KOMPONENT

ENVIRONMENTAL CONTAINMENT STRUCTURES

Containment tank created with Komponent

> *Construction containment structures must prevent accidental release of bulk liquids into the environment. A formidable, but not impossible, challenge*

Receiving, storing, and handling bulk liquid chemicals are an integral part of many industrial operations. Constructing containment structures to prevent any accidental release of these chemicals into the environment presents a formidable, but not impossible, challenge. Releases of large amounts of chemicals due to tank rupture or equipment failure is rare. Minor drippage and spills resulting from material handling pipe connection and disconnections, loose pipe fittings, or worn valve stem or pump packaging are common industrial occurrences.

Prevention of chemical release is an industry goal, and containment of spills from any source is becoming a standard method of operation. Leak-proof containment structures are a necessary part of liquid chemical industrial operations. Described below is a method of designing and constructing leak-proof containment structures at costs competitive with conventional construction.

Tank Farms

The most practical and economical method of storing liquid chemicals in large quantities is in a tank. The storage tanks themselves, which are usually grouped for convenience, provide primary containment. A tank farm consists of multiple tanks within a walled enclosure or dike. The dike structure provides secondary containment in the event of failure of the primary containment. Conventional tank farm construction (Fig. 1) consists of four separate concrete placements. First, the wall footer is constructed, followed by the second placement of the walls. After the next procedure, backfilling and compacting, foundations for each tank are constructed as the third placement. Expansion joints between the slab and the walls, and between the slab and the tank foundations are installed. The fourth placement is an infill slab over all areas within the dike walls not occupied by tank foundations. The last step is placing contraction joints as per good engineering practice to complete the construction procedure.

These joints, and any other cracks which may form, have been identified as potential leak paths for any liquid in the tank farm to enter the subgrade. Besides being a potential leak source, these joints are usually costly to maintain.

New Generation of Tank Farms

Ashland Chemical Company has developed a method of tank farm design and construction which eliminates maintenance cost and provides an environmentally safe tank farm. The best way to eliminate potentially leaky joints is to place a monolithic tank farm slab (Fig. 2). After researching and analyzing other materials and methods of construction, shrinkage compensating concrete (SCC) made with Type K cement was chosen as the material that best meets the company's requirements.

All concrete shrinks during the curing process. It is during this shrinkage phase that cracking occurs. The cracking is called shrinkage, contraction, or tension cracking. SCC expands during the first part of the curing process. Shrinkage cracks would be eliminated if the SCC's expansion is greater than its anticipated shrinkage (Fig. 3). The need for contraction joints would then be eliminated. All other design parameters are in accordance with good engineering practices, standards, and code requirements. ACI 223 "Standard Practice for the Use of Shrinkage-Compensating Concrete" is the accepted reference for design procedures and field practices.

Variable liquid levels in the tanks produce different loading conditions. Subgrade material offers different degrees of resistance, creating various design conditions. Hard bed rock conditions present a straightforward design. Poor soil conditions require more complex design approaches, such as a mat foundation (Fig. 2).

After designing the structure, the special requirements of ACI 223 are checked. First the minimum reinforcement requirements are checked according to Section 3.2.2 of the code. Structural members invariably meet or exceed the minimum reinforcing requirements. The placement of the steel to provide the necessary restraint and prevent curling is critical. Failure to provide the necessary reinforcing restraint will result in unrestrained expansion of the concrete. The result will be cracking during the air drying phase of the concrete cure (Fig. 3).

The curb serves two valuable purposes. The primary purpose is to raise the only construction joint above the surface normally wetted by rainfall. Rainwater collected in the dike is tested and removed after every rain so that the water will not rise to the height of the joint. Since the joint is horizontal, there is no direct path for potential seepage from the dike to the subgrade. Having both faces of the joint exposed for viewing makes inspection easy and documentable. The second purpose the curb serves is to form a self-containment device for the preferred water cure recommended by Section 5.3 of ACI 223. A minimum 7 day water cure is provided by flooding the dike and draping burlap over the curb. Using a standard 2x6 in. wood form creates an economical 5-1/2 in. curb. Chamfering the inside corner provides a smooth transition from slab to wall that minimizes crack inducing stresses created by a sharp corner. A similar but much larger miter is used on the inside vertical face of dike corners.

Secondary Containment Liner

Some cases exist where a secondary liner is installed under the containment structure. A high density polyethylene liner sheet is laid along the bottom and up the inside of the sidewall forms. All joints are fuse welded and a cast-in-place insert is then welded to the top of the liner and the top edge is nailed to the forms. Stainless steel sniffer pipes are embedded in a washed granular fill layer to form the bottom layer.

A geotextile filter fabric separates the bottom layer from the top layer. Crushed stone or other fill material with sharp edges are prohibited because the sharp edges might cut or puncture the liner. The top layer is a sand/stone mixture which enables it to absorb the misting spray. The liner and its cast-in-place insert form an envelope under the containment slab that can be tested for any leakage through the slab. The sniffer pipes have caps at each end and are laid on top of the liner. Saw cuts are made along the bottom leg and a vertical leg extends up through the curb and wall. The exposed caps can be removed and an air pump attached to one of the pipes to draw air through the granular stone filter media. This air can be tested for vapors which would indicate leakage. If any vapors are extracted they can be treated accordingly.

Alternative Design

Substituting a mud mat for the top 2 in. of the subslab fill material makes the construction easier, and ensures the proper placement of the reinforcing steel. The mud mat is a very weak, high slump, mortar-like concrete that forms a porous base on which the monolithic concrete slab is constructed. It forms a rigid support for the reinforcing bar and allows work to continue when other parts of the project are delayed because of bad weather.

Preconstruction Conference

A preconstruction conference is the key to a successful construction project. Attendance is required by key personnel and is stated in the bid documents. This event should be scheduled at least one week prior to the placement, but can be held earlier to meet project needs.

Each of the projects involves a different cast of contractors and suppliers in different cities. A unique benefit of the preconstruction conference is that it allows all the key personnel to meet in the same room and exchange a meaningful dialogue about the project. Responsibilities and duties are defined and working relations are established. Schedules are developed and reviewed. "What if" scenarios are discussed and alternatives are planned.

The key personnel present at the preconstruction conference should be:

Design Engineer of Record – The person with the deepest involvement in all phases of the design construction procedure. The design engineer is involved in the material selection and is responsible for fulfilling all the design requirements. Developing the project design requirements also defines the desired as-built result. These responsibilities make him the most qualified person to conduct the preconstruction conference.

Project Manager – The person with overall project responsibility. He is the administrator of the construction contracts, and is also the person responsible for the project schedule and progress. His presence at the meeting is important to resolve conflicts, and arbitrate contract responsibilities when needed.

Facility Manager or Engineer – Two objectives are met when this person is present. First, this is often the only opportunity the Plant Manager has to find out the particulars of the state-of-the-art containment structure that is being constructed at the facility. Secondly, projects are frequently constructed in an operating facility. All construction activities must be coordinated with plant operations so that the plant and the contractor can conduct their activities with minimum interference.

Cement Manufacturer's Technical Representative – Has a wealth of knowledge and experience with SCC. This person coordinates the cement purchase and delivery to the ready-mix supplier. Mix design, quality control and the required testing are discussed at the meeting and scheduled. Experience from previous projects provides valuable insight and the ability to answer questions.

Ready-Mix Supplier – Scheduling an SCC placement creates unique restraints on the

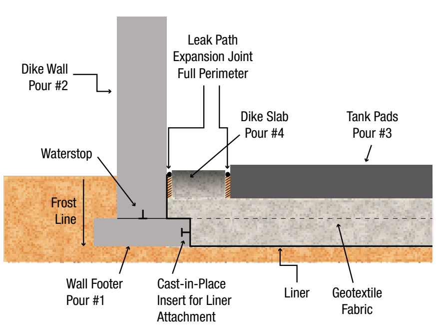

Fig. 1 – Conventional Dike Construction

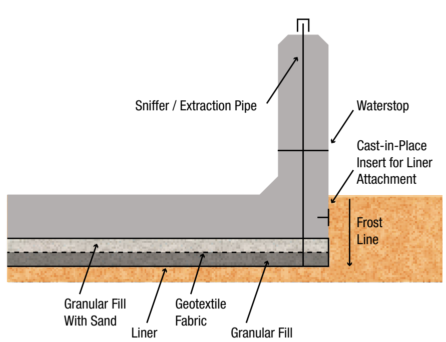

Fig. 2 – Monolithic Dike

concrete supplier. Most concrete suppliers need to dedicate a bin for storage of Type K cement, or make alternative provisions. [Portable silos and slurry machines are available for use on the job site when dedicated silos at the central batch plant are not available.] A high slump concrete, such as our specified 6 in. (+/-) 1 in. slump, is contrary to normal specifications and causes problems for some concrete suppliers. One of the first questions resolved is, where will the slump test be taken? This affects the mix design. The test is taken from the ready mix truck prior to discharge. Availability of trucks, transit delivery times, and continuity of placing are planned for proper execution. Maximum specified mix temperature is 90oF (32oC) at time of discharge. This may require water cooling of the aggregates or equivalent ice in the mix design. Wetting of the aggregates to prevent water absorption from the mix is also needed.

Testing Lab Representative – Type K concrete does not require any special field tests. Test type, frequency, and pass/fail criteria are discussed, as well as responsibility and procedures to follow if a test should fail. Care of test cylinders, particularly for the first 24 hours, is discussed. This may require constructing a "test box" that duplicates the 7 day water cure at the placement.

General Contractor – Depending on the size and nature of the project, the general contractor will either supervise the subcontractors or perform the duties as outlined in each of the following sub-sections. The field superintendent or foreman for each of the subcontractor trades are requested to attend the preconstruction conference.

Subbase Sub-Contractor – Subgrade preparation may require special construction procedures to improve existing soil conditions, or to form a suitable base for the containment structure. The surface on which the concrete will be placed must meet two requirements. First, it must be smooth, level, and capable of supporting the reinforcing bar during construction. Second, it must be capable of remaining stable when wetted to a saturated dry condition. This is achieved when the subgrade has the maximum amount of water it will hold without forming any puddles or surface water. A 2 in. mud mat has proven a very cost effective method of meeting all subgrade requirements. Contractors are encouraged to use it when conditions warrant.

Formwork Subcontractor – Water curing of the concrete requires a leak proof forming system. Formwork, in some cases, should be constructed to provide freeboard for the water cure. On projects that include a liner system, a nailable form system must be used to secure the insert to the forms. Interaction with the liner subcontractor is arranged on projects where a liner is used. Stripping schedules and wall forming that may occur while the base slab is under water cure are agreed upon.

Reinforcing Bar Placement Subcontractor – We have experienced a few cases of concrete cracking on our projects. The principle cause of cracking in SCC has been identified as misplaced reinforcing bars. Investigative coring has shown, in each case, that the horizontal reinforcing bar was located several inches lower than shown on the engineering drawings. The reinforcing bar must be positioned and held in place to resist construction loads, including foot traffic from the placement crews and also the impact of the concrete as it is being placed. Wire chairs are used to support the reinforcing bar. Blocks, bricks, stones, or other "common" supports are prohibited since they disrupt the uniform cross section of the concrete. A uniform cross section, and absence of sharp corners, minimizes stress risers in the concrete that could lead to cracking. Discussion of methods of support that would provide secure positioning of the reinforcing usually leads to the mud mat being selected as the best option. Placing will not be permitted until reinforcing bar placement is inspected and approved by the engineer.

Concrete Placing Subcontractor – SCC is very easy to place when it is placed as discussed in the preconstruction conference. Placing SCC in the same manner as regular concrete is a sure invitation to errors and problems. Engineers have been telling contractors to place stiff concrete for years, now we tell them to place it "wet." SCC requires large amounts of water for hydration. A good portion of this water is supplied in the mix through a maximum water cement ratio of .50 and a slump of 6 in. SCC is a "fat" material allowing the curb to be placed integral with the slab, without creating a sloughing problem within the slab.

Finishing Subcontractor – The standard procedure for determining when to finish the concrete is to watch for bleed water to appear on the surface. There is no bleed water with SCC made with Type K cement. The finishers must test the concrete to determine when to start finishing. Because of the fine grind of the Type K cement, concrete made with Type K cement acts like a high-early in warm weather. Placements should be done when the ambient temperature is below 80°F (27°C). Experience indicates that in cooler weather SCC acts like regular concrete. Our specifications call for two passes with a bull float followed by a finishing broom pass. Finishing with a troweling machine is prohibited unless absolutely needed to close the concrete and is approved by the engineer.

Construction

The purpose of the preconstruction meeting is to prepare all participants for the placement. The period just before the placement is an excellent time to review some of the key points that were discussed earlier. This reinforces the procedure with the contractors and reassures the engineer that all parties are prepared to function as discussed. The engineer's first function is to inspect and test the reinforcing steel for size, location, and placement. The engineer should walk the reinforcing bar, as stated in the preconstruction meeting, to verify that the steel will not be displaced during the placing process. If the reinforcing bar passes the inspection and test then the engineer will authorize the placement to proceed.

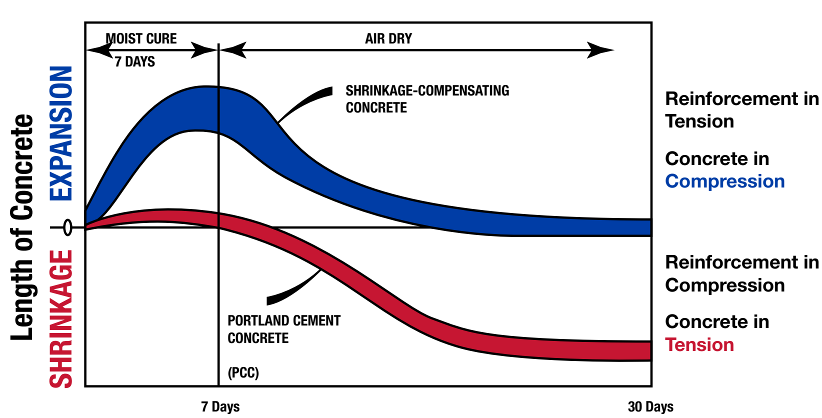

Fig. 3 – Concrete Shrinkage

Preplacement procedures also include wetting the subbase to a saturated dry condition with a misting hose. The reinforcing bar and forms are also misted in warm weather to cool them and prevent localized flash setting of the concrete. Misting of the concrete between the different steps in the construction procedure may be required under certain weather conditions such as direct sun or wind. Spraying the concrete with a water soluble evaporation retardant is also an option.

Long established work habits are hard to break. Some of the items discussed at the preconstruction meeting are contrary to established concrete placement procedures. Attention to the key points unique to shrinkage compensating concrete will result in a successful SCC placement.

Conclusion

The concepts used to construct leak-proof tank farms can be adapted to other containment structures, such as truck loading/unloading stations, railroad loading and unloading stations, drum filling operations, and other areas where leaks or drippages are likely to occur. The size of these structures is limited by design parameters or the contractor's capability to place the concrete.

These environmentally safe state-of-the-art containment structures can be constructed due to the special characteristics of shrinkage compensating concrete made with Type K cement. The expansive properties allow the engineer to design structures without expansion or contraction joints. Additional benefits result from the fact that the SCC concrete is less permeable and more durable than regular concrete of the same strength.

Experience tells us that while the cost of shrinkage compensating concrete varies with the location, time of year, project size, and general construction market, [the material per cubic yard can be] slightly more costly than regular concrete. However, savings resulting from not installing the expansion and contraction joints [and reducing mobilizations with more monolithic pours] will usually make the finished project cost comparable [or less expensive than] with conventional construction. The true benefit is derived from having a leak proof, environmentally safe containment structure.

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