Wisconsin Minimum Design and Construction Standards for Concrete Mixing and Loading Pads and Secondary Containment Structures

David W. Kammel
Professor, Biological Systems Engineering Department
University of Wisconsin Cooperative Extension

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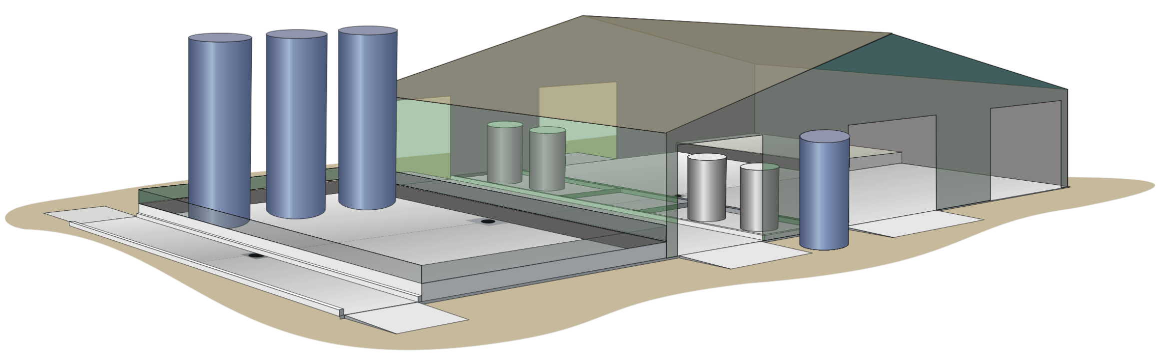


Chapter 1. Functional System Design

David W. Kammel, Professor, Biological Systems Engineering Department,
University of Wisconsin Cooperative Extension

Functional system design of pesticide and fertilizer facilities is best addressed as part of the site plan when developing new facilities or remodeling existing ones. A well-planned and designed facility is necessary for human safety and environmental protection. The facility design provides for several distinct and separate functions:

- Worker safety
- Storage of:
  - Packaged pesticides
  - Solid wastes
- Secondary Containment for:
  - Bulk pesticides
  - Bulk fertilizers
  - Rinsates
  - Sludge
- Operational Area for:
  - Transferring and handling pesticides and fertilizers
  - Mixing batches of pesticide and fertilizer solutions
  - Loading application equipment
  - Unloading transport vehicles
  - Unloading and cleaning out application equipment
  - External washing of application equipment (Not recommended)

Facility Planning

When designing the facility, consider current and planned production levels that can affect the size and scale of the facility. Trends within the agricultural industry continue to see consolidation and centralization to fewer and larger-scale facilities.

Plan a storage facility as an isolated, secured area with a single use, separate from other activities and storage areas (such as feed, seed, and fuel). Design the facility to protect pesticides and fertilizers from possible theft, unauthorized use by untrained personnel, and temperature extremes. Provide security with a properly designed chain link fence or a building with lockable doors. Proper storage protects workers, visitors, children, and animals from unknown or accidental exposure to pesticides and fertilizers. In a properly designed storage facility, the environment, including soil, surface water, and groundwater, is also protected from accidental release by containing a spill within the secondary containment designed integrally into the building until the spill can be properly recovered.

The most critical tools in the long-term effectiveness of a facility are the workers that manage the site. The facility design should accommodate efficient workflow and easy and safe operator movement between functional areas. Workers must have convenient and safe access to bulk tank valves and controls, package product storage, and the related emptying, cleaning, and waste management areas. The facility design should also accommodate regular, safe, and convenient cleaning of the equipment, mixing and loading pad, and related work areas where spills may occur.

Vehicle traffic flow must be planned to accommodate the increased sizes and turning radiuses of the larger tanker trucks bringing products in and the large-scale application equipment and tender vehicles taking product out. When possible, consider a drive-through facility design with one-way traffic to increase traffic flow and safety.

Plumbing and tanks

The design of the plumbing system from the pesticide and fertilizer storage tanks to the mixing and loading pad should also be considered in the overall facility design. Pumps, valves, and quick couplings need to be located within secondary containment to accommodate recovery of small leaks. Loads from the weight and vibration of overhead plumbing lines must be considered in the building design. Tanks that are under-roof and protected from direct sunlight and weather usually have a longer service life than those stored in the open.

When selecting storage tanks, check with both the pesticide manufacturer and tank manufacturer to be sure the tank is resistant to corrosion from the pesticide being stored. Cross-linked, high-density polyethylene or fiberglass tanks of 200 to 600 gallon volumes are usually a good economical selection for rinsate storage. The ability to view liquid levels through plastic or fiberglass tank walls improves management. Polyethylene tanks need to be inspected annually for signs of aging, cracking, or deterioration.

Galvanized or standard, mild steel tanks are not recommended because they corrode quickly causing rust and metal scaling which can plug strainers and plumbing. Type 304 or 306 stainless steel tanks are suitable but are expensive. Rinsate storage tanks should be supported 3 to 6 inches above the concrete floor for easy observation of leaks. Mount the tanks high enough to allow full operation of valves and other equipment. Some operators elevate rinsate holding tanks so they can gravity flow into mix tanks or sprayer tanks.

Use adhesive tank labels to identify pesticide, fertilizer, and rinsate storage tanks, and supplement these with placards or signs at valves and connections.

Mechanical systems

Ventilate storage buildings to prevent fumes from concentrating in the building. Connect smoke or fire detectors to an external site away from the storage building or to the local fire department. For some pesticides, a heating system may be required to maintain safe storage temperatures to prevent product degradation. All wiring and electrical equipment (lights, heating, ventilation) must meet local and national electrical codes.

Worker Safety

The worker safety area should be designed to have all the emergency equipment necessary to prevent harm or provide emergency aid to the workers. Provide an eyewash and/or deluge shower to rinse spilled pesticide and fertilizer from the eyes, face, and body. Also, provide a first aid kit and spill response kit to deal with accidents in a timely manner. Install fire extinguishers and telephones or another two-way communications system. Locate a telephone or other two-way communication system in or near the pesticide storage area for communication with fire, police, and health authorities.

Emergency response plan

Have an Emergency Response Plan (ERP) easily accessible to all employees. The Emergency Response Plan contains valuable emergency information for responding immediately to any emergency including a poisoning, spill, or fire. A pesticide label for each pesticide and a Material Safety Data Sheet (MSDS) for each fertilizer must be included in the plan. Inform all employees where the ERP is filed, and train them to be familiar with these documents at the beginning of employment as well as during annual training reviews and when a new pesticide or fertilizer is added.

Protection standards for agricultural worker

Federal law requires protection of persons that handle and/or apply pesticides used in agricultural production. These rules are primarily implemented through label-specific safety equipment requirements for pesticide handlers. Posting and information requirements along with worker training are implemented to protect agricultural workers and the public who may come into contact with a sprayed crop. Equip the worker safety area in a manner that is consistent with protecting the workers. This includes providing required safety and personal hygiene equipment and having information areas describing pesticides stored and handled at the facility.

Storage for Packaged Pesticides and Solid Wastes

Packaged pesticide (nonbulk container) storage should be considered as it affects the mixing and loading activity and/or the transport of packages to field locations or satellite sales points. Several separate access points to this storage area may be required to allow efficient movement of containers from storage to the mixing and loading pad or from storage to and from delivery vehicles at a different point.

Solid wastes and sometimes hazardous wastes are unavoidable byproducts of fertilizer and pesticide storage and handling practices. At its best, the only solid waste products will be empty triple or pressure rinsed plastic containers, corrugated boxes, paper bags, label booklets, and other packaging materials. The solid waste storage area holds empty containers until they can be disposed of properly.

Poor management of wastes, such as burn piles and outside unroofed areas used to store empty containers, has caused areas to become contaminated over years of use. These areas have been identified as major contamination sources requiring cleanups.

Store empty, triple or pressure rinsed containers, minibulks, metal drums, cardboard cartons, and paper packaging materials in a roofed, curbed, and secured area. Since pesticide residues may occur in any of these materials (especially empty containers), they should be stored under cover and over a secondary containment surface. Security of this area is required to prevent unlawful and unsafe reuse of empty pesticide containers by unauthorized personnel.

Segregate packaging wastes according to their ultimate recycling or disposal method. The facility design should accommodate this in a manner that assures this happens as part of the normal mixing and loading operations. The accumulation of unrinsed containers exacerbates rinsate management problems.

Secondary Containment Structures

Secondary containment structures protect the environment from accidental leaks and spills of the primary liquid storage by preventing the spills from entering the soil and possibly surface water or groundwater. Secondary containment is designed to temporarily hold a release of the fertilizer, pesticide, or rinsate. The spilled product (rinsate) can then be more easily recovered and used in a spray solution instead of being disposed of or leaching into the soil or draining into surface and groundwater. Secondary containment is designed to hold liquid for a short time period, long enough for the owner to manage the release in an appropriate manner. Secondary containment is not designed to hold liquid for an extended time; that is the job for the primary tank. Designing a secondary containment to be totally liquid tight under a long period of hydrostatic pressure would be very expensive and impractical.

Secondary containment is usually designed as an integral part of the storage facility. It should accommodate the storage of bulk liquid fertilizer, bulk liquid pesticides, rinsate, and sludge in separate and segregated areas. Storage of bulk pesticides and bulk fertilizer in a common secondary containment is not recommended but is allowed if the secondary containment is in a fully enclosed building. In the overall facility design, the storage areas for these products are usually placed adjacent to each other to minimize transfer distances and improve operational efficiency.

Fertilizer secondary containment
Large fertilizer tanks are usually stored in a secondary containment structure constructed from concrete, a synthetic liner system, or a relatively impervious soil (bentonite, attapulgite, and natural clay). Fertilizer secondary containment usually covers the largest area because of the size of the tanks used to store fertilizer solutions.

Pesticide secondary containment
Pesticide storage tanks are usually stored in a secondary containment structure constructed from concrete or a synthetic liner system (such as a plastic or fiberglass tub). Secondary containment for storage of bulk pesticides must be separate from fertilizer storage secondary containment. Cross contamination of fertilizer by pesticides results in a rinsate that would be considered a pesticide (which may be more difficult to handle) compared to a rinsate containing only fertilizer (which may be easier to handle).

Rinsate secondary containment
Rinsate storage tanks containing a pesticide rinsate are treated the same as pesticide storage tanks. They must be placed within a secondary containment structure similar to a pesticide secondary containment. If the facility design is such that rinsate containing only fertilizer is generated, that rinsate may be stored and managed as a fertilizer, allowing greater flexibility in its use.

Rinsate tanks should be located close to and adjacent to the mixing and loading pad to allow the operator to conveniently monitor and manage the rinsate accumulation and reuse on a daily basis. If not carefully managed, the rinsates that contain combinations and/or concentrations of pesticides that cannot be safely applied to a target site may be classified as hazardous waste. Segregation and prompt reuse of rinsate according to label directions to the intended target crop is the best method of managing rinsates. Preventing any waste from becoming a hazardous waste because of cross contamination with other products is the best management strategy to allow legal use versus disposal as a waste.

Sludge secondary containment
Sludge is created when application equipment tracks dirt and mud onto the mixing and loading pad. This mud and dirt is then washed into the sump with other pesticide and fertilizer liquids. The mud and dirt become contaminated with these products and must be containerized when removed from the sump. Sludge that is generated from mixing and handling bulk pesticides and fertilizers should also be stored in secondary containment. This sludge must be handled and disposed of based upon the products that are in the sludge. The sludge should be placed in a container made of polyethylene or other suitable material and stored within a secondary containment structure (minibulk storage area, mixing and loading pad, etc.) until properly disposed of.

Operational Area
Secondary containment is sometimes thought of only in the context of the storage of the pesticide, fertilizer, or rinsate; however, the primary component of a facility is the mixing and loading pad, which provides secondary containment for the normal operations performed at a pesticide and fertilizer facility. The mixing and loading pad is within the operational area and provides containment while pesticides and fertilizers are being transferred from storage tanks to

application equipment and tender vehicles. The mixing and loading pad is exposed to wash water and to the small spills and drips occurring during the normal daily routine of transferring pesticides and fertilizers from storage containers into application equipment. The daily leaks from hose connections, spills, or leaking nozzles are contained on the mixing and loading pad.

The mixing and loading pad is a curbed and ramped sloped concrete slab (or other impermeable material). The mixing and loading pad typically houses pumps, valves, hoses, and batch mixing equipment and is central to all the other operations of a fertilizer and pesticide handling facility. Because the pad is where most solid wastes and rinsates will be generated, the design of the pad will determine the productivity of the facility and the amounts of rinsates or wastes generated. Operations in this area present the greatest day-to-day environmental risk of the operation.

Fertilizers and pesticides are mixed and loaded into the application equipment parked on the mixing and loading pad. Operations are typically managed from plumbing controls and associated mixing equipment adjacent to the pad. Batch mixing tanks, temporary storage of pesticide containers, minibulk storage tanks, and the pumps, valves, hoses, and meters used to transfer pesticides and fertilizers from bulk storage are located on the mixing and loading pad. Elevate valves, pump motors, and other electrical equipment on platforms above secondary containment liquid levels.

The mixing and loading pad is sloped to a collection point called a sump. The rinsate can then be transferred from the sump to rinsate storage tanks and used as makeup water for subsequent sprayer loads. Rinsate storage tanks might include several separate storage tanks for pesticide rinsate or fertilizer-only rinsate tanks.

If unroofed, the mixing and loading pad also collects precipitation. To minimize the volume of contaminated precipitation that would have to be handled as a rinsate, the mixing and loading pad should be roofed. Roofing the mixing and loading pads may be an economically viable alternative compared to the cost of storing and using the large volumes of rinsate collected on an unroofed area.

When mixing and loading pads were first designed, many designers thought that they would be a convenient place to wash the exterior contamination of application equipment. Many in the industry may still call the mixing and loading pad a “wash pad.” Mixing and loading pads were originally developed because mixing and loading sites were becoming contaminated from the practice of routinely mixing, loading, and washing application equipment on the soil or gravel drive areas adjacent to a pesticide or fertilizer secondary containment. In addition, application equipment was commonly parked on unroofed areas. Rain washed the contaminated exterior of equipment and caused pesticide and fertilizer residues to build up in the soil over time.

Discharge of rinsate from the mixing and loading pad onto an adjacent area is not allowed. The only option is to collect, store, and use the rinsate in the approved manner, or dispose of it in an approved manner. Discharge of rinsate containing pesticide residues (including precipitation from an area that has not been properly cleaned) can lead to fines and expensive site cleanup liability. Repairing application equipment on the pad allows the collection of any liquid that leaks or is drained from the tanks or booms of the application equipment. When cleaning or repairing equipment on a mixing and loading pad, do not use solvents or degreasers or allow lubricants to drain onto the pad. Mixing these materials with pesticides may result in a rinsate that cannot be used in an appropriate application and can lead to costly waste disposal problems. The mixing and loading pad must be segregated and separate from the pesticide or fertilizer storage areas.

Decide early in the planning process if some of the functions performed in the operational area should be separated into more than one separate and segregated operational areas (mixing and loading pads). For example, to accommodate semi and tanker traffic needs bulk fertilizer loading and unloading might be separated and located away from the mixing and loading of application equipment. Facilities that manage minibulks or other refillable containers may want a separate pad in the facility design to conduct that activity without affecting the daily routine of loading application equipment. Triple- or pressure-rinsing of plastic containers may also be done on a separate pad to allow routine daily cleaning of containers and reduce problems of cleaning dried residue from containers.

Example Facilities

To demonstrate planning and design of facilities, the following sections describe several example facilities. Regardless of the size of the operation, incorporate each of the functional areas into the total system facility plan for all operations. The size or scale of the functional areas of any facility design depends on the type of operation, amount of product stored and handled at the facility, and the number of employees.

As the size of the facility increases, the space needed for each functional area becomes larger and better defined, and it is better to keep the areas separated and segregated. Locate functional areas adjacent to but separate from each other to provide for ease of material handling, efficient traffic flow, easy access from one area to another, and worker safety.

Small-scale facility

Figures 1.1 and 1.2 show a small-scale facility. The mixing and loading pad is designed as a sloped concrete floating slab and combines several functional areas to minimize and optimize the use of the space. Application equipment drives onto the pad from the service road. This design allows driving across the pad from three directions. Worker safety equipment is near the mixing and loading pad. The curbed and sloped mixing and loading pad provides secondary containment for the loading of application equipment. A separate curbed area provides secondary containment for pesticide and rinsate storage tanks and mixing equipment. Secondary containment of minibulks could be on the mixing and loading pad or in a separate secondary containment area. Precipitation that falls onto the pad and becomes contaminated with pesticides or fertilizers is collected and stored as rinsate until it can be used as makeup water for subsequent loads and applied to the appropriate target crop (at, or below, label rates).

A small building located on a raised curb provides security and secondary containment of stored small containers of pesticides. A fence should be used to provide security around the minibulk storage area. Another option would be to build a roof over the entire area including the mixing and loading pad, pesticide storage, and mixing equipment and minibulk storage areas. The size of the mixing and loading pad depends on the size of the application equipment and storage space needed.

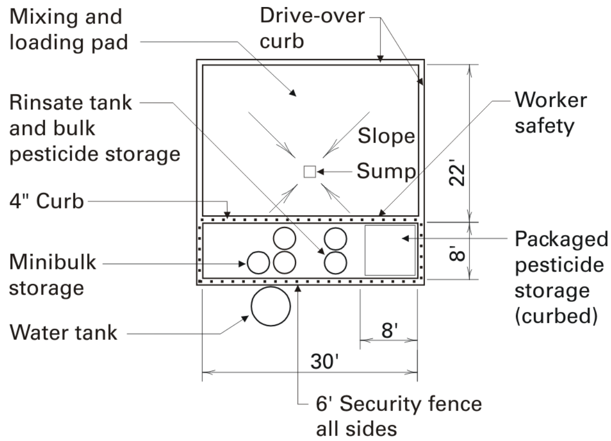


Figure 1.1. Small-scale facility, plan view. Optional roof over entire facility.

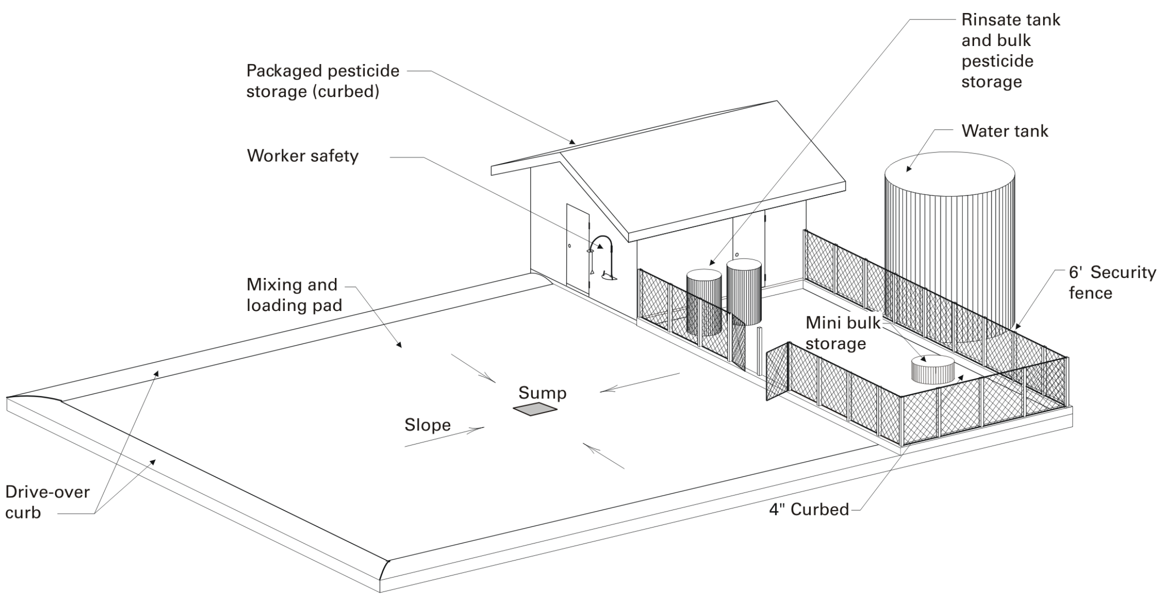


Figure 1.2. Small-scale facility, perspective view. Optional roof over entire facility.

Medium-scale facility

In the medium-scale facility shown in Figures 1.3 and 1.4, a mixing and loading pad is separate from the pesticide secondary containment and packaged pesticide storage. The fertilizer secondary containment is near the mixing and loading pad to reduce plumbing transfer distances. The fertilizer secondary containment can be expanded in the future and is commonly fenced off for security if the tanks are too tall to fit under a roof. Precipitation collected in an open (unroofed) fertilizer secondary containment is collected and stored in a tank within containment. Packaged pesticides are stored in a small room with a curbed secondary containment area adjacent to the mixing and loading pad. A worker safety area would be included in the mixing and loading pad.

An optional building covering the mixing and loading pad and packaged pesticide storage area eliminates precipitation from entering these areas and provides security. In some cases, the fertilizer secondary containment is placed under a roof as well.

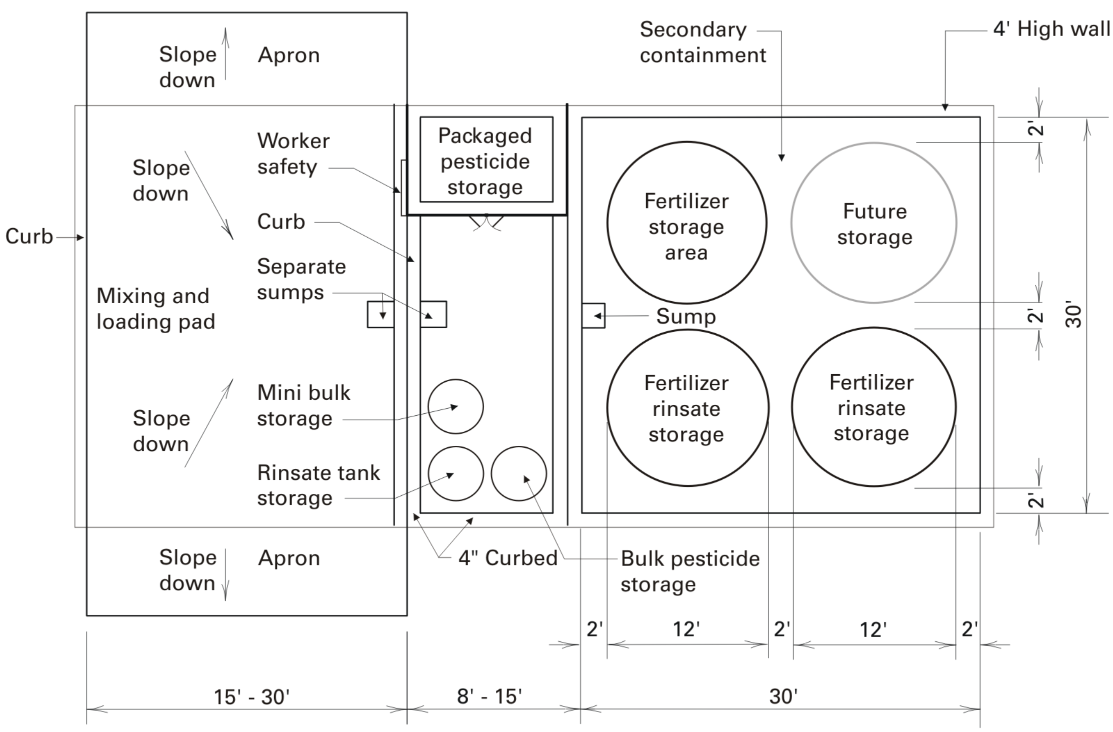


Figure 1.3. Medium-scale facility, plan view. Optional roof over entire facility.

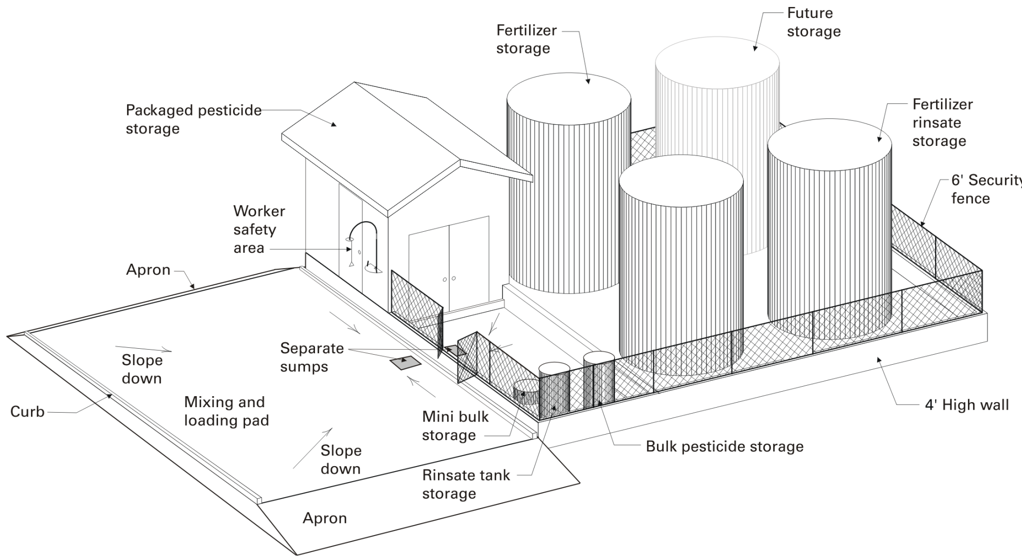


Figure 1.4. Medium-scale facility, perspective view. Optional roof over entire facility.

Large-scale facility

Figures 1.5 and 1.6 show a large-scale facility. For large-scale facilities, the design and layout should allow for future expansion. As the scale for the operations increases, the size of the spaces needed for the functional areas also increases. If the spaces are unroofed, the volume of rinsate from contaminated precipitation falling onto these areas can become a rinsate management problem. To minimize that problem, large facilities should use a building shell to provide a roof and walls to cover the functional areas. The building shell also provides security for the facility. The functional areas in the facility are separated but are placed adjacent to one another to facilitate access by employees and to provide for the efficient transfer and handling of material and loading of application equipment. Worker safety areas would be placed adjacent to the mixing and loading pads and the packaged pesticide warehouse. Offices and worker locker room are provided to accommodate the larger number of employees working in a large-scale facility.

If needed, an additional and separate drive-through mixing and loading pad could be placed adjacent to the central pesticide secondary containment. This allows more than one sprayer to be loaded at a time. The pesticide secondary containment is kept separate, and both mixing and loading pads can share the equipment and storage tanks. Pesticides in minibulks and rinsate storage tanks are placed in a curbed area to provide secondary containment.

The fertilizer secondary containment is adjacent to one of the mixing and loading pads to reduce plumbing transfer distances. A separate bulk fertilizer unloading/loading pad prevents tankers from blocking the main mixing and loading pad(s). The fertilizer secondary containment can be expanded in the future and is commonly fenced off for security if the tanks are too tall to fit under a roof. Precipitation collected in an open (unroofed) fertilizer secondary containment is collected and stored in a tank within containment. In some cases, if the tanks are not too tall, the fertilizer secondary containment is placed under a roof as well. Small packaged pesticides are stored in a warehouse with a curbed secondary containment adjacent to a mixing and loading pad.

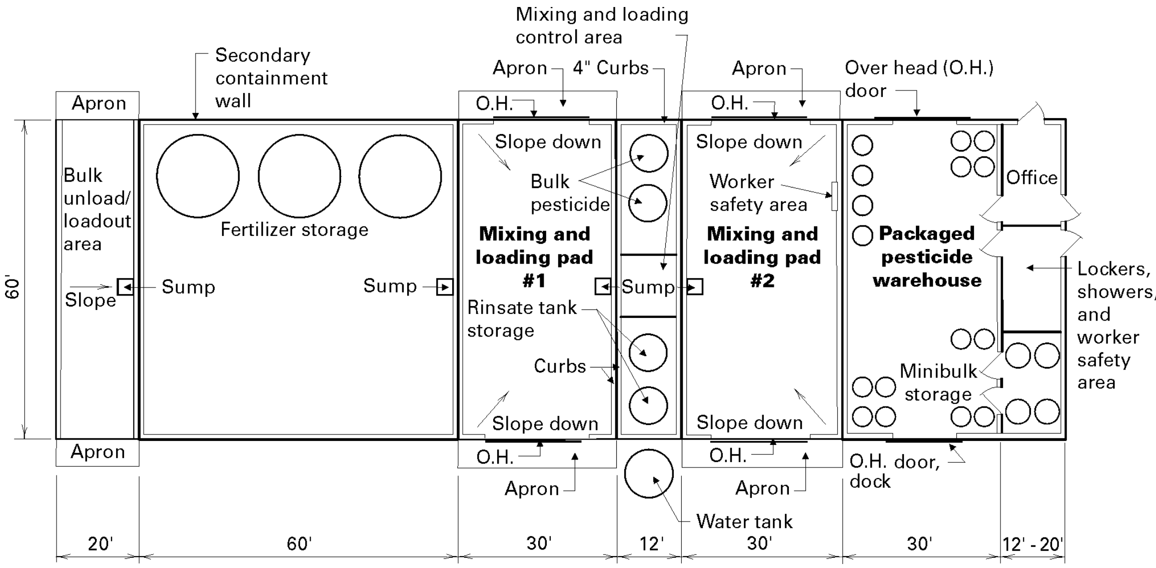


Figure 1.5. Large-scale facility, plan view. Optional roof over entire facility except fertilizer secondary containment and bulk unload pad.

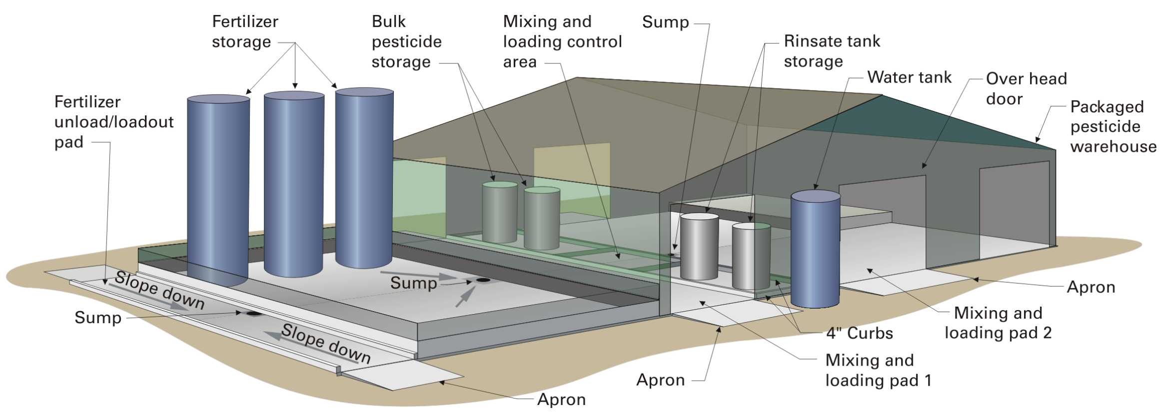


Figure 1.6. Large-scale facility, perspective view. Optional roof over entire facility except fertilizer secondary containment and bulk unload pad.

Chapter 2. Secondary Containment Facility

David W. Kammel, Professor, Biological Systems Engineering Department,
University of Wisconsin Cooperative Extension

Secondary containment refers to structures built around pesticide storage, fertilizer storage, rinsate storage, and areas used for mixing or loading. Secondary containment structures are used to contain pesticides and fertilizers (liquid or dry) that have escaped from the primary storage due to leaks, spills, fire, impacts, vandalism, or ruptured tanks and to prevent them from moving into the environment. Secondary containment systems are designed to provide adequate time for site operators to capture and clean up spills, secure the contaminated materials, and repair damage to the primary storage containers. Secondary containment systems are not designed to hold liquid for long periods.

Proper storage management, that is, preventing or minimizing leaks, spills, and other incidents, is the first and foremost defense against environmental contamination. When an accident occurs, however, the secondary containment is intended to be the safety net. Proper design and construction of a secondary containment are essential. Subsequent routine inspection and maintenance are imperative if a secondary containment system is to function as intended. Worker safety, state, and federal regulations must be taken into account in facility design.

Functional Secondary Containment Design

Fertilizer and pesticide secondary containment structures must be designed as separate and segregated areas. The main functional areas of secondary containment structures are typically identified as:

- Fertilizer Storage
- Pesticide Storage
- Rinsate Storage
- Sludge Storage

Separation and segregation of fertilizer and pesticide secondary containment structures allows the pesticide or fertilizer to be recovered and used as it was intended. This prevents the recovered mixture from potentially becoming a hazardous waste. Storage of bulk pesticide and bulk fertilizer in a common secondary containment structure is not recommended but is allowed if the secondary containment structure is in a fully enclosed building.

A mixing and loading pad can be considered a secondary containment structure for bulk pesticides, bulk fertilizer, and rinsate storage tanks. It must meet the largest storage capacity to meet either a secondary containment capacity or a mixing and loading pad capacity. Multiple product storage and uses of a single area (such as a mixing loading pad) can create management problems. Mixtures of fertilizer, pesticide, and rinsate and other possible wastes may be more difficult to use or dispose of properly.

Provide additional and separate containment pans around valves, pumps, and mixing tanks to catch small leaks and spills that occur regularly in these areas. This confines the released product to a smaller area making it easier to recover and preventing contamination of the larger secondary containment structure. It also minimizes the volume of recovered rinsate that will have to be handled. Precipitation falling in an open contaminated secondary containment structure increases the volume of rinsate that will have to be recovered and handled properly.

Design details

Slope secondary containment floors 2 percent to a single sump so contaminated precipitation (rinsate) can be easily recovered and pumped out. Sump pumps transfer the rinsate into storage tanks within a secondary containment structure. Equip sump pumps with automatic cutoff switches to prevent overfilling the storage tanks. Unless you know for certain what the rinsate liquid contains, it should be tested before deciding how the rinsate can be used appropriately.

Roofs adjacent to a secondary containment structure should be guttered to prevent clean rainwater from draining into the secondary containment structure. It is best to keep clean water clean rather than dealing with a large volume of contaminated rinsate from the secondary containment structure. Any recovered rinsate should be handled in an appropriate manner. This may be as simple as using the rinsate as make-up water for spray solutions. **NOTE:** Never let precipitation accumulate in an open secondary containment structure for more than one or two days. Accumulated liquid within the secondary containment reduces the capacity of the secondary containment to hold the required volumes of the primary storage tanks if they were to rupture. Another reason not to allow precipitation to accumulate in a secondary containment is that secondary containment structures are not designed to be completely watertight under a constant hydrostatic pressure.

Storage tank seats

It is beneficial to elevate steel storage tanks a few inches above the secondary containment floor to keep the tank bottom dry, to prevent corrosion, and to allow the manager to check for leaks. One method of elevating tanks is to place them on a bed of smooth, rounded stones as illustrated in Figure 2.1a. This method also allows the tank to be easily leveled on containment floors that slope to a sump. Another method is to lay preservative treated 2×6 boards flat on the floor spaced a few inches apart with the boards oriented parallel to the slope of the floor. Set the storage tank on the boards, Figure 2.1b. Another approach is to place an additional 4- to 6-inch thick concrete pad on top of the structural floor to elevate the tanks, Figure 2.1c. Extend the tank pads about 2 feet beyond the edges of the tank. If storage tanks are in a secondary containment incorporating a synthetic liner and felt pad, place 6 inches of smooth stone under the tank, Figure 2.2.

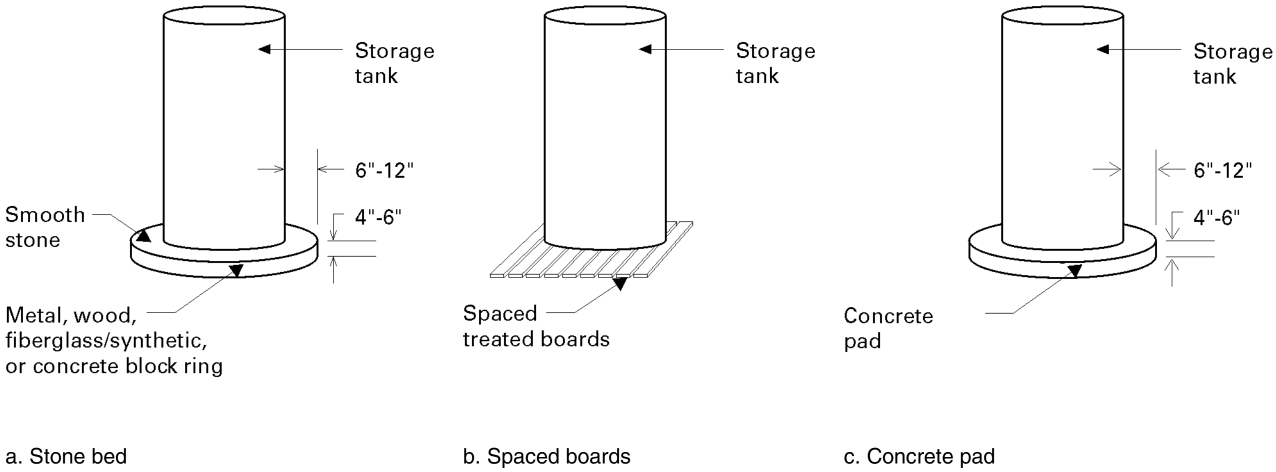


Figure 2.1. Elevated storage tank on stone bed (a), spaced boards (b), concrete pad (c).

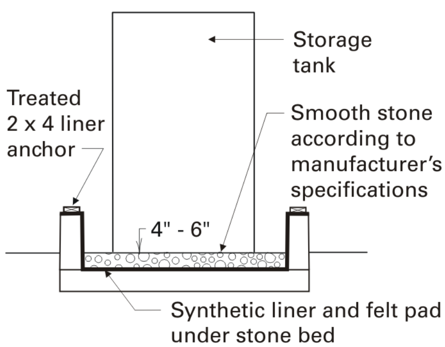
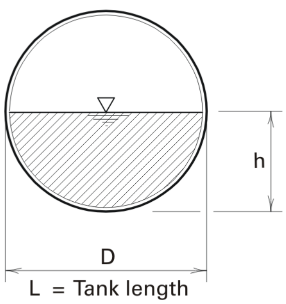


Figure 2.2 Synthetic liner under stone bed.

Sizing Secondary Containments

Secondary containment facilities must be large enough to hold all bulk pesticide or fertilizer that could leak from the largest storage tank, plus any other items that occupy volume within the secondary containment structure, such as other storage tanks, pumps, mixing equipment, concrete anchor blocks, and precipitation that falls within the containment structure.

Secondary containment is designed to hold at least 125 percent (110 percent if tanks are indoors) of the volume of the largest tank plus the displaced volumes of other tanks and equipment in the secondary containment (for example, the amount of liquid displaced by the portion of tanks below the height of the secondary containment wall). Figures 2.3a, 2.3b, and 2.3c and Tables 2.1 through 2.3 show how to calculate the volumes of horizontal, cylindrical, vertical, and cone-bottom tanks.



Horizontal cylindrical tank fluid volume (center section of tank):

$$V_1 = \left[\frac{\pi}{8} D^2 - \frac{D^2}{4}\sin^{-1}\left(1 - \frac{2h}{D}\right) - \left(\frac{D}{2} - h\right)\left(Dh - h^2\right)^{0.5}\right](L)$$

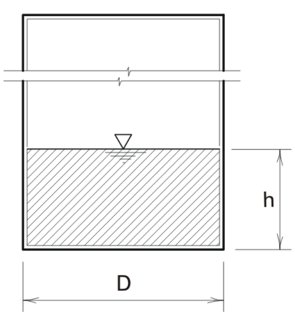
Spherical tank fluid volume (end sections of tank):

$$V_2 = \frac{\pi}{3} h^2 (1.5D - h)$$

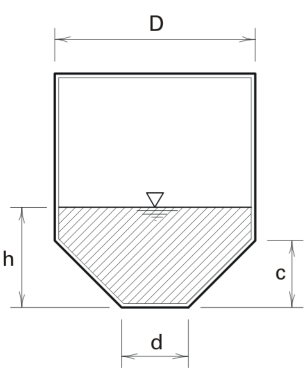
Total tank fluid volume:

$$V = V_1 + V_2$$

a. Horizontal



$$V = \frac{\pi}{4} D^2 h$$



Fluid level above cone:

$$V = \frac{\pi}{3} h\left(D^2 + d^2 + Dd\right) + \frac{\pi}{4} D^2 (h - c)$$

Fluid level within cone:

$$V = \frac{\pi}{3} h\left(K^2 + d^2 + Kd\right)$$

Where:

$$K = \frac{h}{cD} + d\left(1 - \frac{h}{c}\right)$$

b. Vertical tanks

c. Cone bottom tanks

Figure 2.3. Equations for tank volumes.

Table 2.1. Volume of vertical cylindrical tanks.

	Volume (ft^3)		Volume (gal)	
Diameter (ft)	Per foot of height	Per inch of height	Per foot of height	Per inch of height
4	12.57	1.05	94.00	7.83
5	19.63	1.64	146.87	12.24
6	28.27	2.36	211.49	17.62
7	38.48	3.21	287.86	23.99
8	50.27	4.19	375.99	31.33
9	63.62	5.30	475.86	39.65
10	78.54	6.54	587.48	48.96
11	95.03	7.92	710.85	59.24
12	113.10	9.42	845.97	70.50
13	132.73	11.06	992.84	82.74
14	153.94	12.83	1151.46	95.95
15	176.71	14.73	1321.83	110.15
16	201.06	16.76	1503.94	125.33
17	226.98	18.92	1697.81	141.48
18	254.47	21.21	1903.43	158.62
19	283.53	23.63	2120.79	176.73
20	314.16	26.18	2349.91	195.83

Table 2.2. Volume of horizontal cylindrical tanks, cu. ft.

Fluid level, ft	Diameter, ft						
	4	6	8	10	12	14	16
0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.5	0.91	1.13	1.31	1.47	1.61	1.74	1.87
1.0	2.46	3.10	3.63	4.09	4.50	4.88	5.23
1.5	4.30	5.53	6.52	7.39	8.16	8.86	9.52
2.0	6.28	8.25	9.83	11.18	12.39	13.49	14.51
2.5	8.26	11.15	13.42	15.35	17.07	18.63	20.06
3.0	10.11	14.14	17.22	19.82	22.11	24.19	26.10
3.5	11.66	17.12	21.14	24.50	27.44	30.10	32.53
4.0	12.57	20.02	25.13	29.34	33.00	36.29	39.31
4.5		22.75	29.12	34.28	38.74	42.73	46.37
5.0		25.18	33.05	39.27	44.60	49.35	53.68
5.5		27.15	36.85	44.26	50.56	56.13	61.19
6.0		28.27	40.44	49.20	56.55	63.02	68.87
6.5			43.74	54.04	62.54	69.97	76.67
7.0			46.64	58.72	68.49	76.97	84.57
7.5			48.96	63.19	74.36	83.96	92.54
8.0			50.27	67.36	80.10	90.92	100.53
8.5				71.15	85.66	97.81	108.53
9.0				74.45	90.99	104.58	116.49
9.5				77.07	96.03	111.21	124.39
10.0				78.54	100.71	117.65	132.19
10.5					104.94	123.84	139.87
11.0					108.60	129.75	147.38
11.5					111.48	135.31	154.69
12.0					113.10	140.45	161.75
12.5						145.07	168.53
13.0						149.06	174.96
13.5						152.19	181.00
14.0						153.94	186.56
14.5							191.54
15.0							195.83
15.5							199.19
16.0							201.06

Table 2.3. Volume of horizontal cylindrical tanks, gallons.

Fluid level, ft	Diameter, ft						
	4	6	8	10	12	14	16
0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.5	6.78	8.42	9.78	10.98	12.06	13.05	13.97
1.0	18.38	23.17	27.13	30.57	33.67	36.51	39.14
1.5	32.20	41.35	48.80	55.26	61.03	66.31	71.19
2.0	47.00	61.71	73.51	83.64	92.68	100.90	108.50
2.5	61.80	83.41	100.38	114.85	127.68	139.33	150.08
3.0	75.62	105.75	128.78	148.23	165.39	180.92	195.21
3.5	87.21	128.08	158.15	183.25	205.26	225.11	243.34
4.0	94.00	149.78	187.99	219.44	246.85	271.47	294.02
4.5		170.15	217.83	256.40	289.76	319.61	346.87
5.0		188.32	247.20	293.74	333.64	369.17	401.53
5.5		203.07	275.60	331.08	378.16	419.86	457.72
6.0		211.49	302.48	368.04	422.98	471.37	515.13
6.5			327.18	404.23	467.81	523.41	573.51
7.0			348.86	439.25	512.33	575.73	632.60
7.5			366.20	472.63	556.21	628.04	692.17
8.0			375.99	503.83	599.12	680.09	751.97
8.5				532.22	640.71	731.60	811.77
9.0				556.90	680.58	782.28	871.34
9.5				576.50	718.28	831.85	930.43
10.0				587.48	753.29	879.99	988.81
10.5					784.93	926.35	1046.23
11.0					812.30	970.54	1102.41
11.5					833.91	1012.12	1157.08
12.0					845.97	1050.55	1209.92
12.5						1085.15	1260.60
13.0						1114.95	1308.73
13.5						1138.41	1353.86
14.0						1151.46	1395.44
14.5							1432.75
15.0							1464.81
15.5							1489.97
16.0							1503.94

Secondary containment wall height

The maximum allowable containment wall height is 4 feet. Higher walls are expensive to construct to withstand the full hydrostatic head of liquid and increase tank anchoring requirements and the risk of pipe ruptures due to tank flotation. In general, a 4-foot containment wall height is safer, more practical, and more functional than a higher wall. If a higher wall is selected, wide steps or stairs with handrails on both sides of the wall at gates in the security fence may be an adequate solution for worker safety, comfort, and convenience. However, steps over walls present a continual safety problem for workers, especially in icy conditions.

Secondary containment floor area

Additional floor area may be necessary to allow adequate floor space for present and future tanks plus mixing and transfer equipment in the secondary containment structure. Space also may be needed for replacing small existing tanks with larger diameter tanks in the future. Workers also need space to move between tanks and move over containment walls without undue risk or hazards. If possible, orient tank weld seams toward the interior of the containment structure, and orient tank outlet valves toward the center of the containment structure in case there is a plumbing or weld failure. Having the welds and outlet valves toward the interior of the containment structure could possibly prevent a leak from squirting over the secondary containment wall.

Provide at least the required 2 feet between tanks and 2 feet between a tank and a containment wall to allow visual inspection of the tanks. More space may be needed between some of the tanks to allow room for pipes, pumps, and valves, Figure 2.4. The 2-foot distance between a tank and a secondary containment wall may not be adequate to contain spurting (jetting) leaks from tall tanks. Workers should not have to climb over piping to get between tanks. Usually, the guidelines for spacing tanks, rather than the calculated required volume, control the dimensions for floor areas in secondary containments.

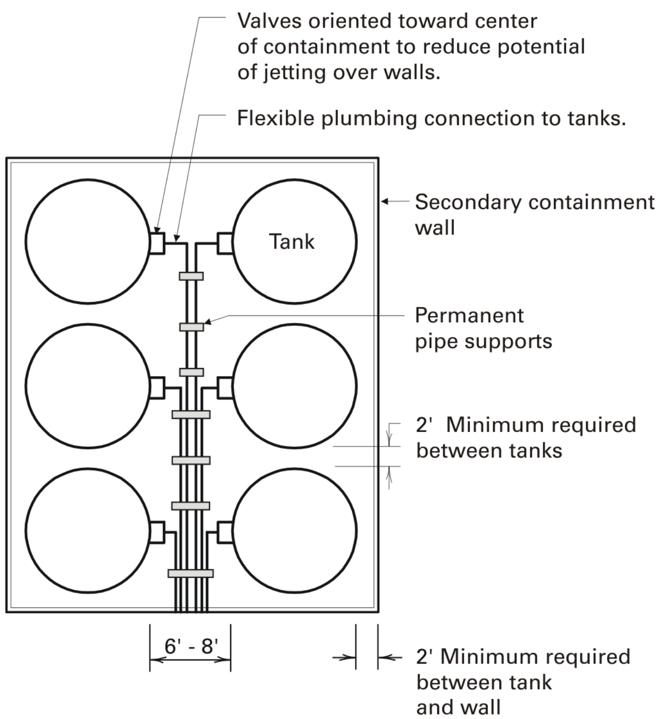


Figure 2.4. Tank spacing in secondary containment.

Figure 2.5 shows the minimum secondary containment floor area (MSCFA) required to provide space for the tanks and the required 2 feet between each tank and the 2 feet between a tank and walls for several common layouts with all vertical tanks of the same diameter. MSCFA is calculated based on inside dimensions of the secondary containment walls. Plan for the future when designing the secondary containment capacity. Even though an operation presently has 8-foot and 12-foot diameter tanks, it may prefer all 12-foot diameter tanks in the future. It is best to design a containment structure for the largest tanks to allow flexibility for changes in the facility.

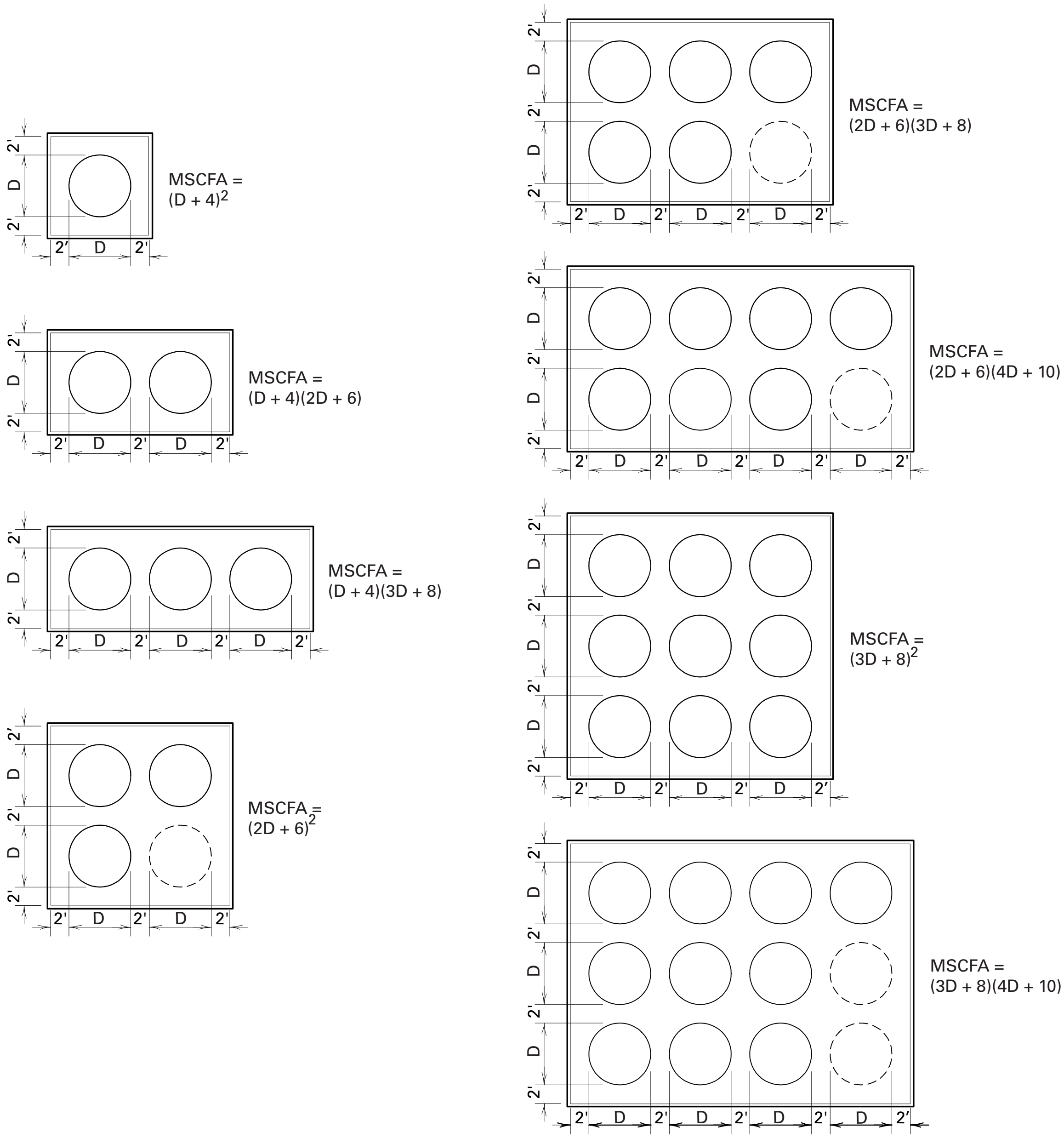


Figure 2.5 The minimum secondary containment floor area (MSCFA) required to provide space for the tanks and the required 2 feet between each tank and the 2 feet between a tank and walls for several common layouts with all vertical tanks of the same diameter.

Secondary containment sizing for vertical tanks only

For vertical storage tanks, which are not elevated above the containment floor, calculate the required secondary containment floor area (SCFA) dimensions inside containment walls by:

$$SCFA = \frac{(LTV)(FF)}{SCVD} + TBA$$

Where:

SCFA = Containment floor area, sq. ft. Use inside wall dimensions of secondary containment walls. For vertical tanks only.

LTV = Largest tank volume, cu. ft. A full tank is assumed. 1 cu. ft. = 7.48 gallons.

FF = Freeboard factor, 1.1 for 110% of largest tank (inside storage), 1.25 for 125% of largest tank. (outside storage)

SCVD = Secondary containment depth, ft.

TBA = Sum of the tank base areas, sq. ft. Do **not** include the tank base area of the largest tank because it is included in LTV. Values for individual tank base areas are in Table 2.1 (use the cu. ft/ft of height values).

A tank sitting on a solid base, such as rocks or boards, is not considered elevated because the base support takes up volume. These calculations do not allow for volume taken up by these supports or other equipment in the containment structure. If the volume of equipment is significant, add additional area. Note that the containment floor area required may be larger than that calculated based on the 2-foot required clearance space between tanks and required 2-foot clearance between tanks and walls. Tables 2.4 through 2.6 give SCFA values for containments with vertical storage tanks of the same diameter. It is estimated that the available secondary containment volume in a stone or gravel bed is approximately L $\times$ W $\times$ D/2.

Table 2.4. Secondary containment floor area (SCFA) for vertical tanks, FF=1.0.

Tank diameter, ft	Tank height, ft	Single tank area, ft^2	Single tank volume, ft^3	Single tank volume, gal.	Cont. depth, ft	Number of tanks 1	2	3	4	5	6	7	8
						SCFA, ft^2							
15	20	177	3534	26437	1	3534	3711	3888	4064	4241	4418	4595	4771
					2	1767	1944	2121	2297	2474	2651	2827	3004
					3	1178	1355	1532	1708	1885	2062	**2299***	**2520***
					4	884	1060	1237	1414	**1653***	**1908***	**2299***	**2520***
14	20	154	3079	23029	1	3079	3233	3387	3541	3695	3848	4002	4156
					2	1539	1693	1847	2001	2155	2309	2463	2617
					3	1026	1180	1334	1488	1642	1796	**2052***	**2244***
					4	770	924	1078	1232	**1476***	**1700***	**2052***	**2244***
13	20	133	2655	19857	1	2655	2787	2920	3053	3186	3318	3451	3584
					2	1327	1460	1593	1726	1858	1991	2124	2256
					3	885	1018	1150	1283	1416	1549	**1819***	**1984***
					4	664	796	929	1062	**1309***	**1504***	**1819***	**1984***
12	20	113	2262	16919	1	2262	2375	2488	2601	2714	2827	2941	3054
					2	1131	1244	1357	1470	1583	1696	1810	1923
					3	754	867	980	1093	1206	**1320***	**1600***	**1740***
					4	565	679	792	905	**1152***	**1320***	**1600***	**1740***
11	20	95	1901	14217	1	1901	1996	2091	2186	2281	2376	2471	2566
					2	950	1045	1140	1235	1330	1425	1521	1616
					3	634	729	824	919	1014	**1148***	**1395***	**1512***
					4	475	570	665	**784***	**1005***	**1148***	**1395***	**1512***
10	20	79	1571	11750	1	1571	1649	1728	1806	1885	1963	2042	2121
					2	785	864	942	1021	1100	1178	1257	1335
					3	524	602	681	759	**868***	**988***	**1204***	**1300***
					4	393	471	550	**676***	**868***	**988***	**1204***	**1300***
9	18	64	1145	8565	1	1145	1209	1272	1336	1400	1463	1527	1590
					2	573	636	700	763	827	891	1027*	1104*
					3	382	445	509	**576***	**741***	**840***	**1027***	**1104***
					4	286	350	**455***	**576***	**741***	**840***	**1027***	**1104***
8	16	50	804	6016	1	804	855	905	955	1005	1056	1106	1156
					2	402	452	503	553	**624***	**704***	**864***	**924***
					3	268	318	**384***	**484***	**624***	**704***	**864***	**924***
					4	201	**264***	**384***	**484***	**624***	**704***	**864***	**924***
7	14	38	539	4030	1	539	577	616	654	693	731	770	808
					2	269	308	346	**400***	**517***	**580***	**715***	**760***
					3	180	**220***	**319***	**400***	**517***	**580***	**715***	**760***
					4	135	**220***	**319***	**400***	**517***	**580***	**715***	**760***
6	12	28	339	2538	1	339	368	396	424	452	481	580*	612*
					2	170	198	**260***	**324***	**420***	**468***	**580***	**612***
					3	113	**180***	**260***	**324***	**420***	**468***	**580***	**612***
					4	85	**180***	**260***	**324***	**420***	**468***	**580***	**612***
5	10	20	196	1469	1	196	216	236	**256***	**333***	**368***	**459***	**480***
					2	98	**144***	**207***	**256***	**333***	**368***	**459***	**480***
					3	**81***	**144***	**207***	**256***	**333***	**368***	**459***	**480***
					4	**81***	**144***	**207***	**256***	**333***	**368***	**459***	**480***

***MSCFA controls secondary containment floor area. See Figure 2.5**

Table 2.4 continued

	Number of tanks									
	1	2	3	4	5	Alt. 5	6	7	Alt. 7	8
Tank diameter, ft	MSCA, ft^2									
15	361	684	1007	1296	1908	1653	1908	2520	2299	2520
14	324	612	900	1156	1700	1476	1700	2244	2052	2244
13	289	544	799	1024	1504	1309	1504	1984	1819	1984
12	256	480	704	900	1320	1152	1320	1740	1600	1740
11	225	420	615	784	1148	1005	1148	1512	1395	1512
10	196	364	532	676	988	868	988	1300	1204	1300
9	169	312	455	576	840	741	840	1104	1027	1104
8	144	264	384	484	704	624	704	924	864	924
7	121	220	319	400	580	517	580	760	715	760
6	100	180	260	324	468	420	468	612	580	612
5	81	144	207	256	368	333	368	480	459	480

Table 2.5. Secondary containment floor area (SCFA) for vertical tanks, FF=1.10.

This table is for containment with all tank diameters the same and no space provided for additional equipment. Additional volume may be needed for precipitation.

Tank diameter, ft	Tank height, ft	Single tank area, ft^2	Single tank volume, ft^3	Single tank volume, gal.	Cont. depth, ft	Number of tanks							
						1	2	3	4	5	6	7	8
						SCFA, ft^2							
15	20	177	3534	26437	1	3888	4064	4241	4418	4595	4771	4948	5125
					2	1944	2121	2297	2474	2651	2827	3004	3181
					3	1296	1473	1649	1826	2003	2179	2356	2533
					4	972	1149	1325	1502	1679	**1908***	**2299***	**2520***
14	20	154	3079	23029	1	3387	3541	3695	3848	4002	4156	4310	4464
					2	1693	1847	2001	2155	2309	2463	2617	2771
					3	1129	1283	1437	1591	1745	1899	2053	**2244***
					4	847	1001	1155	1308	**1476***	**1700***	**2052***	**2244***
13	20	133	2655	19857	1	2920	3053	3186	3318	3451	3584	3717	3849
					2	1460	1593	1726	1858	1991	2124	2256	2389
					3	973	1106	1239	1372	1504	1637	**1819***	**1984***
					4	730	863	995	1128	**1309***	**1504***	**1819***	**1984***
12	20	113	2262	16919	1	2488	2601	2714	2827	2941	3054	3167	3280
					2	1244	1357	1470	1583	1696	1810	1923	2036
					3	829	942	1056	1169	1282	1395	**1600***	**1740***
					4	622	735	848	961	**1152***	**1320***	**1600***	**1740***
11	20	95	1901	14217	1	2091	2186	2281	2376	2471	2566	2661	2756
					2	1045	1140	1235	1330	1425	1521	1616	1711
					3	697	792	887	982	1077	1172	**1395***	**1512***
					4	523	618	713	808	**1005***	**1148***	**1395***	**1512***
10	20	79	1571	11750	1	1728	1806	1885	1963	2042	2121	2199	2278
					2	864	942	1021	1100	1178	1257	1335	1414
					3	576	654	733	812	890	**988***	**1204***	**1300***
					4	432	511	589	**676***	**868***	**988***	**1204***	**1300***
9	18	64	1145	8565	1	1260	1323	1387	1450	1514	1578	1641	1705
					2	630	693	757	821	884	948	**1027***	**1104***
					3	420	483	547	611	**741***	**840***	**1027***	**1104***
					4	315	379	**455***	**576***	**741***	**840***	**1027***	**1104***
8	16	50	804	6016	1	885	935	985	1035	1086	1136	1186	1237
					2	442	493	543	593	643	694	**864***	**924***
					3	295	345	395	484*	**624***	**704***	**864***	**924***
					4	221	271	**384***	**484***	**624***	**704***	**864***	**924***
7	14	38	539	4030	1	593	631	670	708	747	785	824	862
					2	296	335	373	412	**517***	**580***	**715***	**760***
					3	198	236	**319***	**400***	**517***	**580***	**715***	**760***
					4	148	**220***	**319***	**400***	**517***	**580***	**715***	**760***
6	12	28	339	2538	1	373	401	430	458	486	515	**580***	**612***
					2	187	215	**260***	**324***	**420***	**468***	**580***	**612***
					3	124	**180***	**260***	**324***	**420***	**468***	**580***	**612***
					4	93	**180***	**260***	**324***	**420***	**468***	**580***	**612***
5	10	20	196	1469	1	216	236	255	275	**333***	**368***	**459***	**480***
					2	108	**144***	**207***	**256***	**333***	**368***	**459***	**480***
					3	72	**144***	**207***	**256***	**333***	**368***	**459***	**480***
					4	54	**144***	**207***	**256***	**333***	**368***	**459***	**480***

***MSCFA controls secondary containment floor area. See Figure 2.5.**

Table 2.5 continued

Tank diameter, ft	Number of tanks									
	1	2	3	4	5	Alt 5	6	7	Alt 7	8
	MSCFA, ft^2									
15	361	684	1007	1296	1908	1653	1908	2520	2299	2520
14	324	612	900	1156	1700	1476	1700	2244	2052	2244
13	289	544	799	1024	1504	1309	1504	1984	1819	1984
12	256	480	704	900	1320	1152	1320	1740	1600	1740
11	225	420	615	784	1148	1005	1148	1512	1395	1512
10	196	364	532	676	988	868	988	1300	1204	1300
9	169	312	455	576	840	741	840	1104	1027	1104
8	144	264	384	484	704	624	704	924	864	924
7	121	220	319	400	580	517	580	760	715	760
6	100	180	260	324	468	420	468	612	580	612
5	81	144	207	256	368	333	368	480	459	480

Table 2.6. Secondary containment floor area (SCFA) for vertical tanks, FF=1.25.
This table is for containment with all tank diameters the same and no space provided for additional equipment. Additional volume may be needed for precipitation.

Tank diameter, ft	Tank height, ft	Single tank area, ft^2	Single tank volume, ft^3	Single tank volume, gal.	Cont. depth, ft	Number of tanks: 1	2	3	4	5	6	7	8
						SCFA, ft^2							
15	20	177	3534	26437	1	4418	4595	4771	4948	5125	5301	5478	5655
					2	2209	2386	2562	2739	2916	3093	3269	3446
					3	1473	1649	1826	2003	2179	2356	2533	2710
					4	1104	1281	1458	1635	1811	1988	2299*	**2520***
14	20	154	3079	23029	1	3848	4002	4156	4310	4464	4618	4772	4926
					2	1924	2078	2232	2386	2540	2694	2848	3002
					3	1283	1437	1591	1745	1899	2053	2206	2360
					4	962	1116	1270	1424	1578	1732	**2052***	**2244***
13	20	133	2655	19857	1	3318	3451	3584	3717	3849	3982	4115	4247
					2	1659	1792	1925	2057	2190	2323	2456	2588
					3	1106	1239	1372	1504	1637	1770	1902	2035
					4	830	962	1095	1228	1361	**1504***	**1819***	**1984***
12	20	113	2262	16919	1	2827	2941	3054	3167	3280	3393	3506	3619
					2	1414	1527	1640	1753	1866	1979	2092	2205
					3	942	1056	1169	1282	1395	1508	1621	1740*
					4	707	820	933	1046	1159	**1320***	**1600***	**1740***
11	20	95	1901	14217	1	2376	2471	2566	2661	2756	2851	2946	3041
					2	1188	1283	1378	1473	1568	1663	1758	1853
					3	792	887	982	1077	1172	1267	**1395***	**1512***
					4	594	689	784	879	1005*	**1148***	**1395***	**1512***
10	20	79	1571	11750	1	1963	2042	2121	2199	2278	2356	2435	2513
					2	982	1060	1139	1217	1296	1374	1453	1532
					3	654	733	812	890	969	1047	**1204***	**1300***
					4	491	569	648	726	**868***	**988***	**1204***	**1300***
9	18	64	1145	8565	1	1431	1495	1559	1622	1686	1749	1813	1877
					2	716	779	843	907	970	1034	1097	1161
					3	477	541	604	668	**741***	**840***	**1027***	**1104***
					4	358	421	485	**576***	**741***	**840***	**1027***	**1104***
8	16	50	804	6016	1	1005	1056	1106	1156	1206	1257	1307	1357
					2	503	553	603	653	704	754	**864***	**924***
					3	335	385	436	486	**624***	**704***	**864***	**924***
					4	251	302	**384***	**484***	**624***	**704***	**864***	**924***
7	14	38	539	4030	1	673	712	750	789	827	866	904	943
					2	337	375	414	452	**517***	**580***	**715***	**760***
					3	224	263	**319***	**400***	**517***	**580***	**715***	**760***
					4	168	**220***	**319***	**400***	**517***	**580***	**715***	**760***
6	12	28	339	2538	1	424	452	481	509	537	565	594	622
					2	212	240	269	**324***	**420***	**468***	**580***	**612***
					3	141	**180***	**260***	**324***	**420***	**468***	**580***	**612***
					4	106	**180***	**260***	**324***	**420***	**468***	**580***	**612***
5	10	20	196	1469	1	245	265	285	304	**333***	**368***	**459***	**480***
					2	123	**144***	**207***	**256***	**333***	**368***	**459***	**480***
					3	82	**144***	**207***	**256***	**333***	**368***	**459***	**480***
					4	61	**144***	**207***	**256***	**333***	**368***	**459***	**480***

*** MSCFA controls secondary containment floor area. See Figure 2.5**

Table 2.6 continued.

	Number of tanks									
	1	2	3	4	5	Alt 5	6	7	Alt 7	8
Tank diameter, ft	MSCFA, ft^2									
15	361	684	1007	1296	1908	1653	1908	2520	2299	2520
14	324	612	900	1156	1700	1476	1700	2244	2052	2244
13	289	544	799	1024	1504	1309	1504	1984	1819	1984
12	256	480	704	900	1320	1152	1320	1740	1600	1740
11	225	420	615	784	1148	1005	1148	1512	1395	1512
10	196	364	532	676	988	868	988	1300	1204	1300
9	169	312	455	576	840	741	840	1104	1027	1104
8	144	264	384	484	704	624	704	924	864	924
7	121	220	319	400	580	517	580	760	715	760
6	100	180	260	324	468	420	468	612	580	612
5	81	144	207	256	368	333	368	480	459	480

Secondary containment sizing for non-vertical or elevated tanks

For containments that have tanks other than all vertical tanks or containments in which some of the tanks are elevated, calculate secondary containment floor area (SCFA) by:

$$SCFA = \frac{(LTV)(FF) + TBV)}{SCVD}$$

Where:

TBV = Sum of the tank base volumes, cu. ft. Do **not** include the base volume of the largest tank because it is included in LTV.

= BV1 + BV2 + … + BVn

BV = Base volume of an individual tank, cu. ft.

To determine BV:

For vertical tanks:

BV = (VPF) (SCVD - TBE)

Where:

VPF = Volume/unit of depth, cu. ft./ft of depth. Determine from Table 2.1 or the equation in Figure 2.3.

TBE = Tank base elevation, ft. For tanks setting on the floor or a solid base (e.g. stones), TBE = 0.

For horizontal tanks:

BV = The tank volume given in Table 2.2 or calculated from the equation in 2.3 at a fluid level of (SCVD - TBE).

For vertical tanks with cone bottoms:

BV = The tank volume calculated from the equation in Figure 2.3 at a fluid level of (SCVD - TBE).

Example: Calculating secondary containment volume

A liquid fertilizer dealer has two, 12-foot diameter × 20-foot high, three, 10-foot diameter × 15-foot high, and two, 9-foot diameter × 15-foot high vertical storage tanks. The dealer is trying to decide between a 3-foot and a 4-foot secondary containment wall height. An additional 25% of the largest tank is required for freeboard because the secondary containment structure is not roofed (FF =1.25).

From Table 2.1, the largest tank volume LTV = 113.1 cu. ft/ft of depth × 20' = 2,262 cu. ft.

Now determine the area of the bases of the other tanks in the containment structure, TBA:

TBA = 113.1 + 3 × 78.54 + 2 x 63.62 = 476 sq. ft.

Next, calculate the secondary containment floor area, SCFA, for each of the two containment depths.

For 3-foot depth:

$$SCFA = \frac{(LTV)(FF)}{SCVD} + TBA$$

$$= 2{,}262 \times 1.25 / 3 + 476$$

$$= 1{,}419 \text{ sq. ft.}$$

For 4-foot depth:

$$SCFA = 2{,}262 \times 1.25 / 2 + 476$$

$$= 1{,}890 \text{ sq. ft.}$$

The volume displaced by transfer pumps and plumbing is assumed insignificant and is ignored in this example. If large mixing tanks, transfer tanks, or concrete tank supports are to be placed in the containment structure, their displacement area and volume below the level of the containment wall must be included.

As shown in Figure 2.6, the containment structure has to be at least 27 feet wide to allow enough space for the tanks and 2-foot access around tanks. A 27-foot × 53-foot area provides the computed area for the 3-foot depth, but the area needs to be at least 27 feet × 54 feet for all the tanks to fit. For the 2-foot depth, a 27-foot × 70-foot area is required for the tanks and to allow the tanks to fit in the area with adequate clearance.

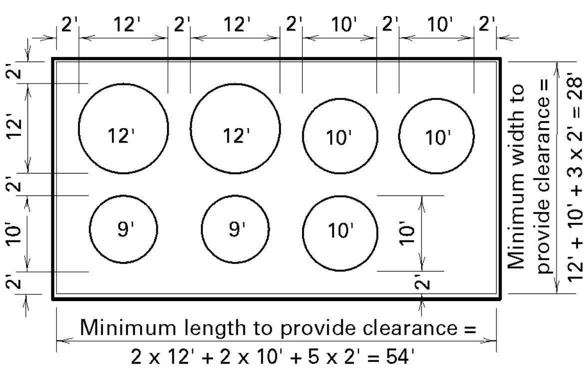


Figure 2.6. Scaled site plan for the secondary containment in the example.

If a tank were to be placed in the empty corner by the 10-foot diameter tanks in the future, its displacement volume would have to be included in the SCFA calculation now. It would be best to design the containment structure for eight, 12-foot diameter tanks, because it would allow more flexibility in future facility changes. From Table 2.6, a 30-foot × 58-foot (1,740 sq. ft. / 30 feet = 58 feet) containment structure would be required for a 3-foot high wall.

NOTE: *To make sure all the tanks and equipment will fit into the containment structure with sufficient clearance, it is extremely important to make a scale drawing of the structure with the tanks drawn to scale in position. The 3-foot wall plan contains more floor slab area than the 4-foot wall plan does, but this is offset by the additional wall area the 4-foot wall plan requires. Savings in concrete should be a secondary consideration after function and safety for secondary containments.*

Curbed Areas

Secondary containment of small storage tank volumes of pesticide or fertilizer can be accomplished by constructing a small curb. Table 2.7 shows secondary containment floor area required to store minibulk containers or drums. Curbs also can be used to provide secondary containment for mixing and loading pads and for pesticide warehouse or storage rooms. Using curbs is an excellent method for containing bottles, jugs, drums, and small minibulk storage tanks.

The curb must surround the complete storage area and must be high enough to have sufficient volume to contain any potential spillage from a primary storage tank. To provide secondary containment for bulk pesticides or pesticide rinsate, the curb must be at least 4 inches high. If the curbed area is not roofed, it should also be designed with any required freeboard. Using small rounded or ramped curbs (less than 6 inches in height) and more area that is horizontal provides the secondary containment capacity required but also allows movement of tanks within the secondary containment structure and more easily accommodates foot traffic between the functional areas. Figure 2.7 shows an example of a curb placed on a mixing and loading pad. Small pesticide packages can be moved easily with hand trucks. Workers also can move more easily without having to climb steps or climb over walls.

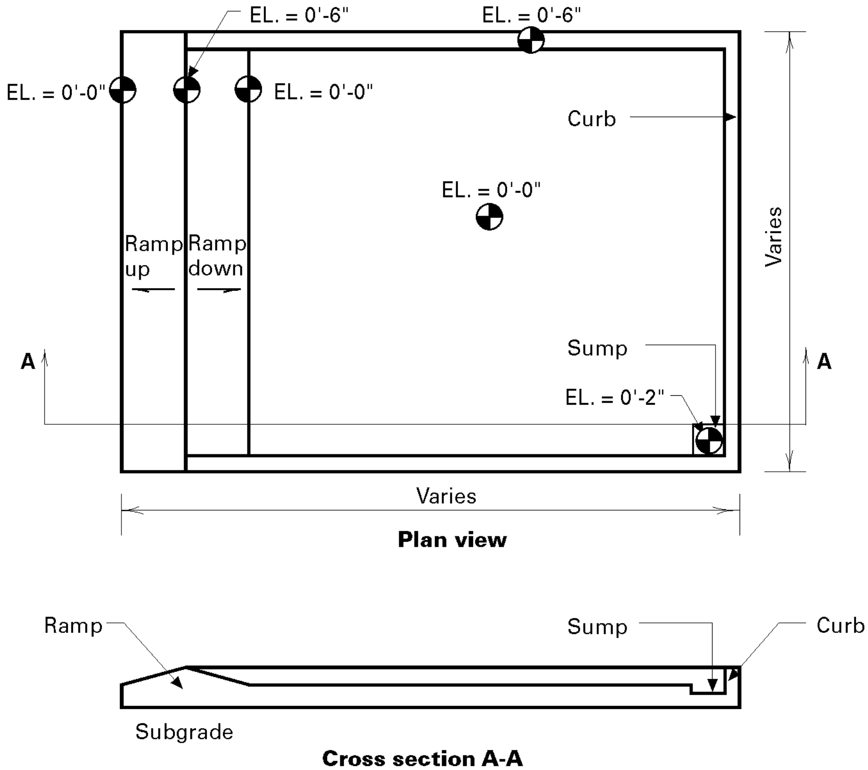


Figure 2.7. Curbed and ramped secondary containment.

Table 2.7. Floor area for curbed secondary containment.
Assuming a 6" curbed area.

Minibulk container size, gal	Containment area per minibulk, ft^2
60	16
110	30
150	41
200	54
250	67
300	81

Concrete Wall and Floor Containment

As the tank size increases, secondary containment volume usually requires an increase in the curb (wall) height to provide the needed volume. A reinforced concrete wall can be designed to withstand the horizontal loads. The concrete wall is usually placed on top of a floating slab to provide an impermeable or liquid tight joint and to create a relatively liquid impermeable system for secondary containment. This is usually called a secondary containment dike.

Synthetic Liners with Concrete Walls

In Wisconsin, synthetic liners (e.g. synthetic rubber, EPDM, polyurea) can be used as secondary containment for bulk fertilizers, but not for bulk pesticides. These synthetic liners can be used to repair concrete containments with cracks or other support walls used to support the horizontal load, Figure 2.8. Flexible liners have factory- or field-bonded seams to form a single continuous barrier that lines the entire secondary containment facility. To be effective, synthetic liners must be extremely durable and chemically resistant to the stored products. Install synthetic liners as recommended by the manufacturer to prevent punctures and tears. Properly designed and installed liners, if protected from puncturing, are superior to concrete liners as a barrier to liquid flow.

Some facilities use a layer of sand or smooth gravel to protect a synthetic liner used on the floor of a containment facility. This practice is acceptable, but if the protective granular cover becomes contaminated, any precipitation in the containment structure also is contaminated. Large (1-inch to 1.5-inch diameter) smooth gravel may be decontaminated by flushing it with a large amount of water, but the flush water would then have to be treated as contaminated. To prevent this situation from occurring, use small pans under pumps, valves, and plumbing connections to minimize contamination of the granular material. Otherwise, the granular fill must be replaced and the contaminated material disposed of properly. Additionally, removing the gravel without damaging the synthetic liner is difficult.

Most manufacturers of synthetic liner materials will guarantee the lifespan of the liner regardless of UV exposure, provided the liner is installed as recommended and is protected from the tank and equipment stresses. It is possible to leave the liner exposed. This would minimize the problems created by contaminated granular material and make the system easier to inspect for damage and clean up after a release.

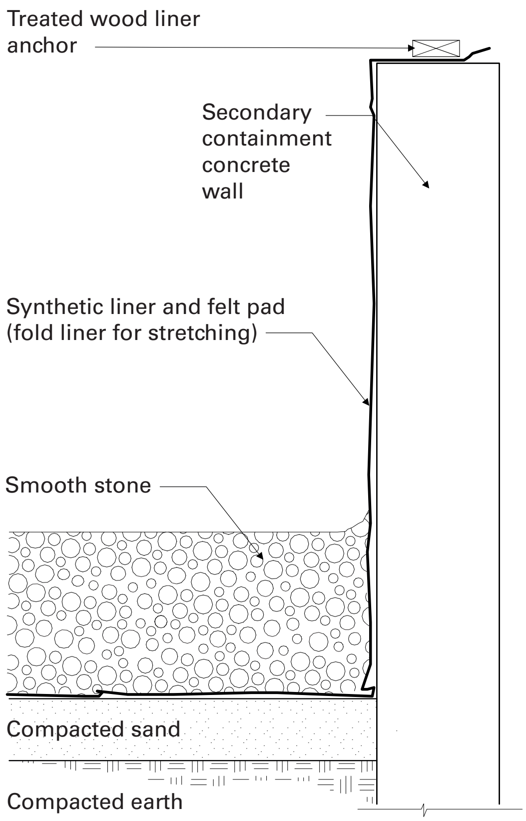


Figure 2.8. Synthetic liner with concrete wall for secondary containment.

Storage Tank Plumbing

Use flexible hoses at the pipe-to-tank connection to allow some flexing of plumbing lines due to thermal expansion and to prevent potential plumbing rupture if one tank floats or shifts. It is possible to have a catastrophic failure of multiple tanks if rigid steel plumbing between multiple storage tanks is used and a rupture of one tank occurs. In the case of multiple tank failures, the secondary containment could overflow.

Elevated pipes are easier to maintain. They must be supported by permanent supports. Do not exceed dimensions for intervals specified in Table 2.8. Run rigid steel pipe to a deck for loading and unloading of pesticides and fertilizers. Do not place rigid pipe near traffic lanes where it is subject to damage by vehicles. Protect rigid pipe from vehicles with steel posts or high curbs. Use flexible hose connections from rigid plumbing or manifolds to vehicles. Permanent plumbing is preferred to eliminate drips that occur when hoses are switched from tank to tank. Do not install pesticide and fertilizer plumbing lines, sump pump lines, or drain lines under secondary containment floors or mixing and loading pads or in inaccessible areas.

Plumbing cannot penetrate through secondary containment walls: plumbing pipes must be run over containment walls rather than through them. It is difficult to seal around pipes that go through walls and very difficult to ensure the integrity of a seal throughout a facility's life.

Table 2.8. Maximum pipe span between supports.

Pipe material	Nominal diameter, in.	Maximum span, ft
Mild steel	2	10
	2.5	11
	3	12
	3.5	13
	4	14
	5	15
	6	17
PVC, Schedule 40	2	4
	3	5
	4	6
	5	8
	6	10

Electrical Systems
If possible, elevate electrical items (motors, wiring, controls, etc.) off the containment floor so they do not become submerged. Ideally, place all electrical components above the top of the secondary containment wall (highest liquid level) so they do not become submerged during a spill. Use Ground Fault Circuit Interrupters (GFCI) on all electric circuits within secondary containment and other parts of pesticide and fertilizer handling facilities as specified by the National Fire Protection Association (NFPA) and the National Electric Code (NEC).

Security Fencing
Vandalism and theft can be major problems for pesticide and fertilizer storage facilities. Use fences or buildings to prevent unauthorized entry to the secondary containment and to protect children, pets, and other animals from accidental entry. Fencing is required to provide security for all storage tanks, mixing and loading equipment, and empty pesticide containers held for disposal unless the entire facility is enclosed inside a secured building. If possible, place all valves, pipes, and pumps inside a fence or building. Otherwise, lock valves when they are not supervised.

Select security fencing that is a minimum of 5 feet high and constructed of 12-gauge hardened steel wire mesh with 3-inch x 3-inch diagonal openings. Ideally, the fencing would be installed independent of the secondary containment structures. If fencing is installed on top of secondary containment walls, the fencing must be installed by attaching the fence posts to brackets bolted to the containment wall as shown in figures 2.9 and 2.10. Use fence gates of a rigid steel frame and wire fence mesh with maximum openings of 1 or 2 inches between the fence posts and gate and the concrete. Do not place fence posts into the top of a concrete wall as this creates a weak section that causes cracks in the concrete.

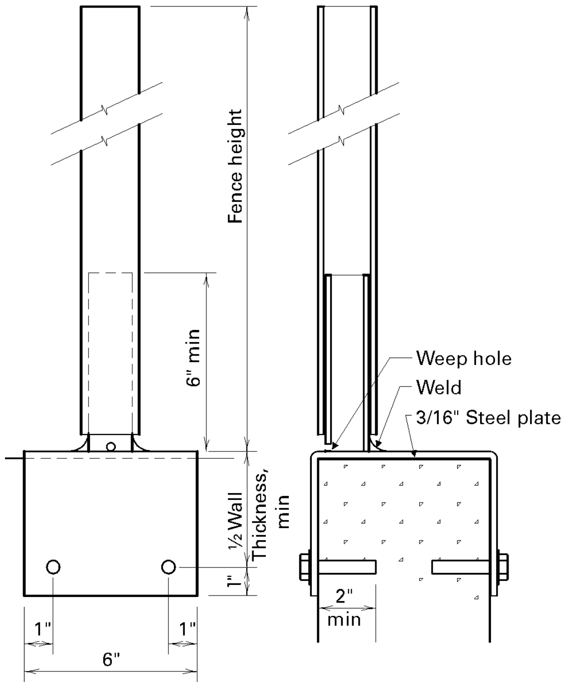


Figure 2.9. Metal saddle support for fence post.

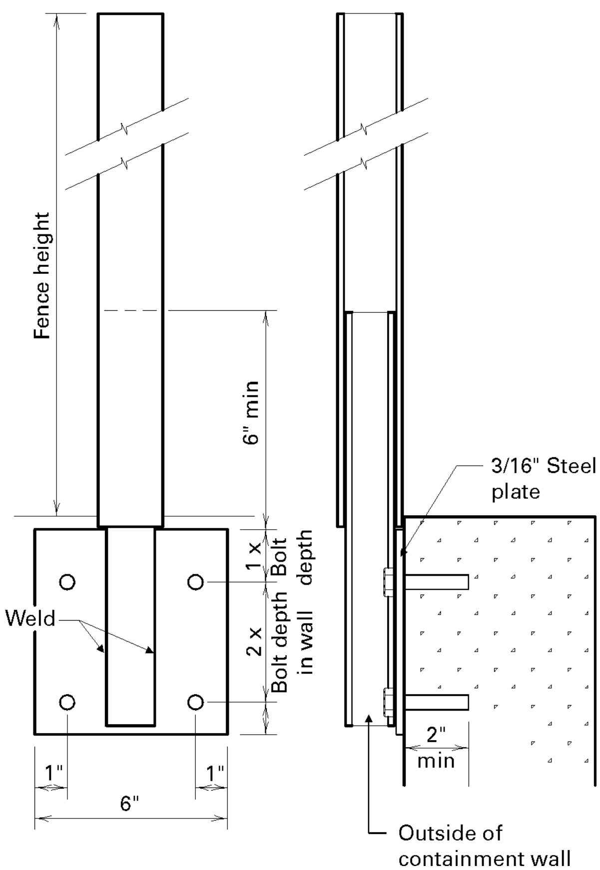


Figure 2.10. Wall plate support for fence post.

Loads from tank anchors

Tanks within a secondary containment must be anchored to prevent floating or tipping due to loading from vertical buoyancy and horizontal wind forces. Tanks are anchored to prevent flotation when fluid levels rise within the secondary containment structure. If tanks are not anchored, one tank failure could raise the liquid level in the secondary containment structure and cause other tanks within the structure to float and possibly tip, resulting in additional tank failures. Since secondary containment is not designed to hold the volume of all the tanks within it, the additional liquid from other failed tanks would overflow the secondary containment causing a spill. Tank anchors and connections must be adequate to resist the calculated loads.

Upward forces due to flotation are equal to the weight of the fluid displaced by the empty portion of the tank that is below the fluid level minus the empty tank weight. Flotation force can be calculated by:

$$FF = FD \times VD - TW$$

Where:

FF = Flotation force, lb

FD = Fluid density of fertilizer, typically 70-85 lb/cu. ft.

VD = Volume of fluid displaced by the tank, cu. ft. Table 2.1 – 2.3

TW = Empty tank weight, lb

When calculating flotation force, assume the worst conditions. Assume one tank is empty when another tank leaks, and assume that the secondary containment will be completely filled to the height of the wall. Flotation forces can be reduced by elevating the tank and/or using cone-bottom tanks because less fluid volume is displaced. Elevated cone-bottom tanks are popular for handling many products because they have fewer flotation problems, and all of the product can be easily removed from the tank.

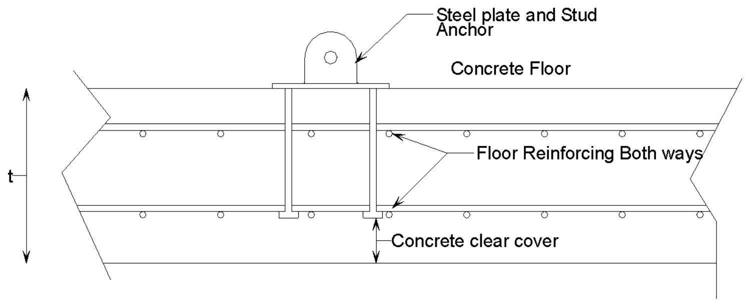
Horizontal wind loads will vary depending on the type of tank, tank width, and tank height. Wind loads place repetitive loads from many directions on the tanks and anchor points over the life of the structure. It is beyond the scope of this discussion to determine loads applied to tanks and the resulting anchor design needs due to wind forces. A professional engineering analysis is needed to determine the loads and the design of the anchors. It is important to consider the loads on both the tank and the secondary containment structure.

It is recommended that if possible tanks should be anchored outside of the secondary containment walls to eliminate the additional load on the wall. Tank anchors can be integrated into the secondary containment floor if the structure is designed to withstand the additional loads due to the loading causes by tank anchors. Anchoring tanks to the secondary containment walls is not allowed.

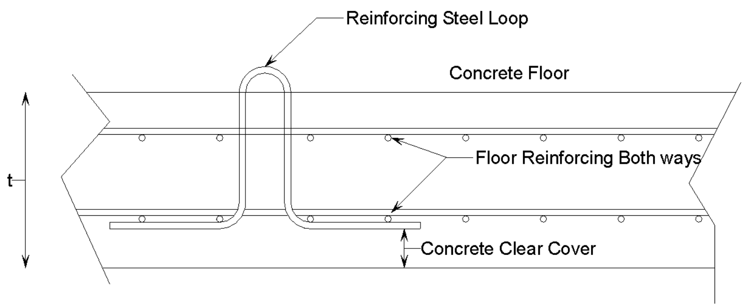
Options for tank anchors

If the design for the tank anchor system is incorporated into the secondary containment floor, the additional tank loads must be accounted for in the secondary containment floor and reinforcing steel design.

Figure 2.11 shows two methods of incorporating anchors into the secondary containment floor. An engineered anchor system design shall be provided for each tank and the secondary containment concrete floor.



a. Tank floor plate anchor



b. Tank floor reinforcing bar anchor

Figure 2.11. Anchors incorporated into the tank floor.

Tanks can also be anchored to the soil or concrete anchors located outside the secondary containment structure. Acceptable anchor designs for this option can be found in Figures 2.12 and 2.13. This option eliminates the need for designing the secondary containment floor to support the additional tank loads and minimizes the potential for cracks in the floor due to the point loads from the tank anchors.

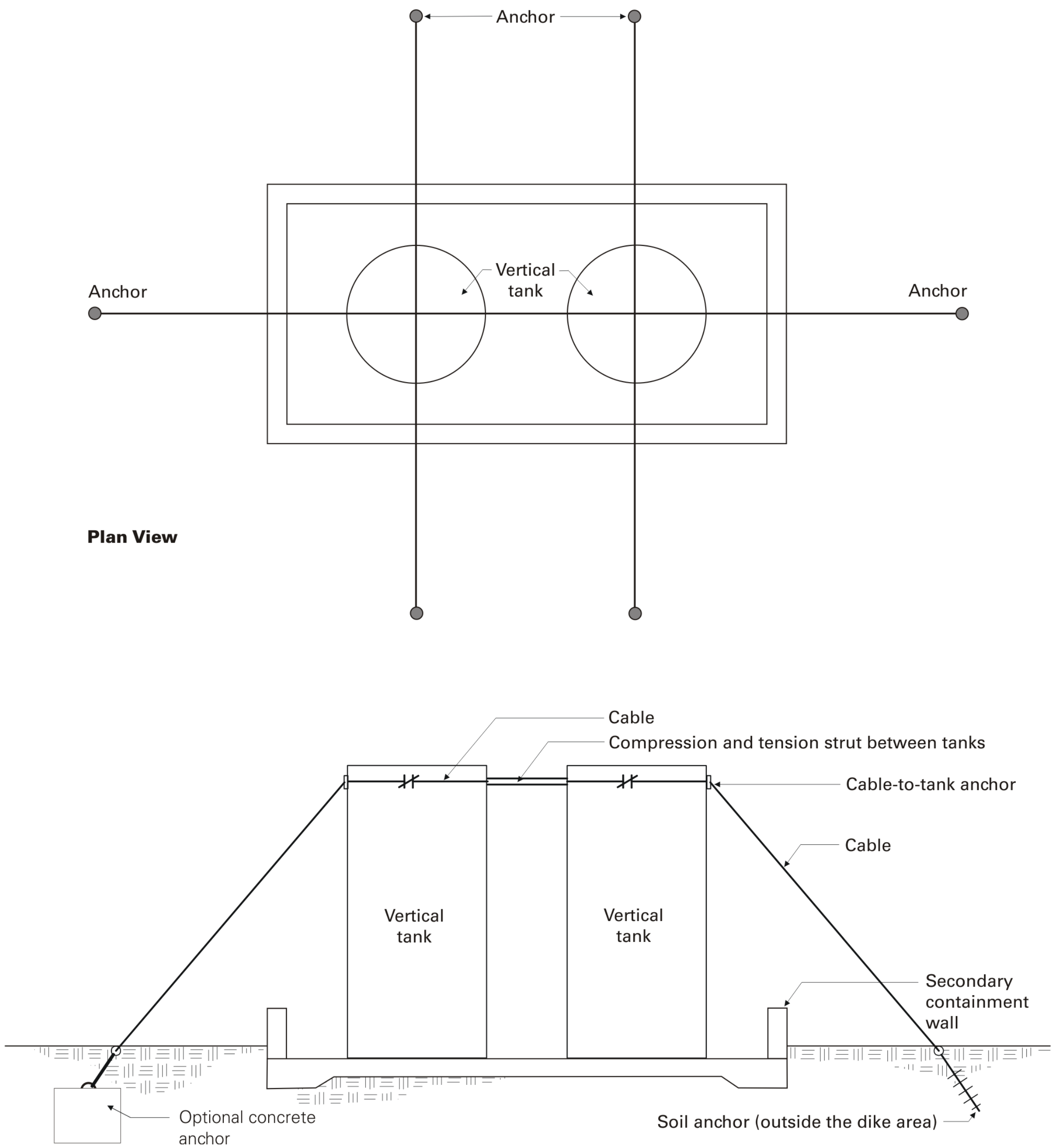


Figure 2.12. Cable anchors located outside the secondary containment structure for vertical tanks.

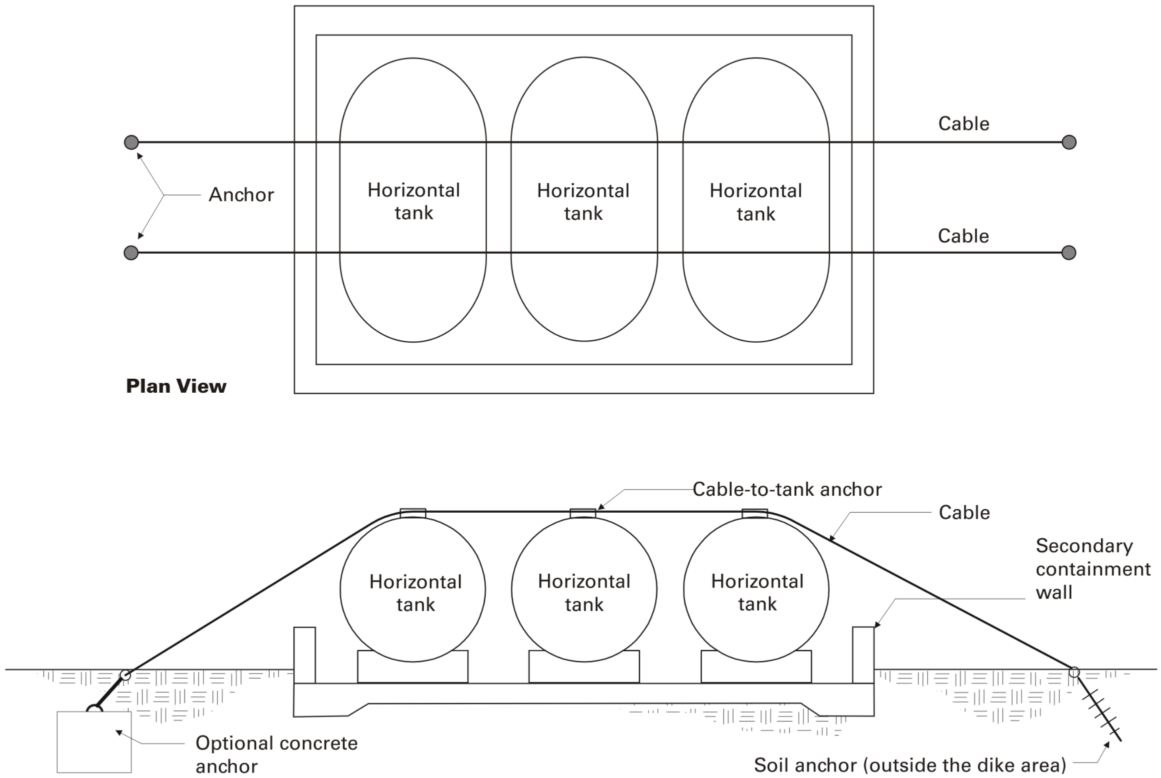


Figure 2.13. Cable anchors located outside the secondary containment structure for horizontal tanks.

Use cables to tie down vertical tanks in at least three equally spaced locations (e.g., 120 degrees apart around the tank's circumference) to prevent the tank from shifting. The cable and the connections of the cable to the tank and the ground anchor need to be strong enough to resist flotation and wind forces. Use cable strength specifications provided by the cable supplier.

Tank anchoring also can be accomplished by providing dead weights such as concrete blocks that sit on the secondary containment floor, Figure 2.14, or outside the secondary containment structure. See Table 2.9 for designs of concrete weights. In all cases, cables must be kept tight so tanks cannot shift.

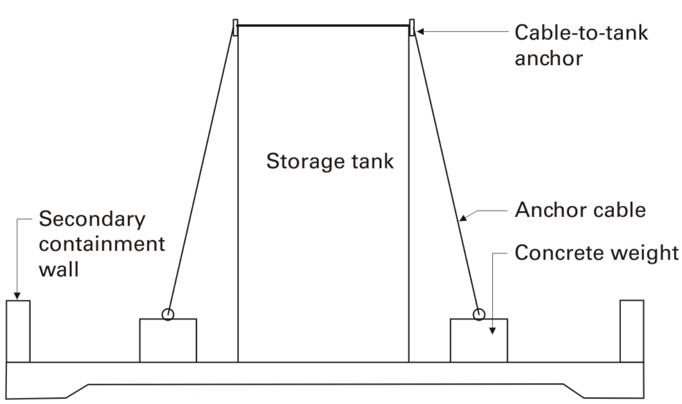


Figure 2.14. Tank anchoring system using concrete weights.

Table 2.9. Concrete weight design.
Use 60 grade steel and make bending diameter at least six times bar diameter.

Cube dimension, ft[a]	Rebar size	Restraint provided, lb — Fluid level around block[b]: None (R_0)	Submerged (R_s) (100 lb/ft^3)	Submerged (R_s) (70 lb/ft^3)
1	#3	150	50	80
1.5	#3	505	165	270
2	#3	1,200	400	640
2.5	#3	2,340	780	1,250
3	#3	4,050	1,350	2,160
3.5	#4	6,430	2,140	3,425
4	#5	9,600	3,200	5,120
4.5	#6	13,665	4,555	7,290
5	#6	18,750	6,250	10,000
5.5	#7	24,955	8,315	13,300
6	#8	32,400	10,800	17,280

[a]Cubed dimension (a) in figure above.
[b]If the blocks are in the containment area, the spilled fluid will tend to float the block. Submerged values are based on a fluid density of 100 lb/ft^3 and 70 lb/ft^3. Use linear interpolation to determine restraint if fluid level is part way up the block as follows:

$$R_h = R_o - \left[(a - h) + a \times (R_o - R_s) \right]$$

Where:

R_h = Restraint with fluid level at h, lb
R_o = Restraint with no fluid, lb
R_s = Restraint when block submerged, lb
a = Block dimension, ft
h = Fluid level from block bottom, ft

Chapter 3. Mixing and Loading Pad

David W. Kammel, Professor, Biological Systems Engineering Department,
University of Wisconsin Cooperative Extension

The mixing and loading pad is the main operational area of the pesticide and fertilizer storage facility. The mixing and loading pad is where application equipment or tender vehicles are parked when spray solutions are transferred to or from the batch mixing equipment, tender vehicle, and pesticide or fertilizer storage area. Soil, surface water, and groundwater can be contaminated in areas where pesticides and fertilizers are mixed and loaded into application equipment if this pad is not designed to intercept and retain the spilled products. Curbed and/or ramped concrete slabs (or their equivalent) are used to provide secondary containment at mixing and loading facilities. Worker safety and state and federal regulations must be taken into account in facility design.

Functions that occur on a mixing and loading pad include:

- Transferring and handling pesticides and fertilizers.
- Mixing batches of pesticide and fertilizer solutions.
- Loading application equipment.
- Unloading transport vehicles.
- Unloading and cleaning out application equipment.
- External washing of application equipment (Not recommended).

The mixing and loading pad is designed to catch leaks and spills that occur from:

- Small daily accidental spills or overflows from application equipment.
- Drips or leaks from plumbing and application equipment.
- Drips from detaching plumbing connections.
- Accidental spills from storage containers.

Mixing and Loading Pad Design

The size and dimensions of the mixing and loading pad depend on the functions performed on the pad and on the type and size of application equipment that will be parked on the pad. To catch any splashed water or boom sprays, design these pads to extend at least 5 feet beyond each end of the extended booms of application equipment. Consider the space needed for workers to get around and between pieces of equipment easily.

A mixing and loading pad can be considered a secondary containment structure for bulk pesticides, bulk fertilizer, and rinsate storage tanks. It must meet the largest storage capacity to meet either a secondary containment capacity or a mixing and loading pad capacity. Multiple product storage and uses of a single area (such as a mixing loading pad) can create management problems. Mixtures of fertilizer, pesticide, and rinsate and other possible wastes may be more difficult to use or dispose of properly.

Figure 3.1 shows a mixing and loading facility. The mixing and loading pad is sized for the application equipment used. The mixing and loading pad floor has a variable slope that increases uniformly from a level perimeter edge (highest elevation) to the shallow sump (lowest elevation).

The centerline valley has a constant slope toward the sump. Sloped access ramps from the edge of the mixing and loading pad are used to ensure that water from the surrounding watershed does not enter the pad. The entire pad could be roofed to prevent precipitation from entering.

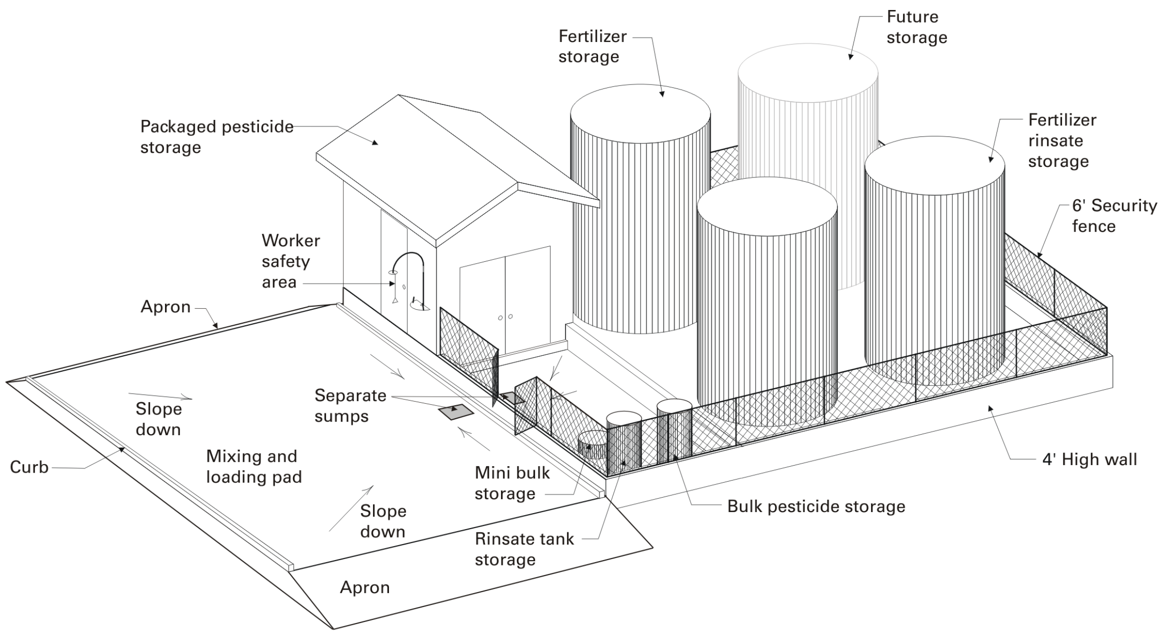


Figure 3.1. Plan view of mixing and loading facility.
The layout of mixing and loading pads can improve operational efficiency and worker safety while reducing environmental contamination risks. The capacity of the mixing and loading pad is designed to hold a minimum of 1000 gallons or 125 percent of the largest container if the largest container is 800 gallons or less. A curbed and sloped reinforced concrete slab is used to form an impervious barrier between the pesticide and fertilizer handling area and the soil below. Install sloping approach ramps (aprons) at vehicle entrances to minimize dust and trash accumulation on the mixing and loading pad. This also prevents surface water from the surrounding area from flowing onto the mixing and loading pad.

Slope the mixing and loading pad to drain liquid to a shallow sump. The sump is designed to temporarily hold rinsate for easy recovery and transfer to storage tanks (located within the secondary containment). If properly filtered and managed, liquid rinsate recovered from the sump may be reused in subsequent spray solutions.

Rinsate management

In most cases, rinsate liquid is recovered from the sump or depression on a routine basis after a loading or when a release occurs. Liquid level alarms may be installed to alert the operator when liquid enters a shallow sump. A pump must be available to transfer the liquid from the shallow sump into a rinsate storage tank located within the secondary containment. The rinsate storage tank must have a minimum available capacity of 200 gallons.

Pesticide and/or fertilizer contaminated precipitation is a major concern when using unroofed mixing and loading pads. The large volumes of contaminated water (rinsate) can be a major management problem. The rinsate is usually collected and stored until it can be used as makeup water in subsequent spray solutions. To minimize the management problems associated with potentially large volumes of contaminated precipitation (rinsate) that can be used in an appropriate manner, roofed mixing and loading facilities are recommended. The challenge for most managers is to keep the contaminated water from becoming a hazardous waste that requires the use of expensive disposal options compared to handling the contaminated water as a rinsate. Surrounding and roofing these areas with a building will keep precipitation from entering the mixing and loading pads and provide security. When a building is integrated into the design, the building loads must be accounted for in the overall design. Information in this document assumes the concrete floor and walls are independent of the building shell and therefore does not account for additional loadings from an attached building shell or other possible loadings from the use of the building. Security fencing should be installed around all mixing and loading pads if there is no building shell in the design.

Mixing equipment area

The pesticide mixing area is usually placed adjacent to the mixing and loading pad. If desired it can be designed as a separate area providing its own separate secondary containment area. Batch mixing tanks, temporary pesticide container storage, pesticide transfer pumps, and plumbing are usually placed in the mixing area. Additional mixing system components like pesticide metering tanks, punch/drain/rinse/crush units, rinsing vacuum probes, and equipment for holding, rinsing, and draining pesticide containers, can also be placed in this area to provide an efficient, safe mixing system.

Bulk fertilizer unloading pad

Large liquid fertilizer storage outlets may need a separate pad for receiving bulk truck shipments while the primary mixing and loading pad is in use, Figure 1.5 (from Chapter 1). A concrete slab with level side curbs and floors that slope to a shallow trough at the center (6-9 inches deep), which drains to a small, shallow sump can provide the required containment volume. Locate it along one side of the bulk fertilizer secondary containment structure. The maximum required capacity for this pad is 1,000 gallons.

Sumps

A sump is a liquid tight recessed area or combination of recessed areas that serve as a collection point for liquids from a mixing and loading pad or a secondary containment structure. Figure 3.2 shows the two common shapes of sumps, and Table 3.1 shows the dimensions that meet the following criteria:

Maximum capacity of less than 50 gallons for all interconnected areas.
Maximum depth of less than 24 inches below the surrounding secondary containment surface.
Maximum depth no greater than the shortest horizontal dimension.

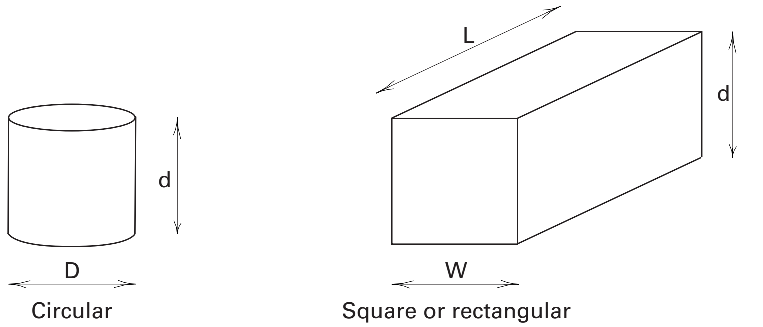


Figure 3.2. Sump definition for capacity and design dimensions.
Note: d ≤ 24".

Table 3.1. Rectangular and circular sumps.

a. Rectangular sump capacity

Width (W) inches	Length (L) inches	Depth (d) inches	Volume (V) cubic inches	Volume (V) gallons
12	40	24	11520	49.9
12	36	24	10368	44.9
12	24	24	6912	29.9
12	12	24	3456	15.0
9	71	18	11502	49.8
9	60	18	9720	42.1
9	48	18	7776	33.7
9	36	18	5832	25.2
9	24	18	3888	16.8
9	12	18	1944	8.4
9	9	18	1458	6.3
6	160	12	11520	49.9
6	72	12	5184	22.4
6	48	12	3456	15.0
6	36	12	2592	11.2
6	24	12	1728	7.5
6	12	12	864	3.7
6	6	12	432	1.9
3	642	6	11556	50.0
3	360	6	6480	28.1
3	180	6	3240	14.0
3	96	6	1728	7.5
3	72	6	1296	5.6
3	60	6	1080	4.7
3	48	6	864	3.7
3	36	6	648	2.8
3	24	6	432	1.9
3	12	6	216	0.9
3	3	6	54	0.2

V < 50 gallons
d < 24 inches
d < 2 * W

One gallon equals 231 cubic inches.

b. Circular sump capacity

Diameter (D) inches	Depth (d) inches	Volume (V) cubic inches	Volume (V) gallons
24	24	10857	47.0
18	24	6107	26.4
12	24	2714	11.8
28	18	11084	48.0
24	18	8143	35.3
18	18	4580	19.8
12	18	2036	8.8
9	18	1145	5.0
35	12	11545	50.0
24	12	5429	23.5
18	12	3054	13.2
12	12	1357	5.9
6	12	339	1.5
49	6	11314	49.0
36	6	6107	26.4
24	6	2714	11.8
18	6	1527	6.6
12	6	679	2.9
6	6	170	0.7
3	6	42	0.2

V < 50 gallons
d < 24 inches
d < 2 * D

One gallon equals 231 cubic inches.

Sumps are not intended to hold liquid for long periods. Rinsate collected in the sump is to be recovered immediately and transferred to a storage tank within a secondary containment structure. The regulatory requirements are to recover and transfer all discharges, spills, and/or rinsate to storage within a secondary containment upon discovery.

The sump is usually covered with an open structural grate for safety; a dust cover over the grate minimizes dust and debris blowing in. The sump grates and covers should support vehicle wheel loading. Sumps must be pumped out as necessary to prevent fluid from flooding the mixing and loading pad and subsequently being tracked off the pad by vehicle tires.

Soil and debris in sumps create a serious disposal problem of potentially hazardous waste. The sump should be cleaned out daily especially during the application season. It is more difficult to use contaminated solids like dirt, rock, and debris as a rinsate and apply the materials to a target crop in an appropriate way. The problem of pesticide-contaminated solids reinforces the value of enclosing the mixing and loading pads within a building shell to reduce solid hazardous waste problems resulting from blowing soil and debris.

Sumps constructed of concrete must be made placed in a continuous pour with the floor of the mixing and loading pad. The concrete thickness of the sump must be equal to or greater than the design thickness of the floor slab of the mixing and loading pad adjacent to it. Penetrations in the sides or bottom of a sump, including gravity drains, are not allowed. Several sump designs can be used in mixing and loading pads. A single sump is the simplest design.

Each secondary containment area or mixing and loading pad should have a separate sump placed monolithically in the floor slab of the system. Figure 3.3 shows how the secondary containment sump would be separated from the mixing and loading sump by the secondary containment wall and the mixing and loading pad curb.

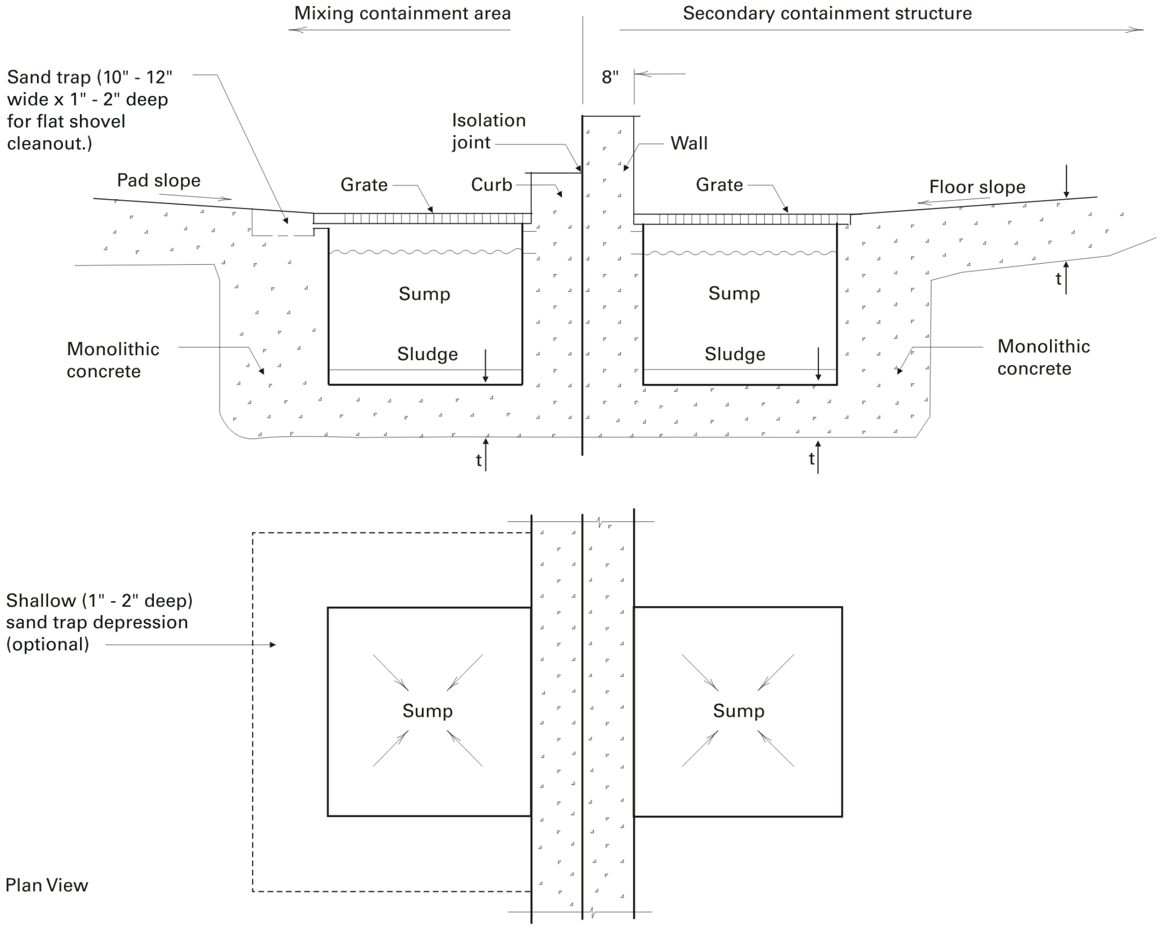


Figure 3.3. Separate sumps for mixing and loading pad and secondary containment structure. See Table 3.1 to size sumps

Center sump designs slope the concrete floor to the middle of the mixing and loading pad as shown in Figure 3.4. Portable pumps or suction hoses are placed in the depression to recover liquid. This design keeps the application equipment level for accurate gauging of tank volumes from visible markings on the tank. Table 3.2. shows rectangular and circular depression dimensions.

Table 3.2. Rectangular and circular depression dimensions.

a. Rectangular depression capacity					b. Circular depression capacity			
Width W inches	Length L inches	Depth d inches	Volume V cubic inches	Volume V gallons	Diameter D inches	Depth d inches	Volume (V) cubic inches	Volume (V) gallons
12	16	6	1152	5.0	15	6	1060	4.6
12	12	6	864	3.7	12	6	679	2.9
8	36	4	1152	5.0	19	4	1134	4.9
8	30	4	960	4.2	18	4	1018	4.4
8	24	4	768	3.3	12	4	452	2.0
8	18	4	576	2.5	8	4	201	0.9
8	12	4	384	1.7	22	3	1140	4.9
8	8	4	256	1.1	18	3	763	3.3
6	64	3	1152	5.0	12	3	339	1.5
6	48	3	864	3.7	6	3	85	0.4
6	36	3	648	2.8				
6	24	3	432	1.9				
6	18	3	324	1.4		V < 5 gallons		
6	12	3	216	0.9		d < 6 inches		
6	6	3	108	0.5		d < D/2		

V < 5 gallons
d < 6 inches
d < W/2
W < L

One gallon equals 231 cubic inches.

A pipe chase (placed monolithically) within the mixing and loading pad floor may be necessary to place plumbing and electrical conduit out of the way of vehicle and foot traffic, Figure 3.5. For example, it may be necessary to provide a pipe chase between a center sump and the secondary containment structure housing the storage tank where liquid is pumped automatically from the sump. This would prevent plumbing from lying on the floor surface and being damaged by vehicle traffic or becoming a trip hazard for workers. The pipe chase is considered part of the sump capacity requirements. Table 3.3 shows the possible dimensions of pipe chases that would meet the sump definition.

Table 3.3. Pipe chase dimension meeting sump or depression definitions.

Width (W) inches	Length (L) feet	Depth (d) inches	Volume (V) cubic inches	gallons
Pipe Chase Design			Sump Capacity	
3	106	3	11448	49.6
6	53	3	11448	49.6
12	26	3	11232	48.6
18	17	3	11016	47.7
4	60	4	11520	49.9
8	30	4	11520	49.9
12	20	4	11520	49.9
18	13	4	11232	48.6
3	53	6	11448	49.6
6	26	6	11232	48.6
12	13	6	11232	48.6
18	8	6	10368	44.9
24	6	6	10368	44.9

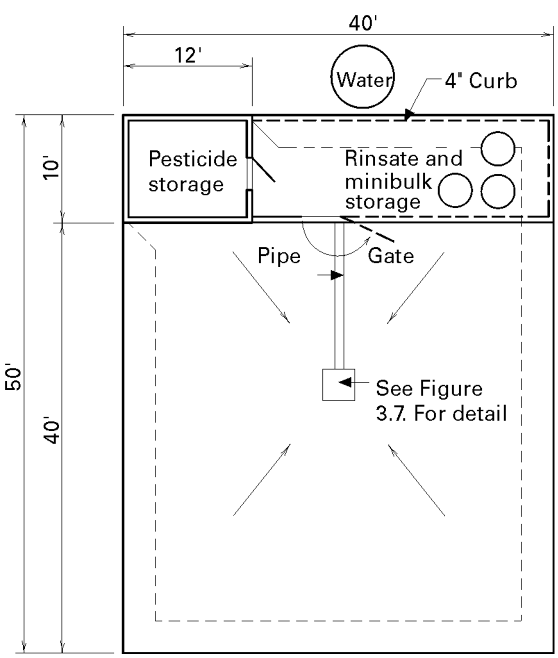


Figure 3.4. Center sump for mixing and loading facility.

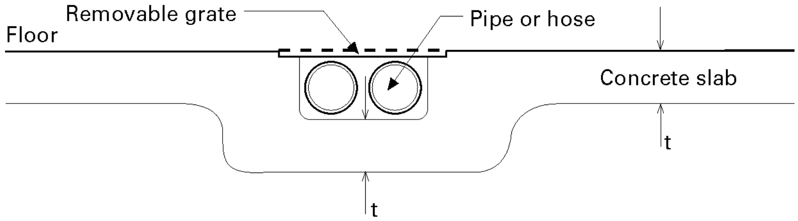


Figure 3.5. Pipe chase in concrete floor.

Side sump designs slope the floor to one side, most likely the side adjacent to the minibulk storage secondary containment area or mixing area as shown in Figure 3.6. The application equipment may be tilted and not read accurately from visual tank markings. It may be advantageous with the side sump design to provide automatic pumping of the sump to a rinsate storage tank. The side sump design also provides plumbing that will not be in the way of vehicle and foot traffic.

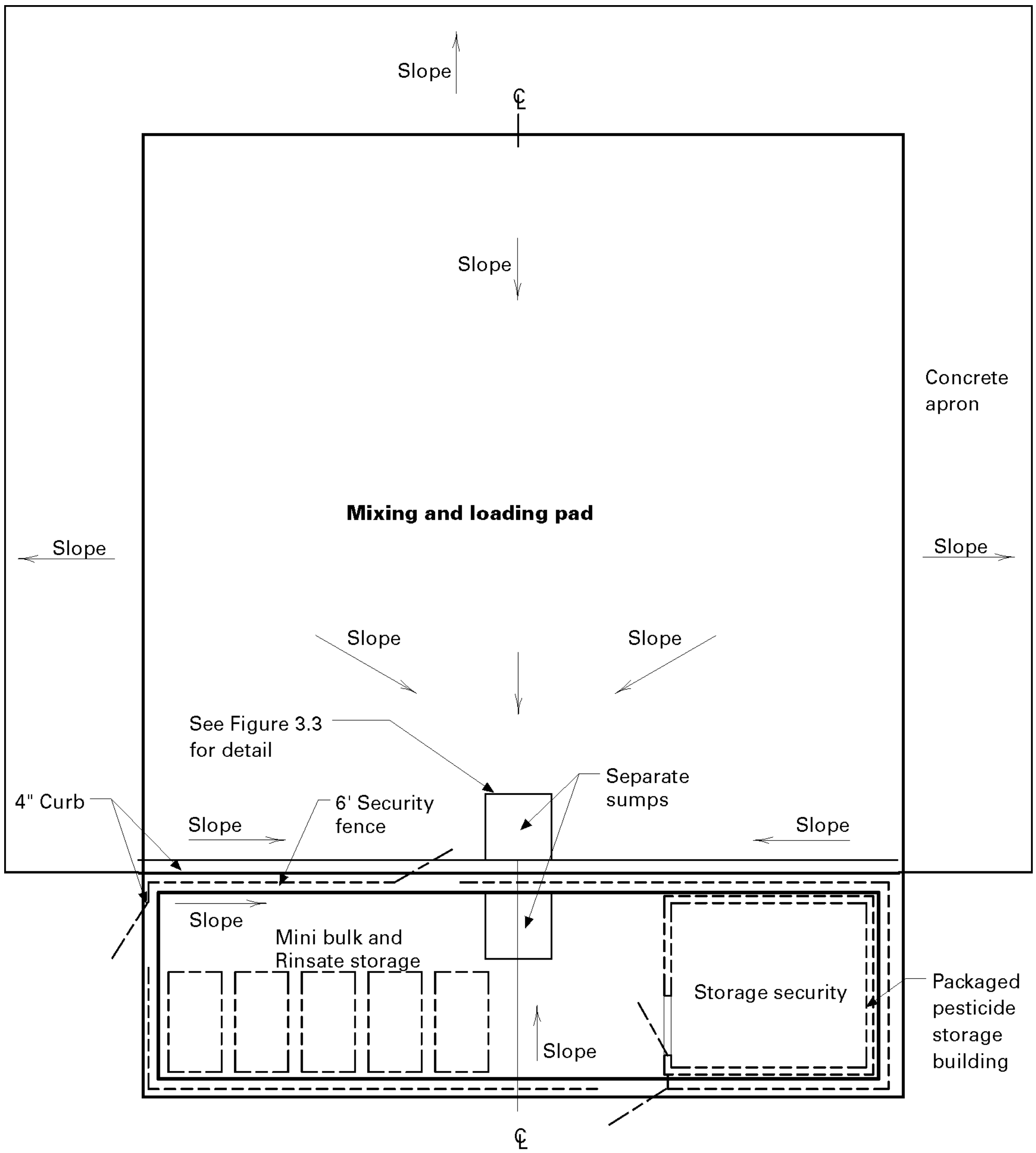


Figure 3.6. Example of side sump design in a mixing and loading pad.

One option to protect plumbing from a center sump or depression would be to build elevated ramp grates that would cover the plumbing and be placed on the floor surface as shown in Figure 3.7. The grates could be removable to allow the pad to be cleaned.

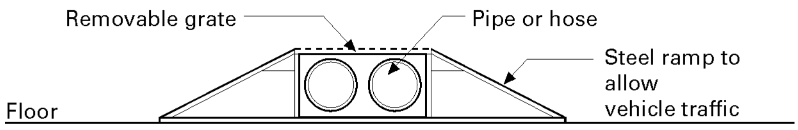


Figure 3.7. Elevated ramp with grates.

To reduce sludge (contaminated soil, rock, and debris) problems in mixing and loading pad sumps where applicator vehicles are washed, some facilities place two prefabricated stainless steel containers in series within a concrete sump, Figure 3.8.

Placing two containers in series within a sump allows segregation of rinsate and contaminated solids (Sludge). The first container acts as a sediment trap or settling basin where larger solids settle out before the liquids overflow into the second container. This design allows easy removal of the containers when they need to be cleaned out or decontaminated. As the water level rises in the first container, it is decanted off and enters into the second container. The pump or suction hose is placed in the second container. This water is filtered and transferred into rinsate storage within the secondary containment structure.

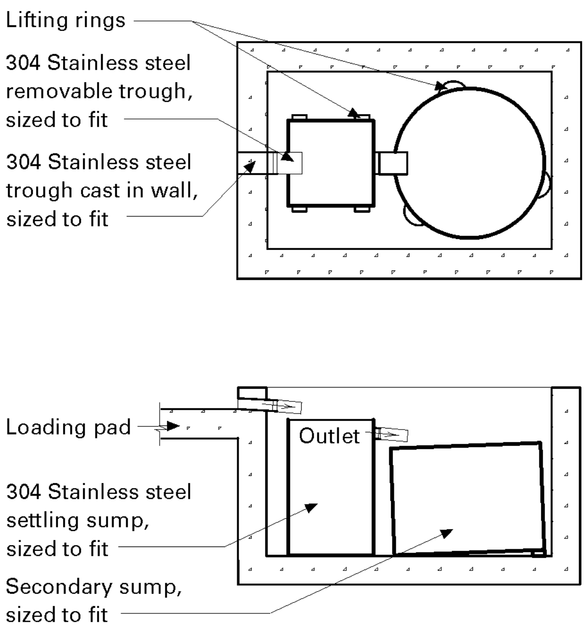


Figure 3.8. Removable stainless steel containers in series within concrete sump. Volume of sump must be less than 50 gallons.

Pumps and Plumbing Connections in Secondary Containment

In bulk handling systems, it is recommended to install transfer pumps, valves, and plumbing connections inside a stainless steel pan, Figure 3.9, or other chemical resistant drip pan or tub. If a seal in a pump, or a plumbing connection, or valve leaks, only the pan becomes contaminated and requires cleanup. Mount the pump motor base above the containment wall height or higher to prevent the pump from becoming submerged in the event of a release that could damage motor windings and/or create a serious electrocution hazard for workers. A disadvantage of elevating pumps is that higher levels of liquid are needed in tanks to prime pumps and/or not all of the product in a storage tank can be removed.

Drips also occur when switching hose connections to and from valves or manifolds. Use dry-break hose connectors to minimize drips during hose changes. Install shutoff valves and unions on each side of pumps so they can be easily drained for minimum leakage and removed for repairs.

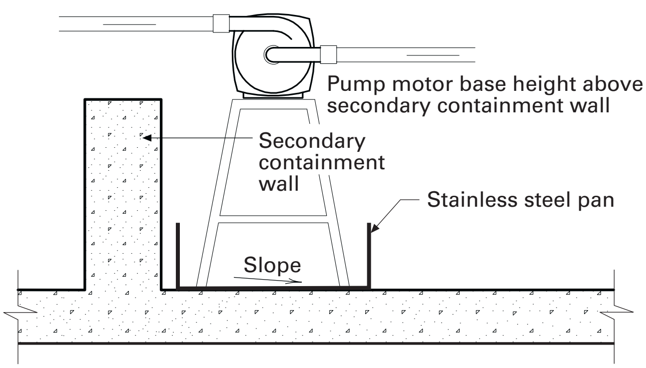


Figure 3.9. Separate pump secondary containment within larger secondary containment.

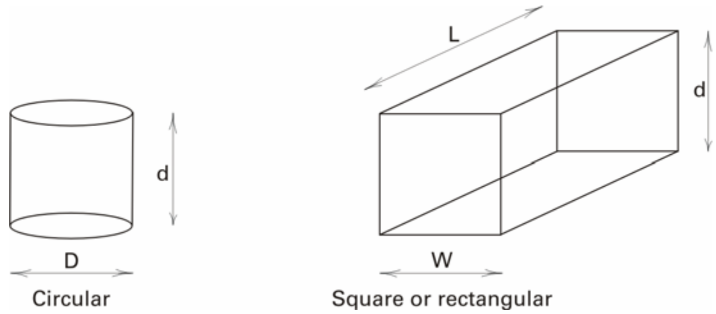


Figure 3.2. Sump definition for capacity and design dimensions
d ≤ 24”, d ≤ D, d ≤ W or L

Table 3.1. Rectangular and circular sumps.

Rectangular sump capacity

Width (W) inches	Length (L) inches	Depth (d) inches	Volume (V) cubic inches	Volume (V) gallons
36	36	8	10368	45
36	36	6	7776	34
36	36	3	3888	17
36	24	12	10368	45
36	24	6	5184	22
36	24	3	2592	11
36	18	12	7776	34
36	12	12	5184	22
30	30	12	10800	47
30	30	6	5400	23
30	24	12	8640	37
30	24	6	4320	19
24	24	20	11520	50
24	24	18	10368	45
24	24	12	6912	30
24	24	6	3456	15
24	18	18	7776	34
24	12	12	3456	15
24	12	6	1728	7
24	12	3	864	4
18	18	18	5832	25
18	18	12	3888	17
18	18	6	1944	8
18	12	12	2592	11
18	12	6	1296	6
18	12	3	648	3
12	12	12	1728	7
12	12	6	864	4

V < 50 gallons
d < 24 inches
d < W or L

One gallon equals 231 cubic inches.

Circular sump capacity

Diameter (D) inches	Depth (d) inches	Volume (V) cubic inches	Volume (V) gallons
48	6	10857	47
48	3	5429	24
36	10	10179	44
36	6	6107	26
36	3	3054	13
30	16	11310	49
30	12	8482	37
30	6	4241	18
30	3	2121	9
24	24	10857	47
24	18	8143	35
24	12	5429	24
24	6	2714	12
18	18	4580	20
18	12	3054	13
18	6	1527	7
12	12	1357	6
12	6	679	3

V < 50 gallons
d < 24 inches
d < D

One gallon equals 231 cubic inches.

Chapter 4. Concrete Materials and Properties

David W. Kammel, Professor, Biological Systems Engineering Department,
University of Wisconsin Cooperative Extension

Soils, Subgrade, and Subbase

For concrete floors to carry a designed load successfully without deterioration, the subgrade and, if needed, the subbase must be uniform and well compacted. The subgrade may need localized blending with backfill to provide adequate support for the structures. A subbase may be required over the subgrade if the subgrade in general is not adequate to support the structures. In some cases, a subbase over the subgrade may not be required, but will add some benefits in construction and performance, Figure 4.1.

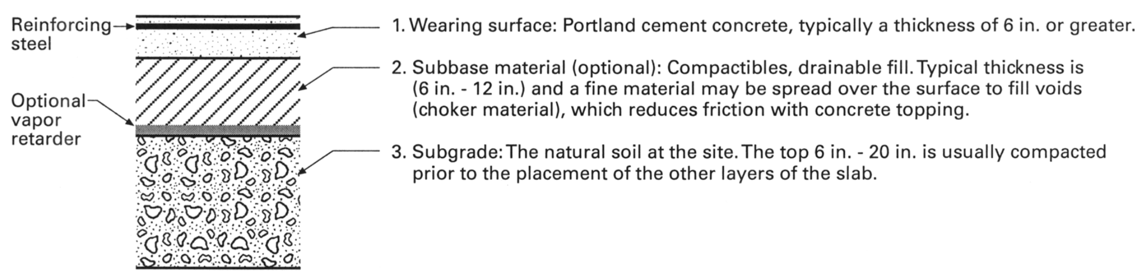


Figure 4.1. Concrete slab on subbase and subgrade.

Subgrade

The subgrade is the original ground, graded and compacted, on which the concrete floor slab is placed. Concentrated loads are spread over large areas by the concrete slab so pressures on the subgrade are usually low. Concrete floors do not usually require strong support from the subgrade, but the subgrade must be uniform, without abrupt changes from hard to soft. The upper portion of the subgrade must have uniform material and density. The strength of the soil (its supporting capacity and resistance to movement or consolidation) is important to the performance of concrete slabs, particularly when the slab must support extremely heavy uniform loads like flat- bottom storage tanks. Soil strength is affected by the degree of its compaction (density) and its moisture content. Compaction by rolling, tamping, or vibrating increases soil density and improves the structural properties of the soil.

The subgrade modulus is one measure of the quality of the subgrade and is related to the soil type. Table 4.1 shows the approximate relationship between subgrade modulus and soil types. The subgrade soil must be classified to identify potential problem soils. Problem soils are highly expansive, highly compressible, or do not provide reasonably uniform support. Where problem soils create non-uniform conditions, subgrade preparation is the most economical and effective method of correction.

Subgrade preparation

The subgrade should be uniform bearing capacity free of organic matter and frost. The subgrade should be either undisturbed or compacted to almost maximum density and moistened with water before concrete is placed. The subgrade cannot have standing or puddled water while the concrete is placed. Minimize variations of the subgrade to provide uniform support under the slab. The following are major causes of non-uniform support.

Expansive soils

Abnormal shrinkage and swelling of high-volume-change soils creates non-uniform support, which can cause the concrete slab to become distorted. Compaction of highly expansive soils when they are too dry can lead to detrimental expansion and softening of the subgrade during future wetting. If expansive soils are too wet when a concrete slab is placed, subsequent drying and shrinkage of the soil may leave portions of the slab unsupported. Selective grading, cross hauling from one part of the site to another, and blending of subgrade soils may be required to obtain uniform conditions in the upper part of the subgrade. For heavy loadings or poor soil conditions, hire a competent soils engineer to make a soils investigation, and design and submit a subgrade construction plan.

Table 4.1. Approximate relationship between soil classifications and subgrade modulus.

A detailed description of the method used to determine the subgrade modulus reaction of soil is given in ASTM D1196, *Non-Repetitive Static Plate Load Tests of Soils and Flexible Pavement components for Use in Evaluation and Design of Airport and Highway Pavements.* When plate bearing tests are not feasible at the jobsite, the k value may be conservatively estimated from the information below. This table is based on *Design of Heavy Industrial Concrete Pavements*, *Appendix A*.

	Classification system designation[a]		Design Subgrade Modulus (lb/in^3)[d]
Soil type	**Unified[b]**	**AASHTO[c]**	
Silts and clays	MLA4	CL	100
Sandy soils	GC SW SM SP SC	A-1-b A-2-6 A-2-7 A-3	200
			300
Sand gravels	GP GW	A-2-4 A-2-5 A-1-a	

[a]Soil surveys published by the National Cooperative Soil Survey (a joint effort of the United States Department of Agriculture's Soil Conservation Service and other federal, state, and local agencies) give estimates of the engineering for the major layers of each soil in the survey area.
[b]United soil classification system (ASTM Designation D2387-69).
[c]American Association of State Highway and Transportation Officials soil classification system (ASTM Designation D3282-73).
[d]Soils designated Pt, OH, and CH along with certain soils designated OL and MH in the United soil classification system and certain soils designated A-5, A-6, A-7-5, and A-7-6 in the AASHTO system are NOT suitable for use as a subgrade material.

Hard and soft spots

If the subgrade provides non-uniform support, the slab will bridge over soft spots and bear on hard spots, eventually cracking under heavy traffic loading. Take special care when excavating and backfilling to prevent localized soft or hard spots. Uniform support cannot be obtained merely by dumping granular material on the soft spot. At transition areas where soil types or conditions change abruptly, mix the replacement soil with the surrounding soil by cross hauling and blending soils to form a transition zone with nearly uniform support.

Backfill

Choose fill material that can be thoroughly compacted to improve the subgrade or raise the area to the desired grade. Backfill with soils like those that are in the surrounding area. Moisture and density conditions of a replacement soil should be similar to those found in adjacent soil. Compact backfill in layers no more than 6 inches thick. Plumbing and utility lines should not be placed under secondary containment structures. Poorly compacted subgrade can cause subsequent settlement problems and premature slab failure.

Frost heaving

In cold regions, frost heaving can cause cracks and serious structural damage to concrete floors. To reduce frost heave problems, drain water away from concrete slabs or walls. Construct a runoff control system around the secondary containment structures to keep water from entering the subgrade or base materials. Watch the runoff control system carefully for two to three years after construction as the landscaping around the site settles. Avoid any ponding near the site. In some cases, it may be necessary to build diversions or provide some drainage around the sites to prevent water from running through the site. Drain runoff from nearby buildings or lots away from the site by properly placed gutters and/or curbs.

Subbase

The subbase is a layer of granular material placed on top of the prepared subgrade, Figure 4.1. If the subgrade provides adequate support for the slab, a subbase may not be necessary. However, when grading and compaction do not produce a uniform subgrade, a granular subbase must be used to provide a more uniform support by equalizing minor subgrade defects. The granular subbase also can provide a capillary break to reduce water transfer and a stable working platform for construction equipment. It is seldom necessary or economical to increase the supporting capacity of the subgrade with a thick subbase. When needed, the subbase must be a minimum of 4-inch thick granular material compacted to near maximum density. If the subbase required is thicker, it must be placed in maximum thickness layers of 4- to 6-inch thick and compacted lifts.

Increasing subbase thickness beyond 4 inches results in only minor increases in subgrade support. Granular material for the subbase can be sand, sand-gravel, crushed stone, or combinations of these materials. A satisfactory, dense-graded material will meet the following requirements:

- Maximum particle size: Not more than 1/8 subbase thickness.
- Passing No. 200 sieve: 15 percent maximum.
- Plasticity index: 6 maximum.
- Liquid Limit: 25 maximum.

Vapor retarder

A vapor retarder can be used to provide additional protection against movement of product through the concrete or failure against impermeable coatings. Do not place concrete directly on a vapor retarder because it prevents drainage of excess bleed water from the slab base during curing and possible ice lenses after. The resulting uneven drying between the top and bottom of the slab aggravates cracking due to plastic and drying shrinkage. If a vapor barrier is used, place a 6- to 8-inch layer of compacted, self-draining granular fill subbase over the vapor retarder before placing the concrete slab, Figure 4.1. Experience has shown that a layer less than 6 inches thick may be slippery and could be damaged easily during concrete placement. Provide good drainage around the structure and a granular fill under the concrete to reduce the exposure of the concrete to subgrade moisture. If an impermeable coating is used on the top of the concrete, water vapor passing up through the concrete is sealed in the slab, which may cause the coating to fail.

Concrete Ingredients

Concrete is a mixture of a paste (consisting of Portland cement and water) surrounding a mixture of coarse and fine aggregates. As the hydration process proceeds, the mixture gains strength. Figure 4.2 shows the relative proportions of the materials used in concrete.

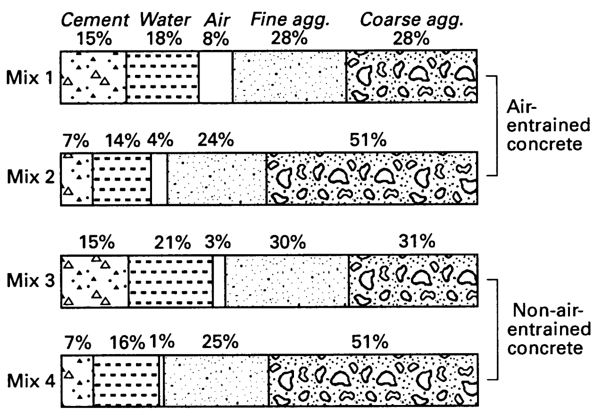


Figure 4.2. Concrete mix proportions.

Portland cement

Portland cement comprises only 7-10 percent of the mix. See Figure 4.2. It is a hydraulic cement (requires water) made up primarily of hydraulic calcium silicates. The Portland cement chemically reacts with water in a process called hydration. The paste (water and Portland cement) added to aggregates acts as an adhesive and binds the aggregates together to form the matrix called concrete. With modern concrete technology, high-strength concrete can be obtained with less cement than before. Where strength alone is the decisive criteria, less cement means greater economy. Surface durability, however, depends upon the surface hardness of the concrete as well as its internal strength and requires more cement. The relationship between cement content, air entrainment, and aggregate size is shown in Table 4.2.

Table 4.2. Cement content, air entrainment, and aggregate size requirements for watertight concrete.
With aggregates well graded up to the maximum practical size, less cement and air entraining are needed, so the mix is more economical.

Maximum size of Aggregate, in.	Cement lb/yd^3	Average air Entrainment, %
1.5	470	5
1	520	6
3/4	540	6
1/2	590	7
3/8	610	7.5

Fly ash

Fly ash and/or other pozzolans can be used to replace some of the Portland cement in the paste. Class F and Class C fly ash replacement of up to 25 percent of the Portland cement is typical. Fly ash as replacement for Portland cement increases strength, reduces permeability, improves durability, improves placing and finishing, and reduces cement content of the concrete. The amount of air-entraining admixture required to obtain a specified air content is normally greater when fly ash is used. Fly ash has a lower heat of hydration, reducing the amount of heat buildup during curing and retarding the setting time of the concrete.

Water

There needs to be enough water to allow the hydration of the paste to complete, but too much water can cause the concrete mix to shrink, which causes cracking. Water can be added only once at the site and only to adjust the slump to the specified value. In a batch, slump can be increased by 1 inch for every 10 pounds of water added per cubic foot of concrete. The potential amount of water to be added to meet the specified slump can be identified on the batch ticket. If the slump is not correct at the site, the owner should reject the load. Additional water can be added, but the owner then relinquishes any warranty on the concrete batch.

Slump

Slump is the measure of concrete workability. Table 4.3 shows slump requirements for liquid tight concrete without water-reducing agents. Excessive slump and consequent bleeding and aggregate segregation are a primary cause of poor performance in concrete slabs. If the finished slab is to be level, uniform in appearance, and durable, it is important that all batches placed have nearly the same slump. Low-slump concrete helps reduce finishing time and shrinkage cracking and can help eliminate surface defects and improve surface durability. Placing low-slump (1.5 to 3 inches) concrete flatwork requires the use of mechanical equipment such as a vibratory screed that rides on the side forms.

Table 4.3. Concrete Slump Requirements.

Slump Requirements	Maximum	Minimum
Flatwork	3 inch	1 inch
Walls	4 inch	1 inch

Water/Cement (W/C) ratio
The amount of water used in a concrete mix is specified as the water cement (W/C) ratio. Concrete needs at least a W/C ratio of 0.4 to provide complete hydration of the Portland cement paste. Figure 4.3 shows the relationship between W/C ratio and concrete compressive strength. A high W/C ratio will have higher shrinkage cracking, as the excess water not used in hydration moves out of the voids. The maximum allowable W/C ratio of 0.45 will provide concrete compressive strength of between 4,500 and 5,000 psi. The relationship between compressive strength and W/C ratio for air-entrained concrete is shown in Table 4.4.

A low W/C ratio provides the following features to concrete:

- Low permeability
- Reduced drying shrinkage and subsequent cracking
- Increased compressive strength
- Increased water tightness
-

Table 4.4. Relationship between W/C ratio and concrete compressive strength.

W/C ratio	Compressive strength (f_c')
.40	5,000 psi
.45	4,500 psi
.48	4,000 psi
.59	3,000 psi

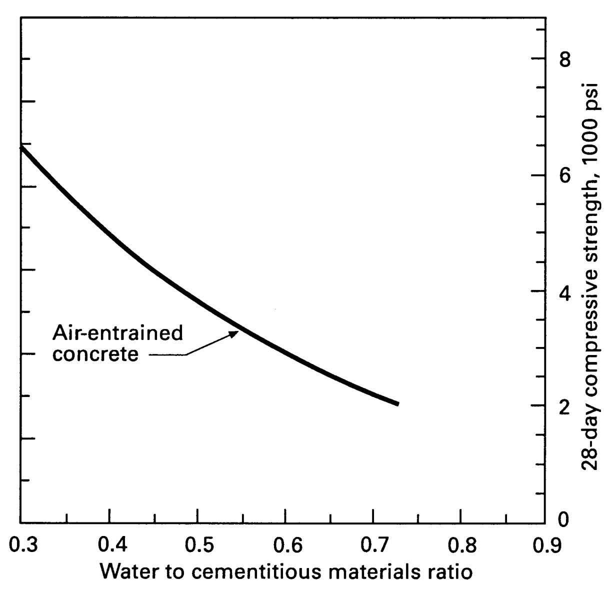


Figure 4.3. W/C ratio and concrete compressive strength.

Water-reducing admixtures

Water-reducing admixtures are used to reduce the quantity of mixing water required to produce concrete of a certain slump. Typically, water reducers can reduce water content 5 to 10 percent. This can help to provide a low W/C ratio. Water-reducing admixtures are needed to improve plasticity for easy placement of dry, stiff concrete mixes, even with air entrainment. Water-reducing admixtures temporarily improve plasticity and flowability (reduce slump) for about 45 to 75 minutes depending on the specific additive and temperature. Thus, difficult-to-place (low slump) mixes can be placed using minimum vibration with little aggregate segregation and no significant voids or bleeding. Eliminating voids improves strength and water tightness. Water-reducing admixtures can increase concrete compressive strength 10 to 25 percent by maintaining the W/C ratio.

Some concrete plants add admixtures as the truck departs the plant so the concrete mixes on the way to the job site. Other plants have the truck operator add the admixture upon arrival at the construction site to fully utilize the available plastic time limit. At a minimum, 25 to 30 revolutions of the mixer at mixing speed are needed to assure uniform distribution of the admixture. Once the time of plasticity passes, the concrete becomes stiff again and begins hardening.

Aggregates

Aggregates are the largest proportion of a concrete mix (70 to 85 percent of the mass). See Figure 4.2. They fill up the voids of the matrix, thereby requiring less paste to bind the matrix together. Aggregates must be of good quality and be just as chemically resistant as the paste. Do not use crushed limestone.

Reduce random shrinkage cracking by using concrete with a minimum shrinkage potential that contains the correct gradation of aggregates. The maximum size and the maximum amount of coarse aggregate (well graded) should be used to produce a mix that is consistent with placing and finishing methods. Selecting a larger aggregate size permits lower water content in the concrete and is more effective in restraining the shrinkage of the cement paste. Table 4.2 shows the maximum allowable aggregate size, cement content, and entrained air.

Coarse aggregate

Use the largest size of aggregate possible to keep the cement content to a minimum. The maximum aggregate size must not exceed:

- 3/4 the clear spacing between reinforcing bars and/or forms.
- 1/3 the depth of a slab.
- 1/5 the thickness of a wall

Fine aggregate

A well-graded aggregate will fill in the voids of the concrete, reducing the amount of cement needed and producing a denser concrete. Table 4.5 shows the specifications for a well-graded fine aggregate. With aggregates well graded up to the maximum practical size, less cement and air entraining are needed, so the mix is more economical.

Table 4.5. Grading specifications for fine aggregate.
(ASTM C 33/AASHTO M 6)

Sieve size	Percent passing by mass
9.5 mm (3/8 in.)	100
4.75 mm (No. 4)	95 to 100
2.36 mm (No. 8)	80 to 100
1.18 mm (No. 16)	50 to 85
600 µm (No. 30)	25 to 60
300 µm (No. 50)	5 to 30 (AASHTO 10 to 30)
150 µm (No. 100)	0 to 10 (AASHTO 2 to 10)

Air-entraining admixtures
Air-entraining admixtures are used to introduce and stabilize microscopic air bubbles into the concrete mix. This can improve the durability of concrete exposed to freeze thaw cycles. Workablity is also improved significantly. A small amount of purposely entrained air is useful in all concrete for reducing bleeding and increasing plasticity. To ensure resistance to scaling, concrete that will be exposed to cycles of freezing and thawing and to pesticides and fertilizers needs a total air content of 5.0 to 7.5 percent, depending upon the maximum size of the aggregate. (See Table 4.2.)

Properties of High Quality Concrete
High quality concrete is extremely important for secondary containment structures and mixing and loading pads to resist deterioration from pesticides and fertilizers and to maintain a watertight structure throughout its design life. Low quality concrete experiences rapid surface deterioration due to chemical attack, physical deterioration, and weathering, and it develops cracks that increase leakage and maintenance expense. The quality of the mortar is critical; the hardness and toughness of the coarse aggregate becomes significant only after the surface mortar has worn away. In flatwork, the workability of the concrete and the finishability of the surface are as important as the strength because they significantly affect the quality of the top 1/16 to 1/8 inch of the surface.

Permeability
Permeability refers to the amount of water migration through concrete or the ability to resist penetration by water or other liquids. Generally, the same properties of concrete that make it less permeable also make it watertight. Decreased permeability improves concrete's resistance to freeze thaw cycles and chemical attack. The Portland cement water paste permeability is related to the W/C ratio, the degree of hydration, and the length of time under a moist curing condition. Good quality, well-consolidated concrete at least 4 inches thick is practically impermeable to the passage of liquid water. The permeability of mature, good quality concrete is approximately 1×10^{-10} cm/sec. One of the best methods for decreasing permeability is to increase the moist curing period and to reduce the W/C ratio to less than 0.5.

Watertightness
Watertightness is the ability of concrete to hold back or retain water without visible leaking. Water leakage will be minimal with W/C ratios less than 0.45. Even though concrete will have cracks, it can be relatively watertight if the cracks are well distributed and small enough to not penetrate the entire thickness of the wall or floor.

Watertight concrete depends on nonporous aggregate being surrounded by high quality, watertight Portland cement and water paste. High quality cement paste requires the right amount and ratio of cement and water and proper moist curing for 7 to 28 days. Cements with high water content increase subsequent concrete shrinkage, which leads to excessive cracks in the concrete.

Air entrainment improves water tightness by improving workability, reducing segregation and bleeding, increasing density, and allowing a lower W/C ratio. Proportion mixtures so concrete can be placed without aggregate segregation. Workability of a stiff, watertight mixture requires vibration to consolidate the mass. During finishing, no excess bleed water should rise to the surface. In tests, there was no leakage through concrete disks with W/C ratio of less than 0.5 when moist cured for 7 days. As the length of the moist curing increased, leakage continued to decrease.

Durability

Durability is the ability to resist weathering, chemical attack, and abrasion. The surface durability of a concrete slab depends on concrete strength. Surface durability improves with a reduction in water content, an increase in cement content, or both. Reducing water content and increasing cement content both increase strength.

Freeze-thaw resistance

The most potentially destructive weathering factor is freezing and thawing. Freezing water and the subsequent expansion in the paste and aggregates causes concrete to deteriorate. Air entrainment in the concrete produces a concrete that is highly resistant to this action. Water is displaced in the microscopic air bubbles, relieving the hydraulic pressure the freezing water generates.

Chemical resistance

Type I (normal) or IA (normal with air entraining) Portland cement is commonly used in secondary containment structures. Air entrainment for most concrete is achieved by using air-entraining admixtures rather than air-entrained concrete. Additional protection can be enhanced with the application of suitable protective treatments. Use sealer materials that remain flexible after curing and aging and when subjected to cold weather. Common types of coatings are epoxies, silicones, polyurethanes, and polyureas. Use only Department of Agriculture, Trade and Consumer Protection (DATCP) approved materials for repairing cracks in containment structures.

If available, a Portland cement that is moderately resistant to sulfates can be used to reduce attack by sulfates and other chemicals. Type II, or Type IIA (air-entrainment incorporated by the manufacturer) Portland cement is suitable to resist 150- to 1,500-ppm sulfate. Type II Portland cement may not be available in many areas. Type V, a cement that is highly resistant to sulfate, is ideally suited to resist severe sulfate exposures of 1,500 to 10,000 ppm but is generally not available and costs more than other cements.

Concrete Mix Design

To get the right quality concrete, the order given to the ready mixed concrete supplier must be clear and contain all the following information: minimum compressive strength, minimum cement content, maximum amount of water, maximum size of coarse aggregate, slump, and amount of entrained air. To help ensure the concrete is impermeable and watertight, DATCP requires the concrete meet the following specifications:

- A compressive strength of 4,500 psi at 28 days
- A W/C ratio minimum of 0.45
- A maximum slump of 3 inches (Use of a water-reducing admixture is recommended to achieve easier workability at placement and improve water tightness and strength of low-slump concrete.)
- Five to 7.5 percent air entrainment

    - Use clean, drinkable mixing water at a pH = 5.0-7.0.
    - Use large (1 to 1.5 inch), clean, impervious aggregate.

Placement

A good quality concrete mix is only part of a good concrete project. The concrete must be placed properly in a well-designed project. To ensure the concrete is placed properly, the following guidelines are recommended:

- Allow no more than 30 minutes between truckloads of concrete during placement. Mix 70 to 100 revolutions at **mixing speed**, then an additional 200 to 230 revolutions (maximum of 300 total revolutions) at **agitating speed**.
- Discharge load within 1.5 hours.
- Minimize discharge drop distance by using a discharge chute.
- Continuous pour in one day, with no cold joints if possible.
- Use vibration during placement; vibrate at 5,000 to 15,000 rpm frequency for minimum aggregate segregation.

Placing concrete in hot weather

Hot weather is defined as any combination of high temperature, (generally above 80 degrees F), low relative humidity, and wind velocity tending to impair the quality of fresh or hardened concrete or otherwise resulting in abnormal properties.

Special provisions shall be made to immediately protect and cure the concrete due to rapid drying conditions. Concrete surfaces shall not be allowed to dry after placement and during the curing period. Wood form surfaces shall be kept continually moist.

In extreme conditions, it may be necessary to (1) restrict placement to late afternoon or evening, (2) restrict the depth of layers to assure coverage of the previous layer while it will still respond readily to vibration, (3) suspend placement until conditions improve.

Placing concrete in cold weather

When the minimum daily atmospheric temperature is less than 40 degrees F, concrete shall be insulated and/or heated immediately after placement. The temperature of the concrete and air adjacent to the concrete shall be maintained at not less than 50 degrees F nor more than 90 degrees F for the duration of the curing period.

The curing period may be reduced to 3 days when Type III cement is used. An additional 100 pounds of Type I cement and a maximum of 6 gallons of added water per cubic yard may be used in lieu of Type III cement.

Combustion heaters shall have exhaust flue gases vented out of the concrete protection enclosure and shall not be permitted to dry the concrete.
The contractor shall furnish the Technician a record of daily maximum and minimum outside air and concrete surface air temperatures during the curing period. The record shall include temperatures at several points along the concrete.

Finishing Concrete

Use a float finish on the surface with an aluminum or magnesium float to minimize coarse surface texture to improve washing and cleanup. Concrete surfaces to be coated with a sealant may need added grit for a rougher texture to improve sealant adhesion and worker safety.

Curing Concrete

Chemical hydration occurs when Portland cement and water are mixed, causing moisture evaporation due to heating. Chemical hydration influences concrete strength, durability, and density. Two factors that must be controlled during curing are evaporation rate and temperature. If evaporative cooling of the concrete is properly controlled during mild or hot weather, the concrete surface temperature remains at a satisfactory level.

Proper curing treatment of concrete after it has been finished is essential. Concrete must be kept moist so the cement will continue to combine chemically with the water. Start this curing process as soon as possible. If it is delayed and rapid evaporation takes place in the early stages, the surface may crack, craze, or dust. The longer the concrete can be kept wet, the stronger, more impervious, and more wear resistant it becomes. Exposed slabs are especially sensitive, as improper curing can significantly reduce surface strength development.

Curing determines the ultimate concrete durability, strength, water tightness, abrasion resistance, volume stability, resistance to freezing and thawing, and chemical resistance to pesticides and fertilizers. Moist curing requires maintaining satisfactory surface moisture content and temperature. Concrete should be moist cured at ambient temperatures above 40 degrees F for at least seven days. In this time concrete will develop 75 percent of its 28-day strength. If possible, a 28-day moist cure is preferred for maximum strength. During cold weather, additional heat and/or insulation will be needed to maintain curing temperatures between 50 and 70 degrees F. Concrete will continue to gain strength as long as it is moist cured. For example, concrete moist cured for 180 days will develop about 130 percent of the 28-day strength. To minimize trapped moisture bubbles in a sealant coating, allow several weeks for green concrete to cure before applying sealants.

Recommended procedures for moist curing concrete include:

- Ponding or immersion.
- Fogging or spraying.
- Periodic spraying. Saturating a covering provides evaporative cooling for hot weather curing.
- Sealing exposed concrete surfaces. Use polyethylene film, impervious paper, or membrane-forming curing compounds as soon as concrete surfaces are finished.
- Supplying additional moisture and heat. Use accelerated, strength-gain curing methods, such as live steam and heating pads, for cold weather curing.

The ponding or immersion method is preferred for hot weather placement, while supplying additional moisture and heat is best during cold weather. Fogging or spraying is an acceptable alternative to ponding or immersion in mild climates. Use insulated blankets, straw, or hay for covering when curing concrete at temperatures below 32 degrees F.

Controlling Cracks in Concrete

Concrete will crack. Proper design is a matter of controlling the cracks. Concrete cracks when tension caused by drying shrinkage exceeds the concrete's internal tensile strength. Cracks result from several reasons, including volumetric change due to drying shrinkage, direct stress due to applied loads, or flexural stress due to bending, frost heaving, and/or subgrade settlement. Cracks rarely affect the structural integrity or the durability of concrete significantly, but they may allow leakage, and they look bad.

Drying shrinkage is an unavoidable, inherent property of concrete that must be recognized and managed to minimize leaking cracks. The magnitude of shrinkage cracking is affected mainly by the water content of the mix measured as the W/C ratio. Less water means less shrinkage. More coarse aggregate in well-graded aggregate also limits shrinkage cracking. ***Do not use admixtures containing calcium chloride to accelerate curing, as they will increase drying shrinkage significantly.***

The following factors affect the amount and severity of cracking:

Water: The amount of water per bag of cement or per cubic yard of concrete is an important factor. Adding excess water increases the tendency towards shrinkage cracking. Water increases shrinkage and reduces strength. Use the lowest practical W/C ratio (0.4 to 0.45, for example, 188 to 212 pounds of water for 470 pounds cement) and aim for a slump of 1.5 to 3 inches.

Aggregate: The smaller the maximum size of well-graded aggregate, the greater the shrinkage of concrete at the same strength. ***Use a graded aggregate with maximum size of 1.5 inches.*** Because clay shrinks more than cement paste, small amounts of certain clays in aggregates cause high shrinkage and cracking.

Bleeding: The upward flow of water in fresh concrete causes pockets of watery paste under the larger pieces of aggregate, especially in deeper sections, which leads to internal voids or cracks and reduced water tightness and concrete strength.

Placing: The rate and conditions of placing affect cracking through bleeding and aggregate segregation in forms or around reinforcement. Let the concrete settle. Use vibration to aid concrete consolidation and settling, but avoid excessive vibration, which causes aggregate separation.

Curing: Moisture conditions during early and subsequent curing are very important. To prevent excessive drying, dampen the subgrade, subbase, forms, and aggregates. Start moist curing immediately using temporary covering or fog spray between placing and finishing, and/or use sunshades to reduce the rate of evaporation.

To reduce cracking in concrete use the following practices:

- Prepare the subgrade properly with correct moisture content.
- Minimize water content by maximizing the size and amount of coarse aggregate and by using low shrink aggregate.
- Use the lowest amount of mix water possible.
- Do not use calcium chloride mixtures.
- Prevent rapid loss of surface water by using spray-on finishers or plastic sheeting.
- Provide contraction joints at appropriate spacings.
- Provide isolation joints between separate structures to prevent restraint.
- If a vapor retarder is used below concrete, use a minimum 6-inch thick layer of slightly damp, compactable, drainable, fine-grade material.
- Properly place, consolidate, finish, and cure concrete.

Chapter 5. Concrete Design and Construction Details

David W. Kammel, Professor, Biological Systems Engineering Department,
University of Wisconsin Cooperative Extension

Concrete design involves three steps.

1. Specifying the proper concrete mix.
2. Specifying the correct design details.
3. Following correct construction practices to place the concrete.

Chapter 4 describes the specifications for concrete materials used in the mix. The following discussion describes the concrete structure design and important details of construction. Correct placement is the last key and will require experienced contractors and proper inspection.

Concrete Structural Design

Design all concrete facilities with two criteria in mind:

1. Design walls and floors to resist the potential tank loads and the hydrostatic and wheel loads that they may be subjected to. Liquid fertilizers are heavier than water and hydrostatic design loads range from to 70-100 lb/ft^3-ft of depth. The most common liquid fertilizers are 28-0-0 or UAN solution at 79 lbs/ft^3 (10.6 lbs/gal) and 10-34-0 at 85 lbs/ft^3 (11.4 lbs/gal). Check with the manufacturer for the density of specific fertilizers, or design for the highest density.

2. Design walls and floors with distributed reinforcing steel to resist cracking. This may require more reinforcing steel than the structural loads criterion.

A minimum of 4,500-psi concrete and Grade-60 reinforcing steel are required for all secondary containment structures and mixing and loading pads. Provide reinforcing support with chairs to position the reinforcing at the proper location in the slab thickness.

Reinforcing Steel

Reinforcing steel bar size and spacing is selected to control shrinkage cracking and/or to resist loads applied due to the use of the structure. A minimum of Grade-60 steel is required in all designs. Distributed steel is sized and spaced to hold together the shrinkage cracking that naturally occurs. These small, distributed shrinkage cracks usually do not penetrate the thickness of the slab or wall and still will provide a relatively impermeable liquid tight barrier. Reinforcement is also spaced to minimize crack width. Having smaller reinforcing bars spaced close together is better than having a few large reinforcing bars spaced far apart. To minimize shrinkage cracking, special effort should be made to reduce the subgrade friction.

Distributed steel can minimize the number of designed joints required in floor slabs. For example, it may be desirable for a mixing and loading pad not to have any joints. Small cracks will occur, but sufficient amounts of distributed steel hold these small distributed cracks together tightly to allow load transfer due to aggregate interlock. Distributed steel does not prevent cracking, compensate for poor subgrade preparation, or increase load carrying capacity. Distributed steel must be cut 2 inches before any designed isolation, contraction, or construction joint. A single layer of distributed reinforcing steel is commonly used in mixing and loading pads. For secondary containment floors, two layers of reinforcing steel must be used to carry the varying moments due to tank loads.

When a single layer of reinforcing is used, it must be placed above the midpoint of the slab. Reinforcing must have at least 11/2 inches of cover at top and 3 inches of cover above the soil surface. The spacing between reinforcing bars also must be large enough to allow aggregate to move between the layers. Bolsters or support accessories such as chairs should be used to support the reinforcing mat(s). Reinforcement and supports should support foot traffic of the concrete placement crew without permanent downward displacement.

Check embedment length for wall-to-floor connections. Embedment length depends on bar size and is needed to develop the tensile load of the reinforcing bar. If embedment length is insufficient, the reinforcing bar will pull out of the concrete before it can transfer the entire load the steel can handle. Table 5.1 shows the embedment length required for different size bars and 2-inch concrete cover. The minimum reinforcing cover for all reinforcing bars is 2 inches.

Table 5.1. Embedment length for 4,500 psi concrete using 60-grade steel*.

Bar size	Cross-sectional area (sq in)	Bar diameter, d (inches)	Embedment length, (inches)
4	0.20	0.500	14
5	0.31	0.625	18
6	0.44	0.750	21
7	0.60	0.875	40
8	0.79	1.000	45

* Multiply table values by 1.2 for epoxy-coated bars.

Floor Slab Design

Floors are designed as slabs on grade. The slab thickness depends on the type of loads on the floor slab. In most cases, the slab thickness is designed as an unreinforced concrete section. Reinforcing is added to control shrinkage cracking and maximize the distance between designed joints. Floor performance is influenced by:

- Uniformity of subgrade and bearing capacity
- Quality concrete
- Structural adequacy (thickness)
- Load transfer at joints
- Type and spacing of joints
- Workmanship
- Under slab treatments (vapor retarders)
- Concrete moisture content and drying rate

Secondary containment floor design

Storage tank loads control thickness for secondary containment floor slabs. See Table 5.2 for the slab thickness required for various loadings and for reinforcing steel areas for secondary containment floors with tank loading only. Reinforcing is selected to minimize crack width and reduce joints needed to control shrinkage cracking. See Table 5.3 for reinforcing schedules for secondary containment floor slabs on grade. Two layers of steel bar reinforcement are needed for secondary containment floors because tank loads induce both positive and negative bending moments in the floor.

Figure 5.1 shows the design detail for a secondary containment floor slab with two layers of reinforcing.

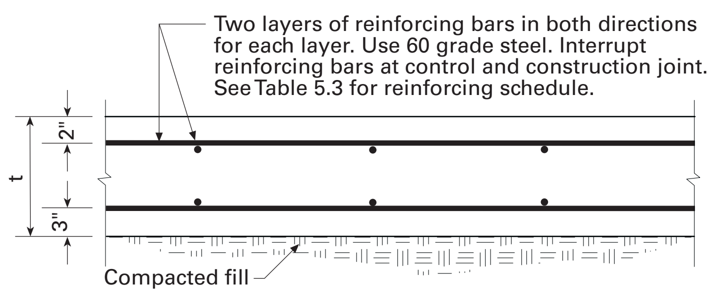


Figure 5.1. Concrete detail for secondary containment floor with two layers of reinforcing. (See table 5.2 for concrete thickness, t).

Table 5.2. Slab thickness and reinforcing steel areas for secondary containment floors with tank loading only. See Figure 5.1 for details.

Subgrade modulus	Maximum tank Height, feet	Concrete thickness, inches	Joint spacing: Less than 10'	10' to less than 20'	20' to less than 30'	30' to less than 40'	40' to less than 50'
			Steel Area (sq. in.) /ft. width of slab Grade-60 Steel				
k = 100	10	8	.400	.400	.400	.480	.576
	15	10	.620	.620	.620	.620	.720
	20	12	.880	.880	.880	.880	.880
	25	14	1.20	1.20	1.20	1.20	1.20
	30	14	1.58	1.58	1.58	1.58	1.58
k = 200	10	8	.400	.400	.400	.480	.576
	15	10	.620	.620	.620	.620	.720
	20	12	.620	.620	.620	.720	.864
	25	14	.880	.880	.880	.880	1.008
	30	14	1.20	1.20	1.20	1.20	1.20
k = 300	10	8	.400	.400	.400	.480	.576
	15	10	.620	.620	.620	.620	.720
	20	12	.620	.620	.620	.720	.864
	25	14	.620	.620	.672	.840	1.008
	30	14	.880	.880	.880	.880	1.008

Table 5.3. Reinforcing schedule for secondary containment floors with tank loading only.
Two layers of reinforcing steel. Maximum spacing 12 inches on center. Reinforcing bar size to be not less than #4. See Figure 5.1 for details.

Subgrade modulus	Maximum tank Height, feet	Concrete thickness, inches	Joint spacing: Less than 10’	10’ to less than 20’	20’ to less than 30’	30’ to less than 40’	40’ to less than 50’
			Reinforcing bar size and spacing 2 layers reinforcing @ maximum 12” o.c. spacing each way Grade-60 Steel				
k= 100	10	8	#4 @ 12”	#4 @ 12”	#4 @ 12”	#4 @ 10”	#4 @ 8”
	15	10	#5 @ 12”	#5 @ 12”	#5 @ 12”	#5 @ 12”	#5 @ 10”
	20	12	#6 @ 12”	#6 @ 12”	#6 @ 12”	#6 @ 12”	#6 @ 12
	25	14	#7 @ 12”	#7 @ 12”	#7 @ 12”	#7 @ 12”	#7 @ 12”
	30	14	#8 @ 12”	#8 @ 12”	#8 @ 12”	#8 @ 12”	#8 @ 12”
k= 200	10	8	#4 @ 12”	#4 @ 12”	#4 @ 12”	#4 @ 10”	#4 @ 8”
	15	10	#5 @ 12”	#5 @ 12”	#5 @ 12”	#5 @ 12”	#5 @ 10”
	20	12	#5 @ 12”	#5 @ 12”	#5 @ 12”	#5 @ 10”	#6 @ 12
	25	14	#6 @ 12”	#6 @ 12”	#6 @ 12”	#6 @ 12”	#6 @ 10”
	30	14	#7 @ 12”	#7 @ 12”	#7 @ 12”	#7 @ 12”	#7 @ 12”
k= 300	10	8	#4 @ 12”	#4 @ 12”	#4 @ 12”	#4 @ 10”	#4 @ 8”
	15	10	#5 @ 12”	#5 @ 12”	#5 @ 12”	#5 @ 12”	#5 @ 10”
	20	12	#5 @ 12”	#5 @ 12”	#5 @ 12”	#5 @ 10”	#6 @ 12
	25	14	#5 @ 12”	#5 @ 12”	#5 @ 10”	#6 @ 12”	#6 @ 10”
	30	14	#6 @ 12”	#6 @ 12”	#6 @ 12”	#6 @ 12”	#6 @ 10”

Mixing and loading floor design

Vehicle loads control floor thickness for mixing and loading pad floor slabs. The concrete slab thickness is determined based on estimated wheel and axle loadings, and soil subgrade design factors. Table 5.4 shows the thickness of concrete needed for various axle loads. Reinforcing schedules for a mixing and loading pad floor slab on grade with one layer of reinforcing are shown in Tables 5.5(alternate) and 5.6. Figures 5.2 through 5.4 show the design detail for a mixing or loading pad floor slab with one layer of reinforcing.

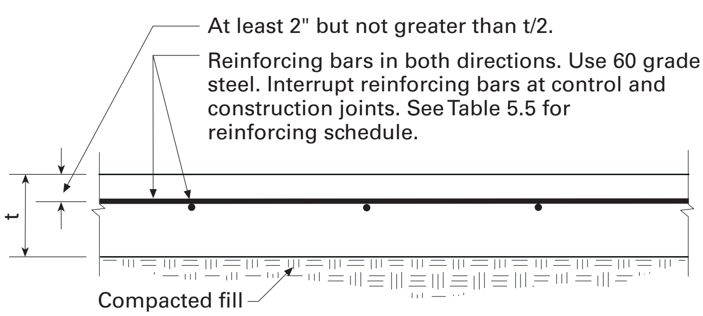


Figure 5.2. Concrete detail for mixing and loading pad floor with one layer of reinforcing. (See table 5.4 for concrete thickness, t).

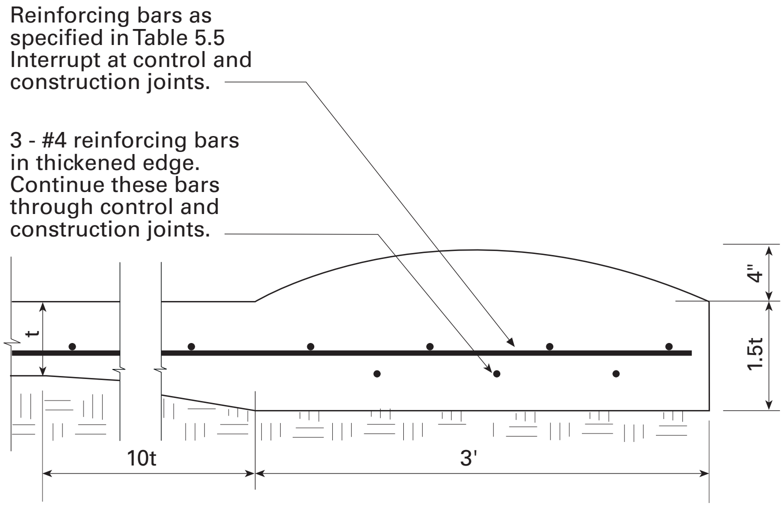


Figure 5.3. Concrete detail for mixing and loading pad floor with integral drive over curb. (See table 5.4 for concrete thickness, t).

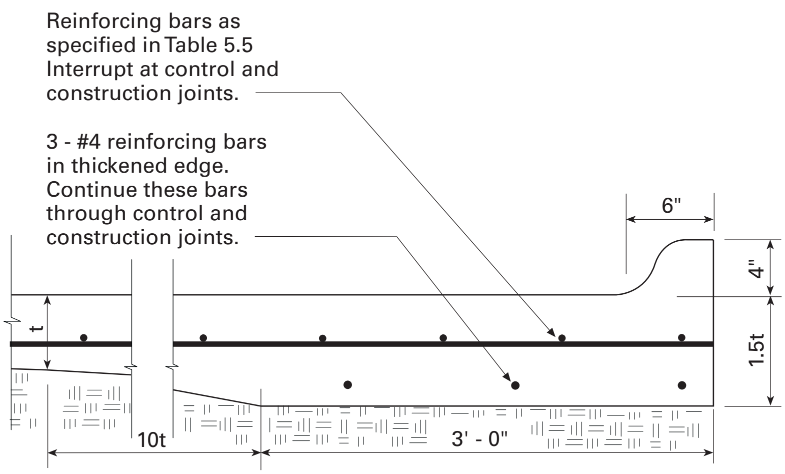


Figure 5.4. Concrete detail for mixing and loading pad floor with integral edge curb. (See table 5.4 for concrete thickness, t).

Concrete sump design

Sumps and depressions must be constructed from a monolithic pour of the concrete used in the floor of the mixing and loading pad or secondary containment structure. They are designed to be liquid tight with no joints or penetrations. The reinforcing schedule and construction detail for a sump and depression is shown in Figure 5.5.

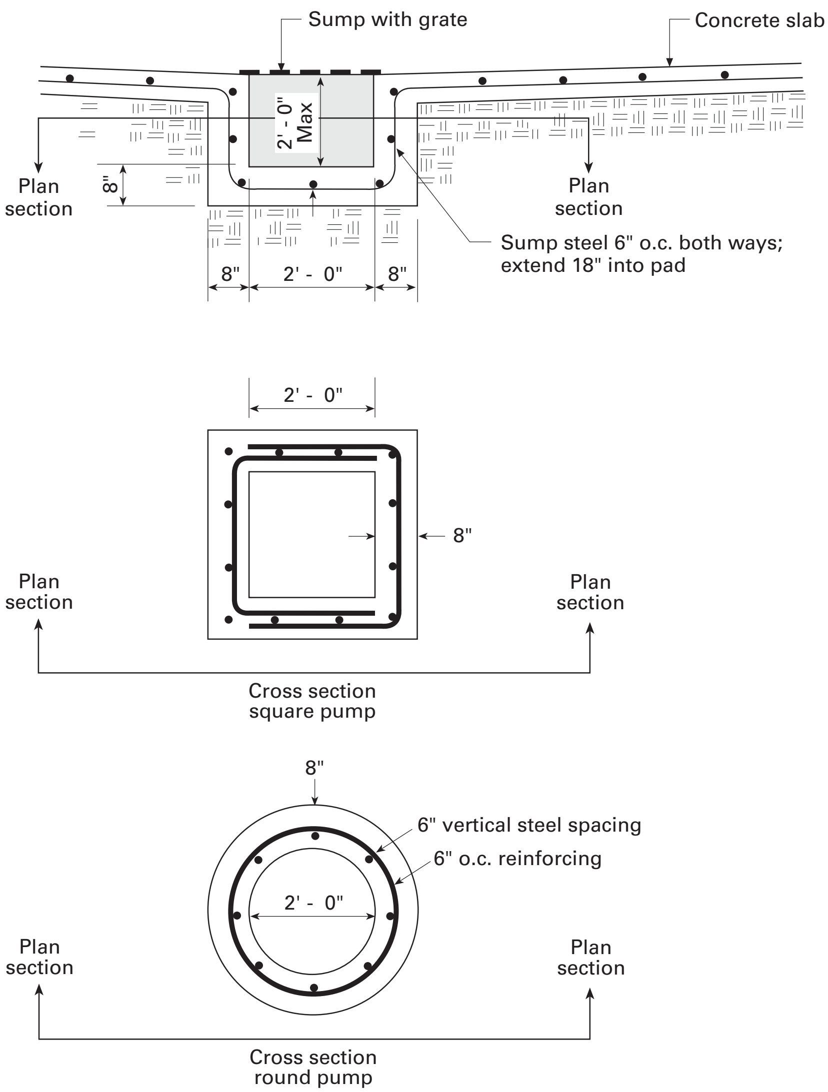


Figure 5.5. Sump or depression reinforcing schedule and design detail.

Table 5.4. Mixing and loading floor slab thickness design.

		Slab thickness, inches	
Subgrade modulus	**Axle load, lbs**	**Single wheels**	**Dual wheels**
k = 100 pci	10,000	6	6
	15,000	6	6
	20,000	8	7
k = 200 pci	10,000	6	6
	15,000	6	6
	20,000	8	6
k = 300 pci	10,000	6	6
	15,000	6	6
	20,000	6	6

Table 5.5. Reinforcing areas for mixing and loading pad floors with vehicle loading only. Single layer reinforcement. Maximum spacing of 12 inches on center. Reinforcing bar size to be not less than #4. See Figures 5.2 through 5.4 for detail.

Concrete thickness, inches	Joint spacing				
	Less than 10'	10' to less than 20'	20' to less than 30'	30' to less than 40'	40' to less than 50'
	Steel area (sq.in.)/ft. of slab width Grade-60 Steel.				
6	.144	.216	.288	.360	.432
7	.200	.252	.336	.420	.504
8	.200	.288	.384	.480	.576
10	.240	.360	.480	.600	.720
12	.288	.432	.576	.720	.864

Table 5.6. Reinforcing schedule for mixing and loading pad floors with one layer of reinforcing. Single layer reinforcement. Maximum spacing of 12 inches on center. Reinforcing bar size to be not less than #4. See Figures 5.2 through 5.4 for detail.

Concrete Thickness, inches	Joint spacing				
	Less than 10'	10' to less than 20'	20' to less than 30'	30' to less than 40'	40' to less than 50'
	Bar size @ spacing Single layer steel spaced each way. Grade-60 Steel.				
6	#4 @ 12"	#4 @ 11"	#4 @ 8"	#5 @ 10"	#6 @ 12"
7	#4 @ 12"	#4 @ 9"	#5 @ 11"	#6 @ 12"	#6 @ 10"
8	#4 @ 12"	#4 @ 8"	#5 @ 9"	#6 @ 11"	#6 @ 9"
10	#4 @ 10"	#5 @ 10"	#6 @ 11"	#7 @ 12"	#7 @ 10"
12	#4 @ 8"	#5 @ 8"	#6 @9"	#7 @ 10"	#8 @ 11"

Secondary containment wall design

Most secondary containment walls are designed on top of a slab on grade to provide an easy and practical way of creating a liquid tight joint between the wall and the floor. Figure 5.6 shows the concrete wall detail for a wall on a floating slab on grade. Additional secondary containment wall loads might include:

- Plumbing and other equipment loads (overhead)
- Hydraulic loads (on walls)
- Storage tank anchor loads (on walls or floors)
- Wind and snow loads on building

The secondary containment wall designs here account only for a hydrostatic load. Since building loads (including wind), anchor loads, and plumbing loads can vary significantly from one site to another these loads are not accounted for in the reinforcing schedules or design details. A professional engineer must account for these additional loads in the design of the structure.

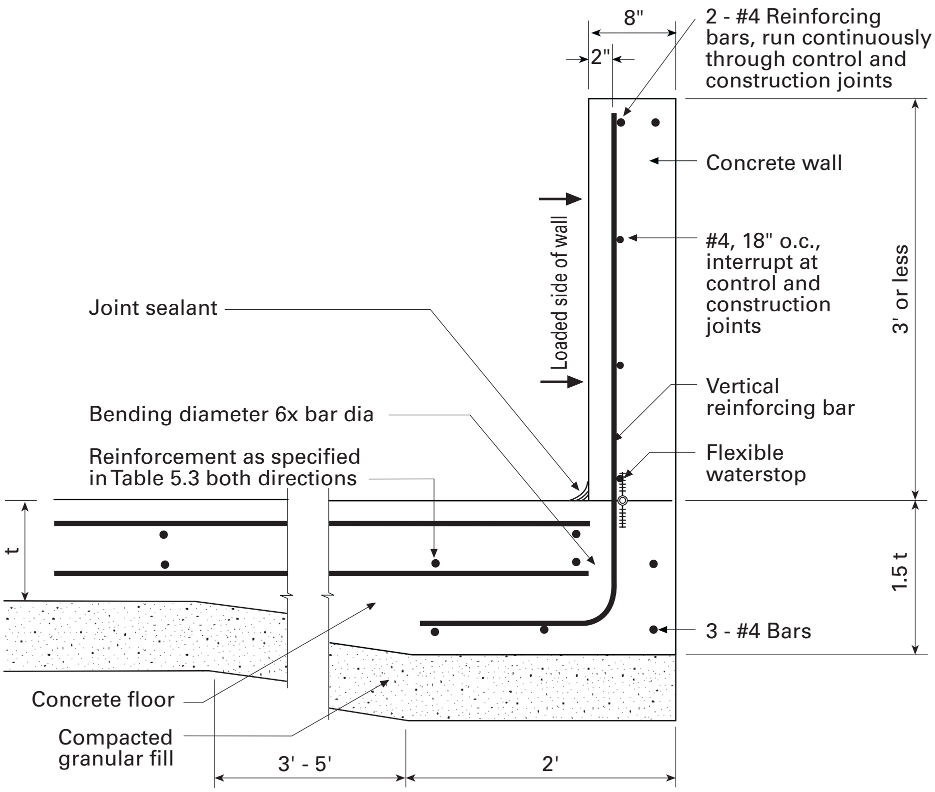


Figure 5.6. Reinforcing schedule and design detail for secondary containment wall.

Figure 5.7 shows the concrete detail for a frost wall for a synthetic liner supported by a concrete wall. When a frost wall is used as a secondary containment wall, providing a liquid tight joint between the wall and the concrete floor is more difficult.

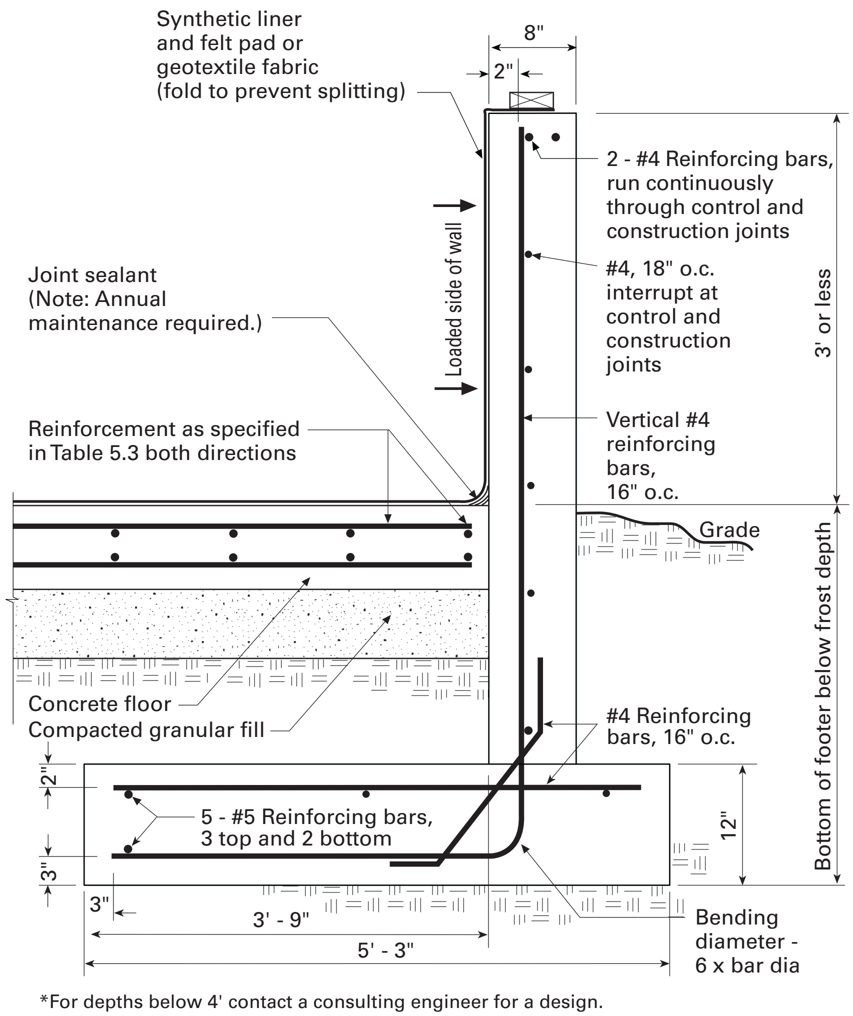


Figure 5.7. Frost wall for structural support of a synthetic liner.

Concrete Joints

Some joints in concrete construction are necessary. However, the watertight construction needed for secondary containment is enhanced when the design requires minimal joints. There are places where no joints are allowed (for example in the "no-joint zone" of a mixing loading pad). The common joints used in concrete slab and wall construction are isolation, construction, and control (contraction) joints. Figures 5.8, 5.9, and 5.10 show locations of the common joints in mixing and loading pads. Figure 5.11 shows common joint locations in secondary containment structures.

Any joints that are likely to be in contact with liquid must be designed as wet joints. Joints that are not likely to be in contact with liquid for long periods can be designed as dry joints.

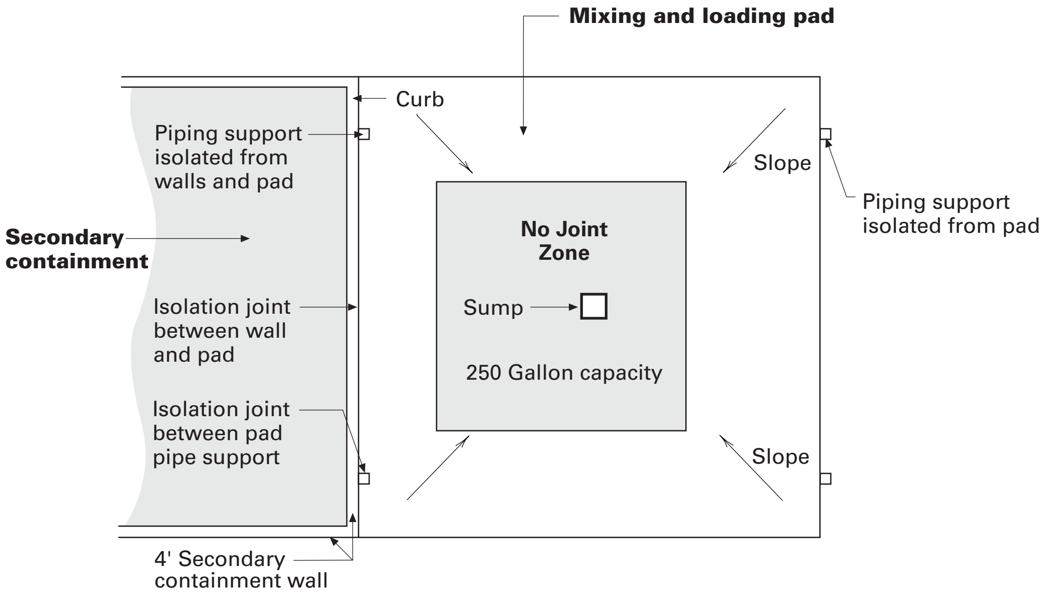


Figure 5.8. Common joints in mixing and loading pad (center sump design) Note location of piping supports.

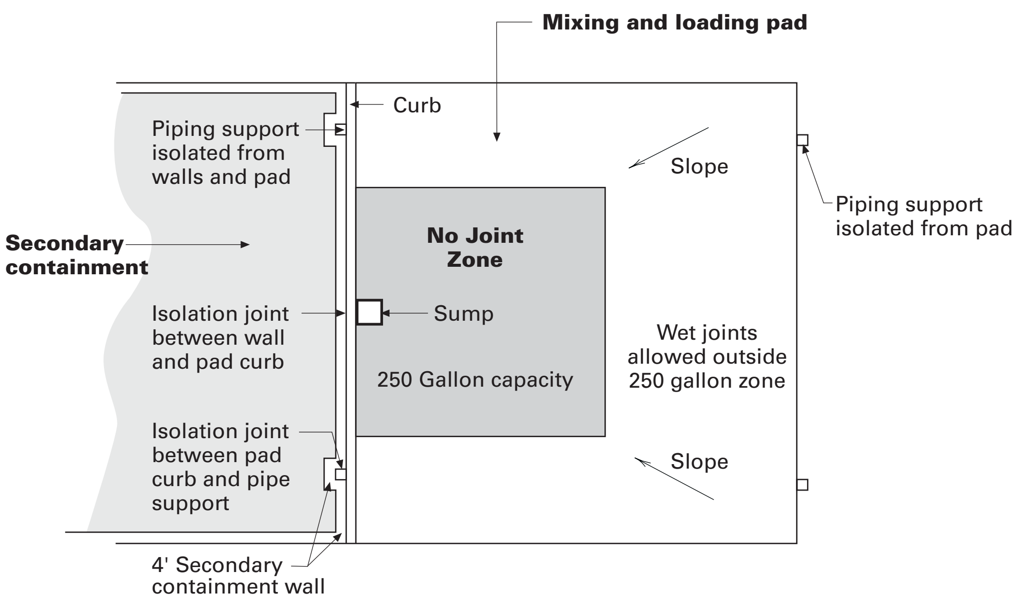


Figure 5.9. Common Joints in mixing and loading pad (side sump design). Note location of piping support outside mixing and loading pad.

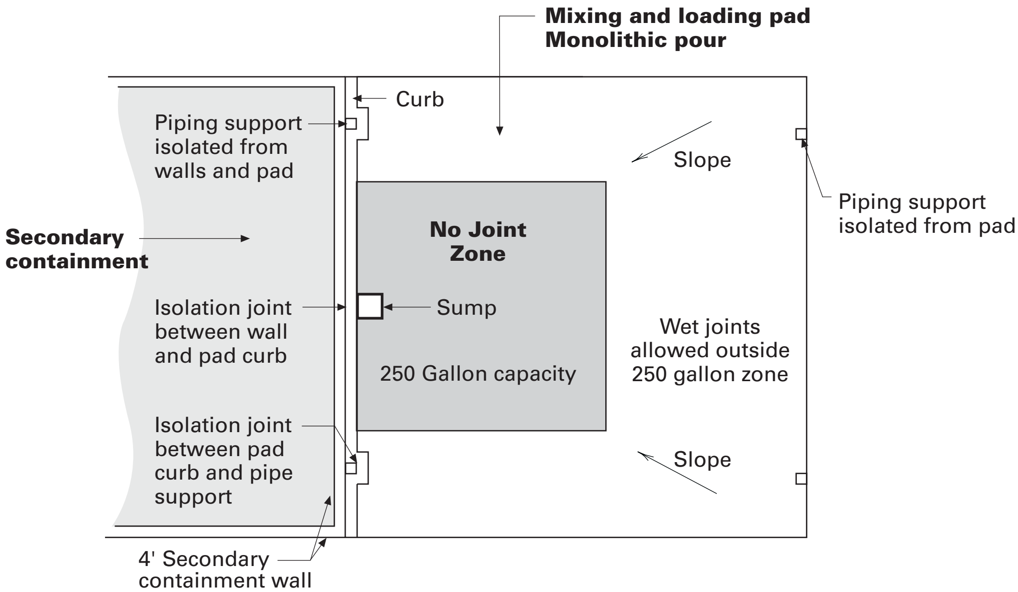


Figure 5.10. Common Joints in mixing and loading pad (side sump design). Note location of piping support outside secondary containment structure.

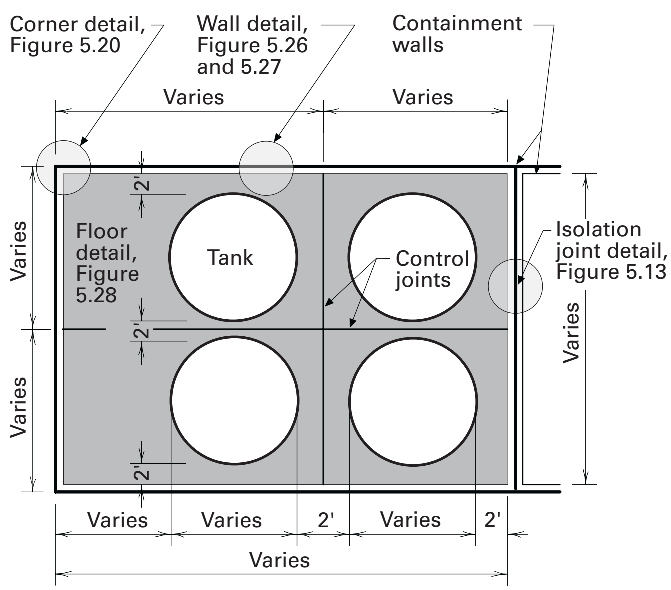


Figure 5.11. Common joints in secondary containment structure.

Dry joints

Dry joints are joints that are unlikely to have hydraulic pressure or standing liquid against the joint for any significant amount of time. They are not designed to be watertight, but will be somewhat impermeable. Any joints located at the highest elevation of a secondary containment structure that will not have fluid contact can be designed as a dry joint. For mixing and loading pads, dry joints cannot be used. Figures 5.8 through 5.11 show the areas where no joints would be allowed and where wet joints would be allowed. Table 5.7 shows where different joints are required, allowed, or recommended. For example a secondary containment structure under a roof, the floor joints can be considered dry joints, but wet joints are recommended. For a mixing and loading pad, no joints would be allowed within the "no-joint zone" (wetted perimeter), and any joints outside the wetted perimeter would be required to be wet joints.

Wet joints

Wet joints are defined as a joint that is likely to have standing fluid or hydraulic pressure against the joint for a significant amount of time. (See Figures 5.8, 5.9, and 5.10). These joints must be designed as watertight joints, which usually require the incorporation of a waterstop or other joint treatment into the joint design. Table 5.7 shows where different joints are required, allowed, or recommended. For example, joints that are located in an unroofed secondary containment floor are likely to have fluid contact and must be designed as wet joints. For mixing and loading pads, no joints are allowed within the 15- x 15-foot area surrounding the sump or lowest elevation that will contain 250 gallons. All other joints outside the "no-joint zone" (wetted perimeter) should be designed as a wet joint.

Waterstops

Flexible waterstops are used in control and construction joints to prevent water leakage in wet joints. A waterstop is a long thin flexible barrier against water leakage that spans across a floor joint, wall joint, or wall-to-floor junction. Materials chosen must be resistant to the pesticides and fertilizers to be encountered. Common waterstop shapes are dumbbell with center bulb; ribbed with center bulb and split ribbed (See Figure 5.12). The center bulb must be positioned at the joint line. Some waterstops can be placed on the subbase before concrete is placed which simplifies construction of the joint. There are also retrofit waterstop designs that allow a wet joint to be installed between existing concrete and new concrete. The waterstop must also be thick enough to withstand folding over during concrete placement. Waterstops made from PVC is not allowed for pesticide secondary containment structures or mixing and loading pads. PE (polyethylene) and Rubber (thermoplastic elastomeric) (cross linked) may be better materials for areas in contact with pesticide materials.

Table 5.7. Joint requirements depending on use in mixing and loading pad and secondary containment structure with or without a roof.
[1]No-joint zone represents the floor area within the 250-gallon capacity. See Figures 5.8 and Figure 5.9 for a definition of a no-joint zone.

Operational Use	Roof over Facility	No Roof over Facility
Mixing and Loading Pad		
• Inside "No-joint zone"[1] • Outside "No-joint zone"[1] • Curb and Floor Joint (Within the Required Capacity) • Curb or Wall (Outside the Required Capacity)	No Joints Allowed Wet Joints Required Wet Joints Required Dry Joints Allowed Wet Joints Recommended	No Joints Allowed Wet Joints Required Wet Joints Required Dry Joints Allowed Wet Joints Recommended
Secondary Containment		
• Floor • Wall	Dry Joints Allowed Wet Joints Recommended Dry Joints Allowed Wet Joints Recommended	Wet Joints Required Dry Joints Allowed Wet Joints Recommended

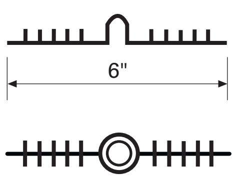


Figure 5.12. Typical waterstops available.

The formwork around waterstops must be tight fitting so a leakage path for the cement mortar does not exist. Concrete must be carefully placed and consolidated to avoid shifting of the waterstop. Position waterstops correctly; locate accurately and firmly brace or lash to reinforcement to prevent movement during placing of the concrete.

Isolation joints

Isolation joints permit horizontal and vertical differential movement at adjoining parts of the structure. (See Figures 5.8, 5.9, and 5.10.) Isolation joints may be needed at the joint between floors and walls or where column foundations and floor slabs adjoin. Isolation joints must be designed as dry joints since they would be difficult to design as a wet joint with a waterstop that could allow movement. An isolation joint detail is shown in Figure 5.13. Isolation joints can only be used at the highest elevation of a fluid retaining structure to protect it from being in contact with standing fluid or under a hydraulic pressure. If the joint is in fluid contact, it must be designed as a wet joint.

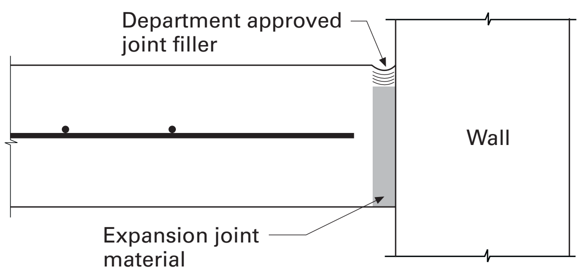


Figure 5.13. Isolation joint.

Construction joints

Construction joints are stopping places in the process of construction. They are usually designed as contraction joints or isolation joints depending on their location. Figure 5.14. A keyway is placed in the form in the first concrete placement and is removed before the next day's concrete placement.

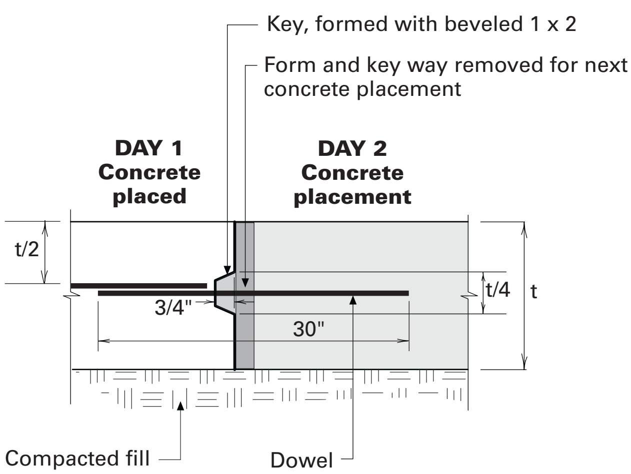


Figure 5.14. Construction joint.

Control (contraction) joints

Designed control joints relieve the shrinkage stress that occurs as the concrete hydrates and drying shrinkage occurs. Placement of control joints is based on the subgrade drag theory, which depends on how much the subbase friction restrains the concrete from moving. A crack will form when the internal stress is higher than the tensile stress of the concrete.

Control (contraction) joints provide (See Figure 5.11) movement in the plane of the slab or wall and induce a controlled crack at a selected location. This movement is due to the natural shrinkage and drying contraction that occurs as the concrete cures and dries out. Figure 5.15 shows a detail of a control joint. Control joints must be constructed to transfer perpendicular loads across the joint by aggregate interlock or if necessary by dowels.

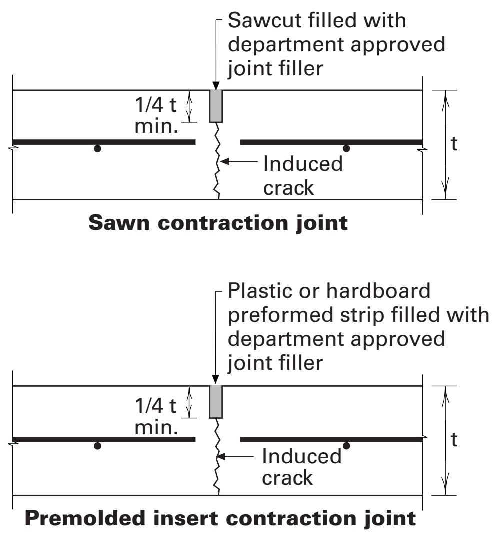


Figure 5.15. Control (contraction) joint.

Control joints can be formed by tooling during the placing of the concrete or sawed into the concrete. Sawed control joints must be sawed within the first 24 hours after the concrete has been poured and preferably within the first 12 hours. The joint becomes a weak section of concrete. Reinforcing must be interrupted (cut) at any designed control joint to promote the crack to occur at the weakened section. It is much easier to caulk or seal a straight, wide joint (1/8- to1/4-inch thick) than a random crack that may develop in unjointed concrete. Joints are usually much larger than cracks and will hold grouts and sealers much better. A control joint in the floor must extend 25 percent of the way through the slab. The line of weakness will concentrate cracking, but still allow the transfer of loads between slab sections through the interlocking aggregates. Locate floor and wall control joints in line with each other. Fill the control joints with a sealant to prevent leakage. Contact the DATCP to identify which joint sealers are approved for use in Wisconsin.

When contraction joints are placed farther apart than 20 feet, dowels must be used to transfer loads. Aggregate interlock will be lost as joint spacing increases and the resulting cracks widen. Interrupt the reinforcing steel at control joints, and place 30-inch long #4 reinforcing bar dowels through the joint every 30 inches along the joint. See Figures 5.21 and 5.22. Control joints must be located in accessible areas, e.g. not under a tank, so the crack can be monitored, and sealant can be easily applied, repaired, or replaced.

A design option for additional load transfer at joints is to thicken the edge of a slab under the designed joint. Thicken the slab at joints to 125 percent of the adjacent thickness, and taper from the thinner section to the thicker section at a slope of no more than 1:10.

Contraction (control) joints in walls are spaced according to the reinforcing specifications in Table 5.8. A control joint in a wall must extend 30 percent of the way through the wall, and half the reinforcing at the joint must be cut to promote a crack at that location.

Maximizing Joint Spacing

A high percentage of distributed steel in the concrete section can increase the distance between contraction (control) joints to a larger distance than what is normally suggested. This is based on ACI 350, which provides guidance on a more liquid tight construction. ACI 350 requires two to three times the amount of steel to increase the spacing of joints as compared to ACI 318 minimum temperature and shrinkage steel. The relationship between control joint spacing and reinforcing needed is shown in Table 5.8. Following the reinforcing suggestions could result in minimizing joints in secondary containment floor areas where liquid is likely to be in contact with the concrete surface.

Table 5.8. Minimum shrinkage and temperature reinforcement.
Spacing of reinforcing not to exceed 12 inches on center. Reinforcing bar size not to be less than #4 Imperial (13 soft metric).

Length between movement joints (feet)	Requirements Steel Area/Concrete Area Ratio
	Grade-60
less than 30	.003
30 to less than 40	.004
40 and greater	.005

Temperature and shrinkage steel recommendations according to ACI 318 require joints at a much closer spacing. Spacing of contraction joints for floor slabs with minimal temperature shrinkage steel are shown in Table 5.9. Joints at this spacing cannot be placed where liquid tight construction is desired (for example on the mixing and loading pad in the no-joint zone). For dry fertilizer loading pads smaller joint spacing following Table 5.5 may be adequate.

Table 5.9.* Spacing of contraction joints in feet.**

Slab thickness, in.	Maximum-size aggregate less than 3/4 in.	Maximum-size aggregate 3/4 in. or larger
6	12	15
7	14	18***
8	16***	20***
9	18***	23***
10	20***	25***

*Table adapted from Table 6-1b, page 55, Concrete Floors On Grade

**Spacings are appropriate for slump between 4 inches and 6 inches. If the concrete cools at an early age, shorter spacings may be needed to control random cracking. A temperature difference of only 10 degrees F may be critical. For slump less than 4 inches, join spacing can be increased by 20%

***When spacings exceed 15 feet, load transfer by aggregate interlock decreases markedly.

Wall-to-floor construction details

Figures 5.16 through 5.19 show details of joints used at an exterior or interior curb or wall for secondary containment. If a wet joint is required to provide a liquid tight joint, a waterstop must be used in the design. If no waterstop is integral to the joint, these details are considered a dry joint and are not liquid tight. Figure 5.20 shows how reinforcing is brought around a corner to minimize stress concentrations at a change in direction of the wall.

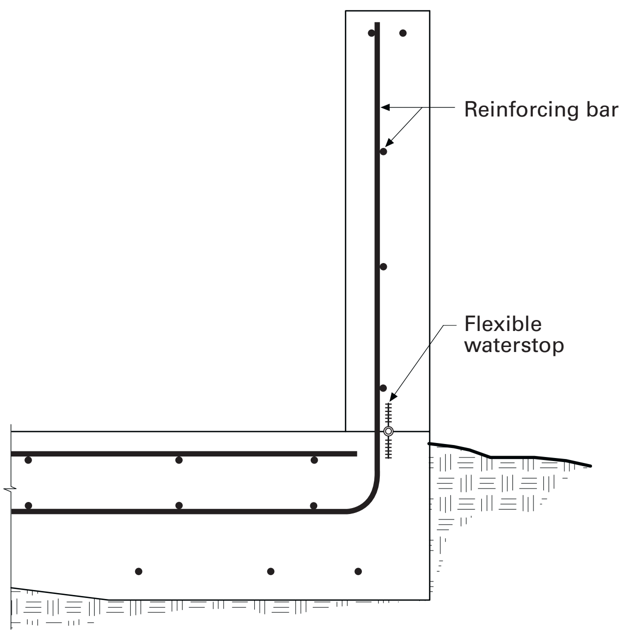


Figure 5.16. Wall-to-floor joint (wet joint).

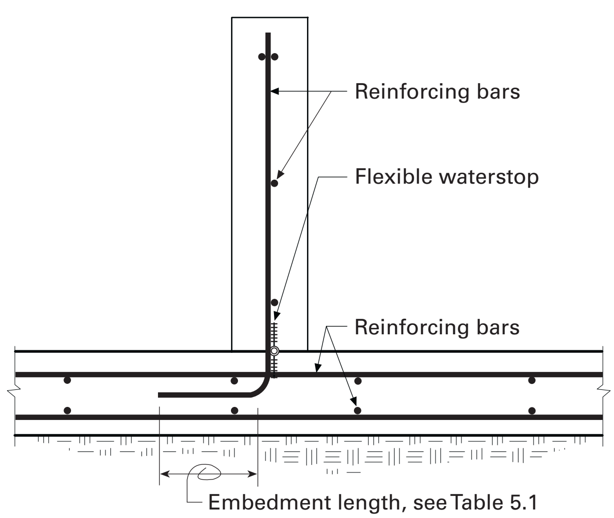


Figure 5.17. Interior wall-to-floor joint (wet joint).

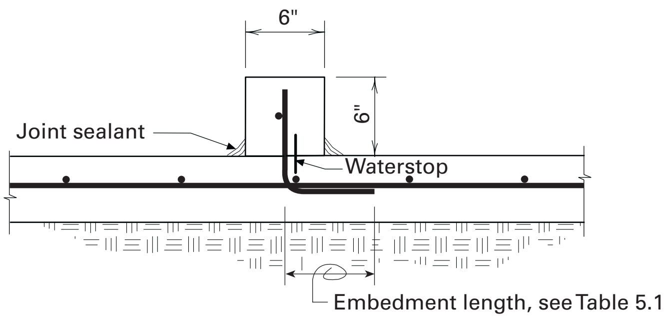


Figure 5.18. Interior curb-to-floor joint (wet joint).

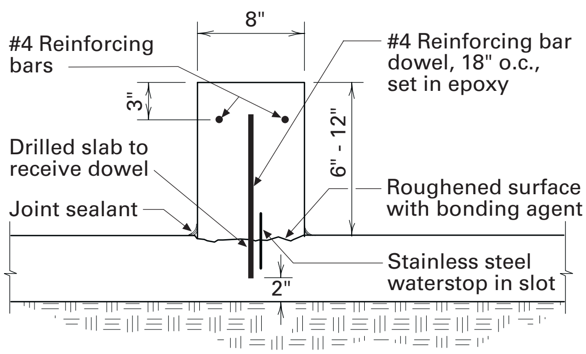


Figure 5.19. Retrofit curb-to-floor joint (dry or wet joint).

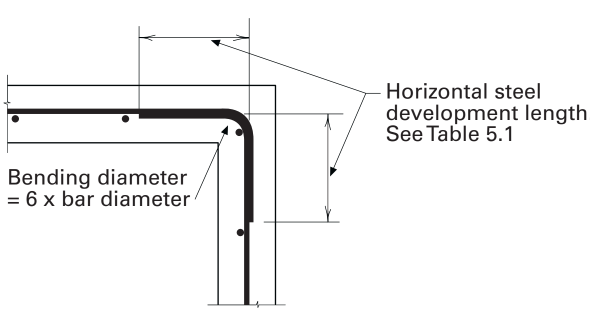


Figure 5.20. Reinforcing detail of a wall corner.

Floor slab construction details

Floor control joint details are shown in Figures 5.21 through 5.22. Although minimizing joints in the floor slab may be desirable, joints may need to be installed in a slab to maintain a more impermeable barrier. If the joints can be placed to minimize the exposure to standing water, it is more economical to design a dry joint. When it is necessary to have a joint in contact with liquid (on mixing and loading pads or outside secondary containment structures), the joint must incorporate a waterstop and be designed as a wet joint. Although it is desirable to place the floor slab in a continuous concrete placing, it may be necessary to stop construction. Figures 5.23 through 5.25 show wet and dry construction joints for floor slabs.

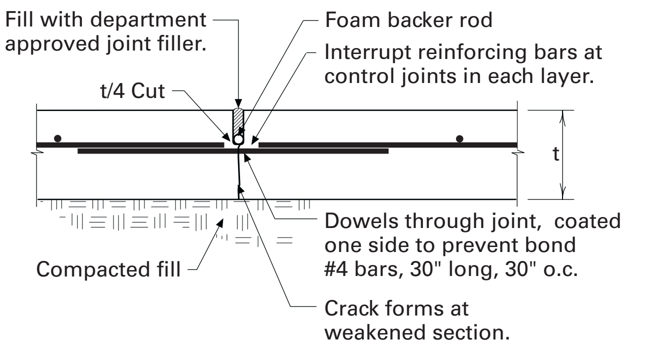


Figure 5.21. Floor sawn control joint with joint filler (dry joint).

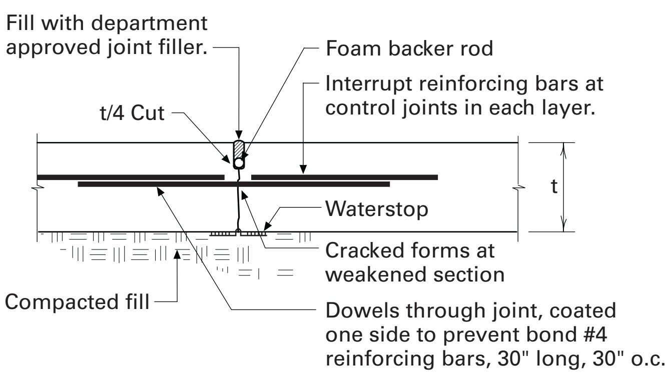


Figure 5.22. Floor sawn control joint with waterstop at bottom (wet joint).

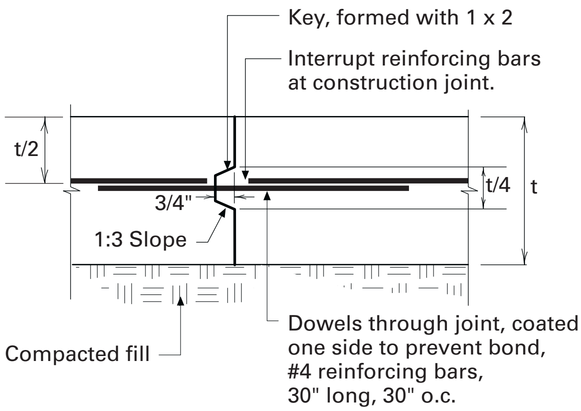


Figure 5.23. Floor construction joint (dry joint).

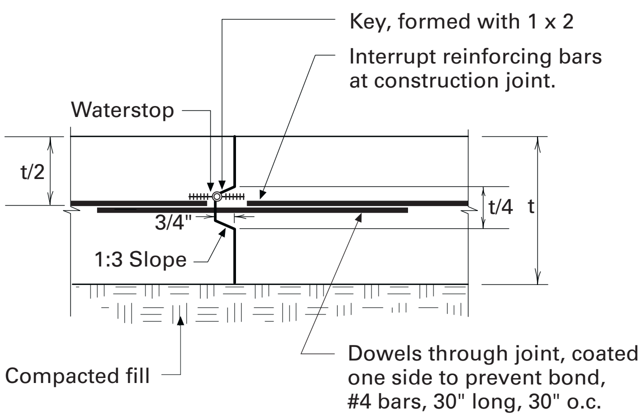


Figure 5.24. Floor construction joint with waterstop at midpoint (wet joint).

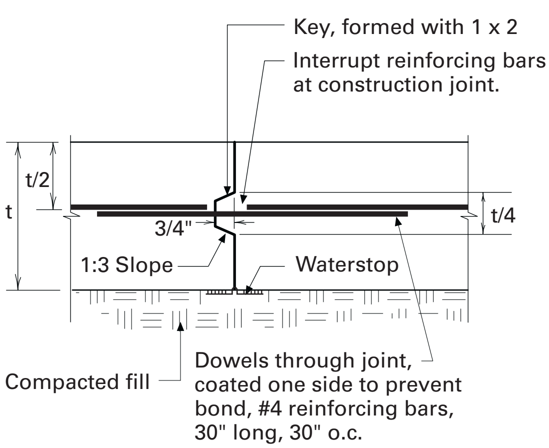


Figure 5.25. Floor construction joint with waterstop at bottom (wet joint).

Wall construction details

Wall and floor joints must be designed integral to each other. A wall joint must be placed in a wall to match any floor joint designed into the slab. If this procedure is not followed, the floor crack will likely reflect into the wall and propagate into a diagonal or random wall crack. Figures 5.26 through 5.29 show wall control joints and wall construction joints.

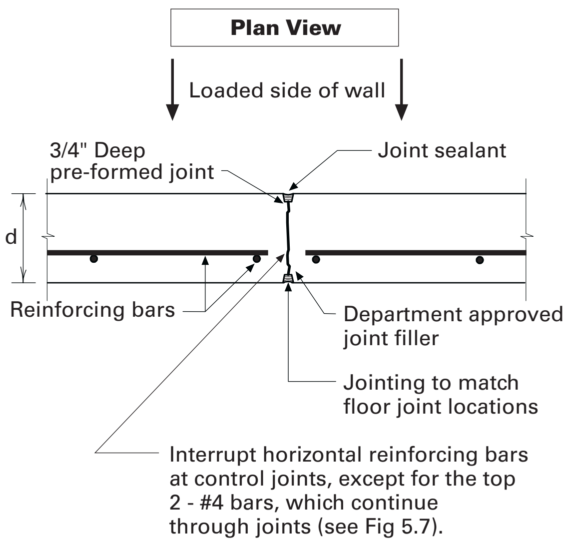


Figure 5.26. Wall sawn or formed control joint with joint filler (dry joint).

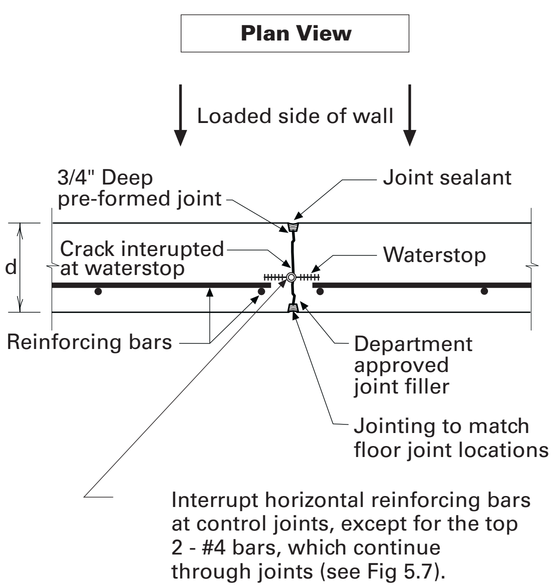


Figure 5.27. Wall sawn or formed control joint with waterstop at midpoint of wall (wet joint).

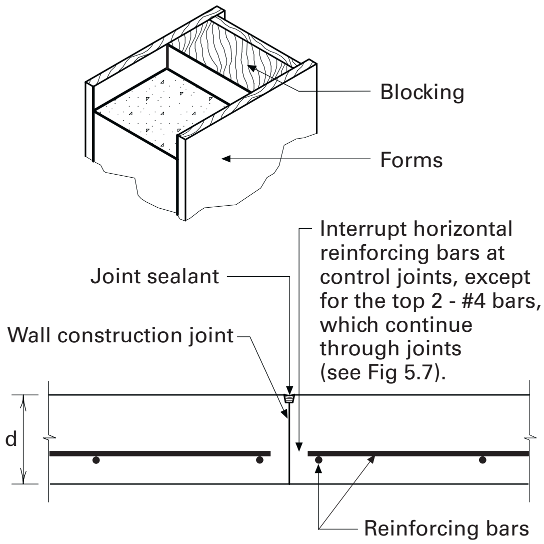


Figure 5.28. Wall construction joint (dry joint).

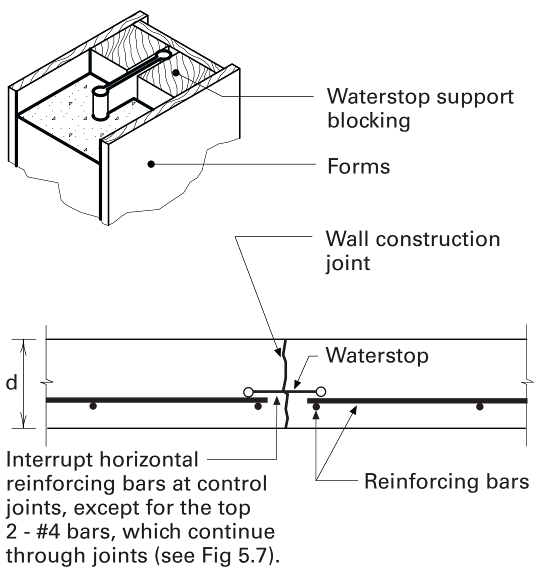


Figure 5.29. Wall construction joint with waterstop at midpoint of wall (wet joint).

Floor isolation joint detail

A floor joint between a mixing and loading pad and an adjoining concrete surface or structure will most likely be an isolation joint. It must be located at the highest elevation of the secondary containment so it is not likely to have fluid contact. The thickened edges at the joint help transfer load to and from the two separate concrete pours. Figure 5.30 shows an isolation joint detail.

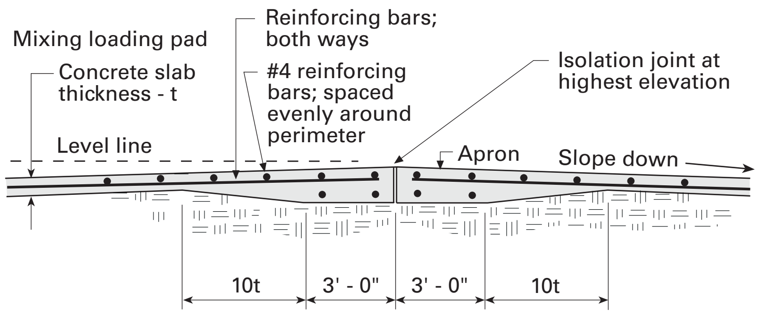


Figure 5.30. Floor Isolation joint (dry joint).

Chapter 6. Concrete Specifications and Installation

Wisconsin Construction Specification for Secondary Containment and Mixing and Loading Areas

David W. Kammel, Professor, Biological Systems Engineering Department,
University of Wisconsin Cooperative Extension

Contents

Part I. Installing Concrete

1. Scope

The work shall consist of forming, placing, finishing, and curing Portland cement concrete and the furnishing and placing of steel reinforcement and waterstops as required on the construction drawings.

Failure to meet any requirements contained in this specification shall be cause for rejection of the concrete installed.

2. Materials

Portland cement shall meet the requirements of ASTM C 150.

Reinforcing steel shall be free from loose rust, oil, grease, paint, or other deleterious matter. Steel bars for concrete reinforcement shall meet the requirements of ASTM A 615. The steel shall be deformed, Grade-60, billet-steel bars as noted on the plans.

Waterstops shall be made of rubber (natural or synthetic) for pesticide mixing and loading pads and secondary containment, or vinyl chloride polymer or copolymer having a minimum width of 6 inches and a minimum web thickness of 3/16 inches. Waterstops shall be one of the following types: those intended for placement entirely within the concrete cross section or those anchored to the subgrade or subbase prior to pouring concrete over them. Those placed within the concrete shall have ribbed or bulb-type anchor flanges and a hollow tubular center bulb. All waterstops shall be placed or installed per the manufacturer's recommendations.

Curing compound shall be a liquid, membrane-forming compound suitable for spraying on the concrete surface. The curing compound shall meet the requirements of ASTM C 309 Type 2 (white pigmented).

3. Preparing the subgrade and forms

The site shall be graded to the dimensions and elevations as specified in the construction plans.
The subgrade shall be:

- Of uniform material and density (without abrupt changes from hard to soft).
- Prepared to adequately support reinforcement chairs.
- Prepared so as to prevent significant displacement or deforming by foot traffic during construction.
- Free of organic matter and frost.
- Free of standing or puddled water while the concrete is placed.
- Either undisturbed or compacted to almost maximum density and moistened with water before concrete is placed.

When needed, the subbase must be a minimum of 4-inch thick granular material compacted to near maximum density. If the subbase required is thicker, it must be placed in maximum thickness layers of 4- to 6-inch thick and compacted lifts. Granular material for the subbase may be sand, sand-gravel, crushed stone, or combinations of these materials that meets the following requirements:

- Maximum particle size: Not more than 1/8 subbase thickness.
- Passing No. 200 sieve: 15 percent maximum.
- Plasticity index: 6 maximum.
- Liquid Limit: 25 maximum.

Concrete shall not be placed on mud, dried earth, uncompacted fill, frozen soil, or in standing water.

Concrete shall not be placed directly on a vapor retarder. If a vapor retarder is used, place a 6- to 8-inch layer of compacted, self-draining granular fill subbase over the vapor retarder before placing the concrete.

Prior to placement of concrete, the forms shall be free of chips, sawdust, debris, water, ice, snow, extraneous oil, mortar, or other harmful substances or coatings. Rock surfaces shall be cleaned by air-water cutting, wet sandblasting, or wire brush scrubbing as necessary.

The forms shall be substantial and unyielding and shall be constructed so that the finished concrete will conform to the specified dimensions and contours. Forms shall be mortar tight. Forms with torn surfaces, worn edges, dents, or other defects shall not be used. Forms shall be coated with a form release agent before being set into place. Excess form coating material shall not come in contact with the steel reinforcement or with hardened concrete against which fresh concrete is to be placed.

4. Placing reinforcing steel

Any oil on the reinforcing steel or other surfaces required to be bonded to the concrete shall be removed. Reinforcement shall be accurately placed as shown on the drawings and secured in position in a manner that will prevent its displacement during the placement of concrete. Metal chairs, metal hangers, metal spacers, plastic chairs, or concrete chairs shall be used to support the reinforcement.

Reinforcement for sloped slabs or flatwork shall be supported by a minimum of one support chair every third bar or every 4 feet in each direction, whichever spacing is smaller. Support chairs shall have a minimum basal area of 4 square inches in contact with the subgrade.

Tying steel to protruding steel or form construction in contact with new concrete shall not be started until the concrete has cured a minimum of 12 hours.

5. Placing waterstops

Waterstops shall be located as shown on the drawings and secured in position so that displacement does not occur during concrete placement. Waterstops placed within the concrete will normally need to be installed using multiple concrete pours and should be secured to reinforcement bars using wire or “hog ring” type fasteners. Contractors must install waterstops following the waterstop manufacturer’s recommendations.

Factory fabricated waterstop corners and transitions shall be provided, leaving only straight butt joint splices for field fabrication. Splices in waterstops shall be welded as recommended by the manufacturer.

6. Placing and finishing concrete

Concrete shall not be placed until the subgrade, forms, and steel reinforcement and waterstops have been inspected and approved by the Technician. Any deficiencies are to be corrected before the concrete is delivered for placement.

The contractor shall furnish the Technician a delivery ticket as specified in Part II for each load of concrete delivered to the site.

Concrete shall be delivered to the site and discharged into the forms within 1-1/2 hours after the introduction of the cement to the aggregates. When a water-reducing agent or superplasticizer is used, the manufacturer's recommended time limit for discharge after addition shall apply. In hot weather, as defined in Section 9, or under conditions contributing to quick stiffening of the concrete, discharge of the concrete shall not exceed 45 minutes unless a set-retarding admixture is used or the mix is remaining workable.

Upon the concrete's arrival at the job site, addition of water will be allowed to adjust the slump, provided such addition does not exceed the specified limits of the slump or maximum water content contained in the design mix. A small amount of concrete may be discharged prior to the addition of water. Final placement of the batch shall begin immediately after mixing of the added water is completed. No additional water shall be added to the mix after placement has begun.

Concrete shall be deposited as closely as possible to its final position in the forms and shall be worked into the corners and angles of the forms and around all reinforcement and embedded items in a manner to prevent segregation of aggregates. Placement of concrete for sloped slabs may also be achieved by gravity flow. All placement shall be done in a manner that prevents incorporation of subgrade material into the concrete.

The Technician shall obtain adequate documentation of the constructed slab thickness to ensure concrete placement as shown in the construction plan.

If the concrete sets during placement to the degree that it will not flow and merge with the succeeding pour when tamped or vibrated, the contractor shall discontinue placing concrete and install a formed construction joint. The contractor shall be prepared to install unplanned construction joints in the event that there is an interruption of the pour, equipment breakdown, or other problem that makes unplanned stopping the placement of concrete necessary. Prior to commencement of concreting operations at the construction joint, the joint surface shall be cleaned to remove all laitance, exposed sand, and surface mortar by one of the following methods:

1. The joint surface shall be cleaned to expose coarse aggregate by sandblasting or air-water cutting after the concrete has gained sufficient strength to prevent displacement of the coarse aggregate or cement fines. The surface of the concrete shall not be cut so deep as to undercut the coarse aggregate. The joint surface shall be washed to remove all loose material after cutting.

2. According to methods specified by the approver of the construction plan.

The surfaces of all construction joints shall be wetted and standing water removed immediately prior to placement of the new concrete. The new concrete shall be placed directly on the cleaned and washed surface. New concrete shall not be placed until the hardened concrete has cured at least 12 hours. The newly placed concrete shall be consolidated to achieve a good bond with the previously hardened concrete.

Concrete mixes not containing superplasticizer shall not be dropped more than 5 feet vertically unless suitable equipment is used to prevent segregation. Concrete mixes containing superplasticizer shall not be dropped more than 12 feet vertically and shall be placed in lifts not exceeding 5 feet in depth.

Immediately after the concrete is placed in the forms, it shall be consolidated by vibration or hand tamping as necessary to ensure dense concrete. Walls 4 feet high and higher shall be vibrated. Concrete supplied with superplasticizer shall be placed with a minimum amount of vibrating and finishing effort. Vibration shall not be applied directly to the reinforcement steel or the forms nor to concrete that has hardened to the degree that it does not become plastic when vibrated. Each pour shall be consolidated to ensure a monolithic bond with the preceding pour. The use of vibrators to transport concrete in the forms, slabs, or conveying equipment will not be permitted.

Vibration is required at all joints that contain integral waterstops.

All flatwork shall be screeded to grade and then bull-floated. Vibratory screeding may be used instead of bull-floating. An additional finish may be specified. All flatwork surfaces shall be true and even and shall be free from open or rough spaces, depressions, or projections.

Sloped slabs shall be worked to a uniform grade, maintaining the specified thickness, and finished in a manner to ensure dense concrete. All sloped slab surfaces shall be smooth and shall be free from open or rough spaces, depressions, or projections.

7. Removing forms

Forms shall be removed in such a way as to prevent damage to the concrete. Supports shall be removed in a manner that will permit the concrete to take the stresses due to its own weight uniformly and gradually. Wall forms and forms for joints with waterstops shall not be removed for 24 hours after the concrete is placed. Other forms may be removed when the concrete is sufficiently cured so that the concrete will not be damaged.

Immediately after the forms are removed, concrete that is honeycombed, damaged, or otherwise defective shall be repaired or replaced as directed by the Technician. Repairs are to be made according to American Concrete Institute (ACI) 301, Specifications for Structural Concrete. The procedure is in the section for repair of surface defects other than tie holes. All repaired areas shall be cured as specified in Section 8.

For structures that are not required to be liquid tight, form ties shall be removed flush with or below the concrete surface. For structures that are to be liquid tight, form ties shall be removed to a minimum depth of 1/2 inch. All cavities or depressions resulting from removing the form ties shall be patched with commercially available patching products including:

- Portland cement mortar modified with a latex bonding agent conforming to ASTM C 1059, Type II.
- Epoxy mortars and epoxy compounds that are moisture-insensitive during application and after curing and that embody an epoxy binder conforming to ASTM C 881, Type III.
- Nonshrink Portland cement grout conforming to ASTM C 1107.
- Packaged dry concrete repair materials conforming to ASTM C 928.

The age of stripped concrete or slabs shall be at least 7 days before any load (including backfill) is applied other than the weight of the wall, forms, scaffolds for succeeding lifts, or light equipment.

8. Curing

Concrete shall be cured for a period of at least 7 days after it is placed except as stated in Section 10. Exposed concrete surfaces shall be kept continually wet during the entire curing period or until curing compound is applied.

Curing compound shall be applied at the rate recommended by the manufacturer, as a minimum. It shall form a uniform, continuous, adherent film that shall not check, crack, or peel and shall be free from pinholes or other imperfections.

Curing compound shall not be used at construction joints or other areas that are to be bonded to additional concrete. These areas shall be wet cured. Surfaces subjected to heavy rainfall or running water within 3 hours after the application of curing compound or surfaces damaged by subsequent construction operations during the curing period shall be recoated in the same manner as the original application.

9. Placing concrete during hot weather

For the purpose of this specification, hot weather is defined as any combination of high temperature, (generally above 80 degrees F), low relative humidity, and wind velocity tending to impair the quality of fresh or hardened concrete or otherwise resulting in abnormal properties.

Special provisions shall be made to immediately protect and cure the concrete due to rapid drying conditions. Concrete surfaces shall not be allowed to dry after placement and during the curing period. Wood form surfaces shall be kept continually moist.

In extreme conditions, it may be necessary to (1) restrict placement to late afternoon or evening, (2) restrict the depth of layers to assure coverage of the previous layer while it will still respond readily to vibration, (3) suspend placement until conditions improve.

10. Placing concrete during cold weather

When the minimum daily atmospheric temperature is less than 40 degrees F, concrete shall be insulated or housed and heated immediately after placement. Concrete admixtures other than those banned can be used to adjust the concrete mix to compensate for concrete placement during cold weather. The temperature of the concrete and air adjacent to the concrete shall be maintained at not less than 50 degrees F or more than 90 degrees F for the duration of the curing period.

The curing period may be reduced to 3 days when Type III cement is used. An additional 100 pounds of Type I cement and a maximum of 6 gallons of added water per cubic yard may be used in lieu of Type III cement.

Combustion heaters shall have exhaust flue gases vented out of the concrete protection enclosure and shall not be permitted to dry the concrete.

The contractor shall furnish the Technician a record of daily maximum and minimum outside air and concrete surface air temperatures during the curing period. The record shall include temperatures at several points along the concrete.

11. Joints

Concrete joints shall be of the type and at locations shown on the construction drawings. Joints containing waterstops shall be inspected before concrete placement.

Sawn or hand tooled joints with integral waterstops shall be placed within 12-24 hours (maximum) after concrete placement.

Part II. Furnishing Concrete

1. Scope
The work shall consist of furnishing Portland cement concrete as required on the construction drawings. All materials, test procedures, and admixtures shall meet the requirements of the latest edition of the applicable ASTM designation.

The mix proportion in this specification is required to yield a 28-day compressive strength of 4,500 psi or more. The contractor shall provide a concrete mix design and laboratory testing that verifies the concrete supplied will produce compressive strengths that equal or exceed 4,500 psi.

Failure to meet any requirement in this specification shall be cause for rejecting the concrete.

2. Materials
The contractor shall provide the Technician with test data, independent laboratory reports, or other evidence from the concrete supplier showing that all materials meet the requirements of this specification.

The use of any admixtures in the concrete mix shall be in strict compliance with the manufacturer's recommendations.

A. Portland cement shall conform to ASTM C 150 and shall be Type I, or lA, II, or IIA, III or IIIA.
B. Fine aggregate shall conform to ASTM C 33 and be composed of clean, uncoated grains of material.
C. Coarse aggregate shall be gravel or crushed stone conforming to ASTM C 33 and be clean, hard, durable, and free from clay or coating of any character. The maximum size coarse aggregate shall be 1-1/2 inches.
D. Water shall be clean at a pH = 5.0-7.0 and free from injurious amounts of oil, salt, acid, alkali, organic matter, or other deleterious substances.
E. The water-cement ratio shall be no greater than 0.45 (4,500 psi).
F. Air entraining agent shall conform to ASTM C 260 and shall be between 5-7.5 percent.
G. Pozzolan (fly ash) shall be in strict compliance with ASTM C 618, Class F or C. The loss of ignition shall not exceed 6 percent.
H. Ground Granulated Blast Furnace (GGBF) Slag shall conform to ASTM C 989.
I. Water-reducing admixtures shall conform to ASTM C 494, and superplasticizers shall conform to ASTM C 1017 and may be the following types:
    1. Type A - Water-reducing admixture.
    2. Type D - Water-reducing and retarding admixture.
    3. Type F - Water-reducing, high range admixture (superplasticizer).
    4. Type G - Water-reducing, high range, and retarding admixture (superplasticizer). Type D or G admixture may be used at the option of the contractor/supplier when the air temperature is more than 80 degrees F at the time of mixing and/or placement.
J. Calcium chloride or other antifreeze compounds or accelerators will not be allowed.

3. Concrete Mix Design
To help ensure the concrete is impermeable and watertight DATCP requires the concrete meet the following specifications:

- Have a compressive strength of 4,500 psi at 28 days
- Have a W/C ratio minimum of 0.45

- Have a maximum slump of 3 inches and minimum slump of 1 inch
- Have 5 to 7.5 percent air entrainment

Follow the procedures listed below to ensure a proper design

1. Use a water-reducing admixture for easier workability at placement and improved water tightness and strength of low-slump concrete.
2. Use clean, drinkable mixing water at a pH = 5.0-7.0.
3. Use large (1 to 1.5 inch), clean, impervious aggregate.

The air content (by volume) shall be 5 to 7.5 percent of the volume of the concrete at the time of placement. This requirement shall be met by using Type IA, IIA, or IIIA Portland cement or the manufacturer's recommended quantity of an air-entraining agent.

The slump shall be 1 to 3 inches (flatwork) 1 to 4 inches (wall) except when a water-reducing agent or superplasticizer is used in the concrete mix. When a water-reducing agent or superplasticizer is used, the slump shall be 3 inches or less before the addition of the admixture and shall not exceed 8 inches following addition and mixing. Additional water-reducing agents or superplasticizer shall not be added to the concrete mix after discharge of the concrete at the job site has commenced.

The oven dry weight of the fine aggregates shall be 30 to 45 percent of the total oven dry weight of the combined aggregates.

The contractor/supplier may use the following mix proportions per cubic yard to produce concrete with a minimum compressive strength of 4,500 psi. Other mix proportions proposed by the contractor/supplier may be submitted to the Technician for approval prior to use.

Portland cement*, lbs/yd^3	**Maximum water,** lbs/yd^3**	**Nominal minimum aggregate size, in.**	**Fine aggregate, fineness module = 2.50, lbs/yd^3**	**Coarse aggregate, lbs/yd^3**
665	300	3/4	1,040	1,800
590	265	1½	930	2,110

Reference page 171 of *Design and Control of Concrete Mixtures* for W/C ratio of 0.45.
* Water-reducing agent or superplasticizer may be added to the mix.
**Total of aggregate moisture, mixing water added at the plant, and mixing water added at the job site.

4. Mixtures and Mixing

Ready-mixed concrete shall be batched, mixed, and transported in accordance with ASTM C 94.

Concrete shall be uniform and thoroughly mixed when delivered to the forms.

No mixing water in excess of the amount shown for the design mix or in an amount that would cause the maximum slump to be exceeded shall be added to the concrete during mixing or hauling or after arrival at the delivery point.

The concrete shall be batched and mixed such that the temperature of the concrete at time of placing shall not be less than 50 degrees F nor more than 90 degrees F.

Allow no more than 30 minutes between truckloads of concrete during placement.

Mix 70 to 100 revolutions at mixing speed, then an additional 200 to 230 revolutions (maximum of 300 total revolutions) at agitating speed.

Discharge load within 1.5 hours.

Minimize discharge drop distance by using a discharge chute.

When possible, concrete shall be placed in a continuous pour in one day, with no cold joints.

Use vibration during placement; vibrate at 5,000 to 15,000 rpm frequency for minimum aggregate segregation.

5. Batch Ticket Information

The contractor shall obtain from the supplier a delivery ticket for each load of concrete before unloading at the site. The following minimum information shall be included on the load ticket:

A. Name of concrete supplier and batch plant.
B. Name of purchaser and job location.
C. Date of delivery.
D. Truck number.
E. Amount of concrete delivered.
F. Time loaded or time of first mixing of cement and aggregates.
G. Mixing water in the load added as free water.
H. Type and amount of cement.
I. Type and amount of admixtures.
J. Weights of fine and coarse aggregate.
K. Percent moisture content or weight of free water contained in the aggregates.

The contractor or inspector shall also include the following additional information on the load ticket:

A. Water added by the receiver of the concrete.
B. Time the concrete arrived at the site.
C. Time the concrete was completely unloaded.

Upon completion of the concrete placement, copies of all load tickets shall be provided to the Technician. Materials information that will remain constant throughout the job may be provided by the supplier and approved by the Technician prior to placing concrete. This materials information may be omitted from the load ticket.