exceed the allowable bearing capacity of the soil.

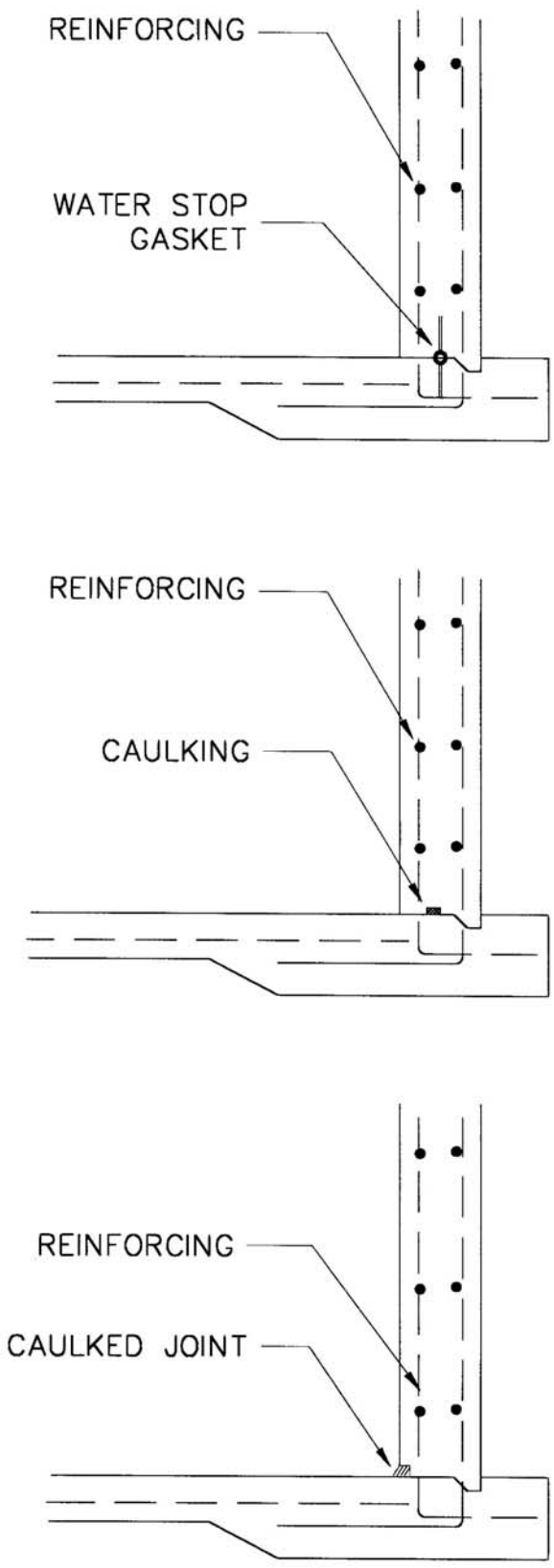
5.1.2. Sub Grade Preparation – The existing sub grade shall be cleared of all stones, topsoil, wood, mud and other debris, and compacted to 95% standard Proctor density. Soft areas shall be overexcavated and replaced with granular fill placed in 150 mm lifts and compacted to 95% standard Proctor density. The sub grade shall be free of frost before concrete placement begins.

5.2. Concrete Floors and Slabs – When designing concrete floors for liquid manure storages, high water table conditions shall be avoided or prevented and the design of the floor system shall handle all of the design loads without leakage. Particular attention is required to ensure that construction joints, shrinkage leak-seal gaskets, caulking and reinforcing do not permit any leakage.

5.2.1. Subsurface drains shall be installed under the foundation and the floor of concrete manure storage structures. The subsurface drain shall be surrounded by a filter cloth and be installed in 20-mm aggregates with a maximum of 5% of finer aggregates. The subsurface drains must all be routed to one or more collection sump pit(s).

5.2.1.1. Where a secondary containment membrane is installed under the floor of a concrete storage structure, the subsurface drain shall be installed in accordance with section 5.2.1, but on top of the secondary containment membrane.

5.2.2. Structural Design and Detail – The floor of the liquid manure storage shall be designed either as a steel reinforced structural slab or as a floor slab on grade in accordance with ACI 360 of a minimum depth of 125 mm over a uniformly compacted, coarse aggregate base that has a minimum depth of 150 mm. The base is required for uniform support and distribution of loads. It also acts as a positive drainage system to relieve ground water pressure and to detect leaks.



Typical water proof joints: mechanical waterstop (top), caulked cold joint (middle) and caulked formed joint (bottom)

5.2.2.1. The design of concrete floors and slabs on grade shall conform to the engineering methods contained in CSA A23.3, when applicable, and ACI 350 and ACI 360. The design method shall provide for adequate structural strength as well as prevent excessive cracking due to shrinkage and tensile loading. Publications CSA A23.3, the PCA bulletins, ACI 350 and the ACI 360 suggest alternate design procedures based on limiting cracking in concrete.

5.2.2.2. Where utilized, construction joints in liquid manure storage floors shall be capable of resisting differential movement between floor sections, shall be water-tight and shall protect reinforcing steel from corrosion. Tongue and groove joints with epoxy coated smooth bars across the joints are required. The joints should also have mechanical water-stops or be appropriately caulked.

5.2.2.3. Alternative acceptable construction is an appropriately designed, joint-free floor slab with enough reinforcing to prevent shrinkage or stress cracks. Such a design, however, may be limited by the floor area and loading criteria.

5.2.2.4. Effective vibratory equipment during concrete placement in footings shall be used to achieve the concrete density and uniformity necessary for impermeability.

5.2.3. Corrosion Protection – Reinforcing steel shall be protected by providing a 50 mm concrete cover.

SECTION 6 - WALLS

6.1. Placement of Concrete – Placement of concrete shall follow accepted engineering practice in accordance with the CSA A23.1 and including the following:

- concrete shall be placed sequentially in floor slabs and walls in order to avoid segregation and maintain uniform construction lines;
- a vibrator shall be used for consolidating concrete around reinforcing steel and to create dense, water-tight concrete that is free from blemishes or a honey-combed surface;
- appropriate curing shall be used; and
- defective areas shall be patched and sealed.

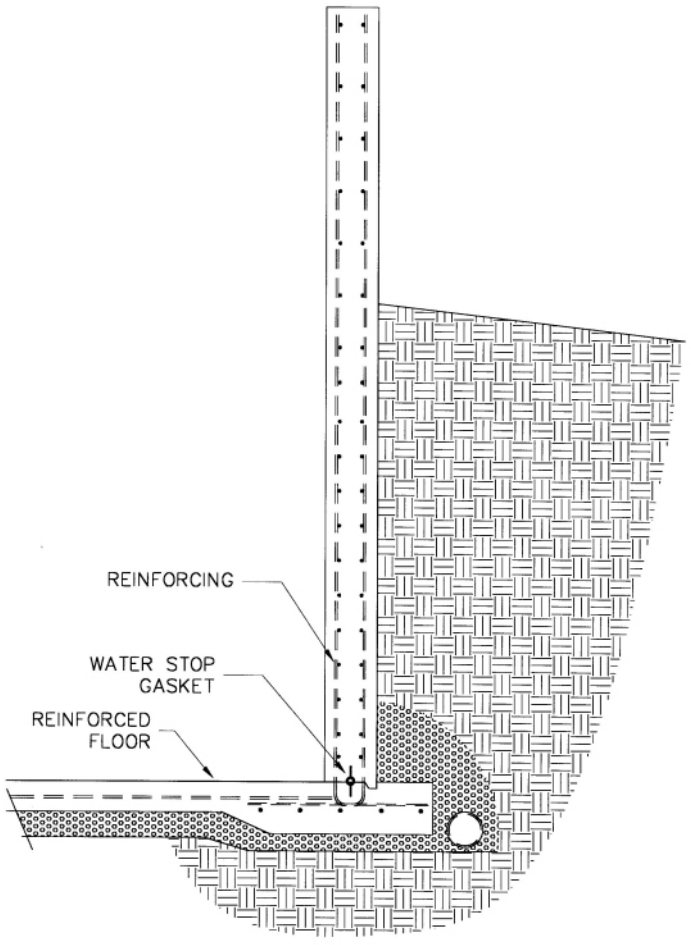
6.2. Form Ties and Construction – Form ties and construction shall follow accepted engineering practices in accordance with ACI 350 and include the following:

- the design shall allow a cone-shaped depression that is appropriate for follow-up grouting;
- form tie holes shall be sealed to prevent corrosion; and
- effective form coating or release agents shall be used to assure a smooth finish.

6.3. Water Tight Joints – The joints between wall panels as well as the joints between the bottom panels and the floor shall be made water tight. Water-tight construction joints are specified in the ACI 350 and shall be suitable non-metallic material or appropriately caulked joints.

6.4. Minimum Wall Specifications – Notwithstanding the other design requirements addressed previously, the wall design must be in accordance with the following specifications.

6.4.1. The minimum wall thickness shall be 250 mm or the wall thickness required, as per the structural design procedure and loads described in section 4, whichever is greater.



TYPICAL CONCRETE TANK DETAIL

Typical features of concrete liquid manure storage structures

6.4.2. A minimum clear cover of 50 mm of concrete shall be maintained.

6.4.3. A minimum horizontal spacing of 100 mm between rows of reinforcing steel shall be maintained.

6.4.4. Reinforcement shall be laid out in 2 rows horizontally and vertically. The maximum spacing of horizontal reinforcing steel shall be 300 mm.

6.5. Wall-Foundation Anchoring – Epoxy coated steel reinforcing bars shall be used to anchor the walls to the foundation.

SECTION 7 - SAFETY

7.1. Worker Safety – Whenever work involves repairs to an existing manure storage structure or its expansion or modification, regardless whether or not manure gases are expected, the provisions of The Workplace Safety and Health Act W210 shall be met.

7.2. Manure Gases – The gases generated by the storage of liquid manure can be fatal and explosive in confined areas. Inhalation of these gases can be a serious health risk. The concentration of manure gases is higher and more dangerous in confined areas where the liquid manure is stored. Liquid manure storages with covered tops are particularly dangerous. NEVER ENTER A LIQUID MANURE STORAGE without the proper breathing apparatus.

7.3. Safety Responsibilities - The Engineer shall provide recommendations regarding:

7.3.1. Signage - signs that clearly describe the risk of manure gas and any other potential hazard, and which prohibit entry into the manure storage, shall be posted around the liquid manure storage and any appurtenance listed under 7.4.3. These signs shall be posted in accordance with ASAE S441 and include the phone numbers of people to contact in case of an emergency.

7.3.2. Breathing Apparatus: availability of a breathing apparatus to workers in areas with concentrated manure gases. Manure gases are released in higher concentrations during agitation.

7.4. Access – Access limiting devices shall be included in the design of all manure storage structures and all appurtenances associated with the design.

7.4.1. If the concrete manure storage includes a permanently installed ladder to access the top of the storage, access to the ladder shall be restricted. This can be achieved by removing the bottom 2.4 metres (8 feet) or by installing a fence and lockable gate around the bottom of the ladder. This will prevent access by both children and vandals.

7.4.2. Where uncovered concrete storage structures presents less than 1.2 m of elevation difference between the top of the wall and the uppermost surface of the backfill material, a suitable fence 1.2 m high shall be installed on top of the storage structure wall.

7.4.3. Lift stations, valve access holes, pump out access ports and other similar appurtenances large enough to allow for workers, operators or by-stander's access must be securely capped with a locked or sealed cover, grate or latch door fabricated from weather and manure resistant material.

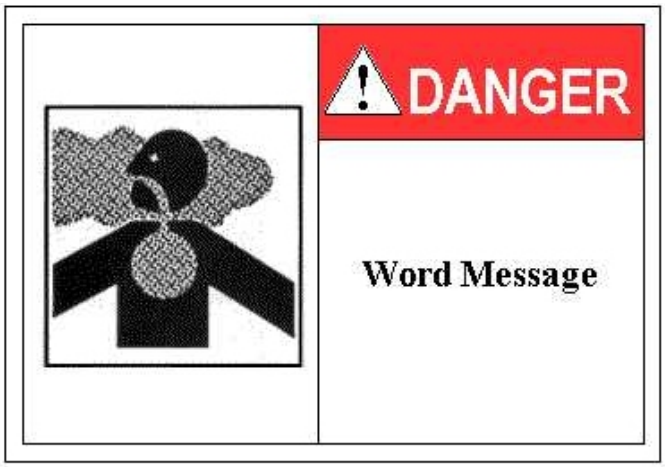
SECTION 8 - QUALITY ASSURANCE

8.1. Inspection – During construction, the concrete manure storage structure shall be inspected by the Engineer to ensure that it was built as designed and is in compliance with all applicable technical reference document, standards, codes and regulations.

8.2. Cold Weather Concrete Practices - CSA23.1 specifies temperatures requirements for proper curing of concrete. Cold weather concrete pour will require additional precautions and steps to ensure that curing carries out as required to ensure proper concrete strength.

8.2.1. Concrete shall not be placed against any surface that will lower its temperature below the lower limit of CSA A23.1, Table 14. This requires that a minimum temperature of 10°C be maintained in all concrete sections thinner than 1 m. For thicker elements, a minimum temperature of 5°C is permitted.

8.2.2. Curing conditions for all concrete shall be maintained for a minimum of three (3) days in accordance with the above criteria. A record of temperatures under cold weather protection shall be maintained and submitted with engineering inspection reports.



The Engineer is responsible for ensuring that proper signage will be installed.

8.3. Quality Control – In order for the Engineer to certify that a manure storage structure will meet the calculated design specification, the concrete quality and placement procedures must be documented. The Engineer shall record, during construction, and retain any required document on the following quality control check points:

- Copies of the concrete suppliers "mix/delivery ticket", which states all the pertinent properties of the concrete mix;
- Sampling and collection of test cylinders for strength determination;
- Random slump measurements;
- Photographs of formwork, reinforcement, joint sealant, waterstops, or any other critical components; and,
- Record notes of curing and protection applied by the contractor.

8.4. Permanent Forms – Where permanent forms are used, the quality of the finished concrete surface, the presence of voids or improper placement of concrete cannot be visualized. It is the responsibility of the Engineer to devise and carry out a sound and rigorous post-construction quality assurance protocol to verify that proper construction techniques were followed during concrete placement.

8.5. Final Inspection – The Engineer shall make arrangements with the regulatory agency for a joint final inspection after completion of the construction and before commissioning of the manure storage structure.

SECTION 9 - ISSUANCE OF CERTIFICATES

9.1. Certificate – The Engineer shall provide the appropriate regulatory agency with a final letter of certification indicating that the manure storage structure has been completed in conformance with submitted **engineering plans** and **meets required codes, regulations and Technical Reference Document mentioned herein.**

9.1.1. The letter of certification shall be affixed with the Engineer's seal in a manner acceptable to the guidelines of the Association of Professional Engineers and Geoscientists of the Province of Manitoba.

9.1.2. Pre-Engineered Structures – Pre-cast concrete storage structures most commonly consist of pre-engineered, pre-stressed wall sections that are post tensioned with cables. Only those pre-engineered tanks that are specifically designed for liquid manure storage, and certified by a registered professional Engineer are acceptable.

9.1.3. Independent Engineering Design – Where concrete manure storage structures are not pre-engineered and certified, independent engineering design and approval from the appropriate regulatory agency may be required.

9.2. Construction Report - The letter of certification must be accompanied with a prepared construction report.

9.2.1. In the case of concrete liquid manure storage structures, the construction report must provide accurate information on the following aspects of the construction work:

- Inspection dates with corresponding construction progress summary;
- Construction details that are not consistent with submitted plans;
- "As Built" drawings;
- Concrete cylinder 28-day test results;
- Type of concrete vibrating equipment and where used during pour;
- Voids and honeycomb areas patched;
- Record notes of curing methods and protection applied by the contractor; and,
- Subsurface drain installed and details about the material used to cover the drains.

9.2.2. Certification can be provided if construction details do not conform to engineering plans submitted provided these details were approved by the regulatory agency and referenced in a construction report.

SECTION 10 - RESOURCE INFORMATION

Resource Information	Abbreviation used
Standards	
Technical Reference Document *Role and Responsibilities of the Engineer*	RRoE
CSA A23.3 *Design of Concrete Structures*	CSA A23.3
CSA A23.1 *Concrete Materials and Methods of Concrete Construction*	CSA A23.1
National Building Code of Canada (Parts 3 & 4)	NBC
National Farm Building Code of Canada	NFBC
ACI 350R *Environmental Engineering Concrete Structures*	ACI 350
ACI 360R *Design of Slabs on Ground*	ACI 360
ASAE EP470 *Manure Storage Safety*	
ASAE S441 *Safety Signs*	ASAE S441
ASCE 7 *Minimum Design Loads for Buildings and Other Structures*	ASCE 7
ASAE EP393.2 *Manure Storages*	ASAE 393.2
Additional Sources of Information	
Midwest Plan Service *TR-9: Circular Concrete Manure Tanks*	MWPS
Portland Cement Association Bulletin – *Design and Control of Concrete Mixtures – Canadian edition*	PCA-CA
Portland Cement Association Bulletin – *Circular Concrete Tanks without Prestressing*	PCA
Portland Cement Association Bulletin – *Rectangular Concrete Tanks*	PCA
Jofriet, J.C., Y.H. Zhang, J.W. Johnson and N. Bird. 1996. Structural design of liquid manure tanks. Can. Agric. Eng., Vol. 38 (1):45-52.	
Jofriet, J.C., R. Green and T.I. Campbell. 1987. Design recommendations for reinforced concrete cylindrical storage structures for aqueous materials. Can. Civil Eng., 14(4):542-549	
Organizations/Associations/Societies	
Canadian Standards Association	CSA
American Society of Civil Engineers	ASCE
American Concrete Institute	ACI
American Society of Agricultural Engineering	ASAE
Portland Cement Association	PCA
National Association of Corrosion Engineers	NACE