Upper Chiquita Reservoir Floating Cover and Liner

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ABSTRACT
The Upper Chiquita Reservoir is a large potable water reservoir located in Rancho Santa Margarita in Orange County California. The reservoir contains 244 million gallons of domestic water and covers an area of 18 acres. The reservoir was constructed on the western slope of the Chiquita Canyon by creating an earthen dam across the canyon. The reservoir is lined and covered with geosynthetic barrier materials with a defined-sump style cover. This case history details the construction of the reservoir lining and cover system including some of the unusual design details caused by the shape and size of the project. The paper also covers the difficulties caused by the excessive rainfall and the solutions to a leakage issue that developed after construction.

1. INTRODUCTION

1.1 Background

Figure 1: Aerial view of the Upper Chiquita Reservoir under construction.

The Upper Chiquita Reservoir is a large reservoir that is part of the Santa Margarita Water District in Southern California. The Santa Margarita Water District (SMWD) is the second largest water district in Orange County covering 52,000 acres of land just east of Mission Viejo and San Juan Capistrano. The SMWD provides water to about 155,000 residents and businesses in Mission Viejo, Rancho Santa Margarita, Coto de Caza, Las Flores, Ladera Ranch, and Talega.

All domestic water supplied to the SMWD has to be purchased from outside sources as there are no local water sources. Most of the region's water is piped from the Diemer Filtration Plant in Yorba Linda. In the past few years the district has experienced major supply disruptions with the unplanned break in the district supply pipeline in 1999, and the additional planned outages of the Diemer Filtration Plant in several recent years. Any disruption in water supply was requiring immediate and severe water conservation measures in the district.

The main purpose of the Upper Chiquita Reservoir was to increase reserve storage capacity to ensure water security to the customers served by the SMWD. The total installed cost for the investigation, design, and construction of the reservoir was $53 million and was a shared project between a number of local agencies. These agencies included the SMWD, the City of San Clemente, San Juan Capistrano, Moulton Niguel Water District (Laguna Niguel), and South Coast Water District (Dana Point). The reservoir is operated by the SMWD.

2. THE RESERVOIR

Figure 2: Site visit during the construction of the dam.

The Upper Chiquita Reservoir is one of the first large emergency potable water reservoirs to be built in Orange County in decades. It has a design capacity of 244 million gallons (750 acre-feet) and has a surface area of approximately 18 acres. The reservoir is of new construction being built into the side slopes of the Chiquita Canyon. The reservoir was formed by constructing an earthen dam across the mouth of a section of the canyon to create a roughly triangular containment. At its deepest point it is 120 feet deep with side slopes ranging from 3 to 1 up to about 2 to 1. The construction of the reservoir began in June of 2009 and was put into service in October of 2011.

The reservoir has a number of interesting details. The first is the depth and the steepness of the slopes. This led to safety concerns during construction and led to problems in removing rainwater during an exceptionally rainy season.

The second issue was the irregular shape of the containment. Designing a defined-sump floating cover on an unusual shape requires some different techniques. In this case a bench was built into the side slopes at the half-way point. This earthen bench provided a flat surface on which to construct the floats and weights that tensioned the cover. The bench also acted as an intermediate anchor for the lengthy slopes and contained a drain system to monitor leakage for dam safety purposes.

3. THE GEOSYNTHETICS

3.1 Geosynthetic Under Drain

Figure 3: Placement of the geocomposite underdrain.

A geosynthetic under drain was placed as the first layer of material underneath the entire reservoir. This underdrain was placed to monitor the performance of the lining system and to provide drainage during construction. The underdrain also provided drainage for the earthen dam section. The underdrain consisted of a tri-planar double-sided geocomposite. The core of the geocomposite was 300 mil (7.6mm) thick and was sandwiched between two layers of 8 oz/yd^2 (270 g/m^2) non-woven polypropylene geotextile.

3.2 Geomembrane Lining System

The original specification for the primary geosynthetic barrier system (geomembrane) called for the use of a three-ply 60 mil (1.5mm) Chlorosulphonated Polyethylene (CSPE) geomembrane. During the time of construction there were challenges in the supply of CSPE materials and the lining was changed to a flexible polypropylene material in order to get both the lining and the cover materials delivered on time. The final liner material selected was a 60 mil (1.5mm) thick three-ply fabric –reinforced flexible polypropylene geomembrane (fRPP).

The fRPP materials for the liner were prefabricated prior to installation according to a detailed panel layout. All seams were welded using a 3” wide wedge welder that bonded the materials together edge to edge without leaving a flap of material at the seams. In order to reduce creases in the lining material the fabricator on this project used a 36’ wide winder to create rolls of fabricated materials that did not require any folds in the material. There is some thought that creases in fRPP materials can lead to stress concentrations that can initiate failures. This is especially problematic in thicker materials such as a 60 mil material. By fabricating without folds this particular fabricator was eliminating this area of potential problems.

Figure 4: 36 ft wide prefabricated liner panels

The liner was anchored to the perimeter of the containment using a concrete stub wall and steel battens. This concrete wall went around the entire perimeter.

Once the lining system was in place the entire area was surveyed using an electrical leak location method. Weather problems prevented the reservoir from being installed in a straight-forward fashion and earthworks, lining installation, and cover installation all took place at the same time in different parts of the reservoir. In order to test areas that couldn't be filled with water the leak location survey was performed with the Water Puddle Method (ASTM D7002). In this method a flow of water is delivered to the survey probe which is directed at the liner. The water is swept across the liner surface and penetrates any defects that are present. Contact with the ground below the liner generates a signal that the operator can use to locate the defect.

3.3 Floating Cover System

The Upper Chiquita Reservoir is one of the larger covered reservoirs in California and also one of the most irregular. The irregular shape is a challenge when designing the method in which the cover will rise and fall in response to water level changes. The design of this cover used the "defined sump" method of construction as first described in US Patent 3,991,900 (1976). A defined sump floating cover uses a series of weighted sumps and floats to maintain tension on the cover material as it changes elevation with water movement. The design of the cover layout needs to maintain continuous tension on the cover at all times to prevent wind damage.

The material used for the cover was a Chlorosulphonated Polyethylene (CSPE) three-ply fabric-reinforced 60 mil (1.5mm). During the construction period for this project the primary supplier of CSPE resins chose to close their plant and supplies of the CSPE resin were restricted. This resulted in allocations of resin which would have impacted the construction schedule. There was sufficient available material for the cover but not for the cover and the liner. That led to the change in the liner from a CSPE to an fRPP material. Note that since the time of this project the secondary manufacturers of CSPE resin have increased capacity to meet demand. CSPE has been used for many floating covers in the California area and has a strong performance record. The CSPE for this project was issued with a 30-year weathering warranty.

The cover system was factory prefabricated to match a detailed panel layout prior to deployment in the field. The normal sequence of operations for cover construction is to complete the liner installation and then to start placing the cover. The cover is usually installed over the entire area of the containment before floats, sump weights, and other details are added. In this project the excessive rain forced changes to this sequence. Since the base of the containment could not be kept free of water the liner and then the cover were advanced down the side slopes with the base remaining open. Only when the base was finally dried out could the liner, and then the cover, be completed.

Layout and location of floats and sump weights is usually accomplished on site once the cover panels are installed and tested. A special bench was included in the earthworks of this project to provide a flat area about half-way down the slopes where the main floats and sump weights for the cover could be constructed. Much of the detail work on the cover took place on this bench while the base of the containment was still too wet for construction. Another adaptation to the weather was to transfer the construction of appurtenances back to the factory. This moved a significant amount of the field labor inside when the weather was poor.

The final cover design covered an area of 900,000 ft2 (84,000 m2) and included 18 hatches, 71 air vents, and 40 rainwater removal pumps. Once the cover was completed it was inflated with air using fans on the access hatches. Because of the size of this cover it was inspected in sections. Sand bags were used to isolate sections so that each area was inflated in turn. The reduced the risk of damage in the event of unexpected winds. The cover was 100% inspected from the inside for any defects (defects show as pinholes light). Once the cover inspection was completed the air was released and the cover was ready for service.

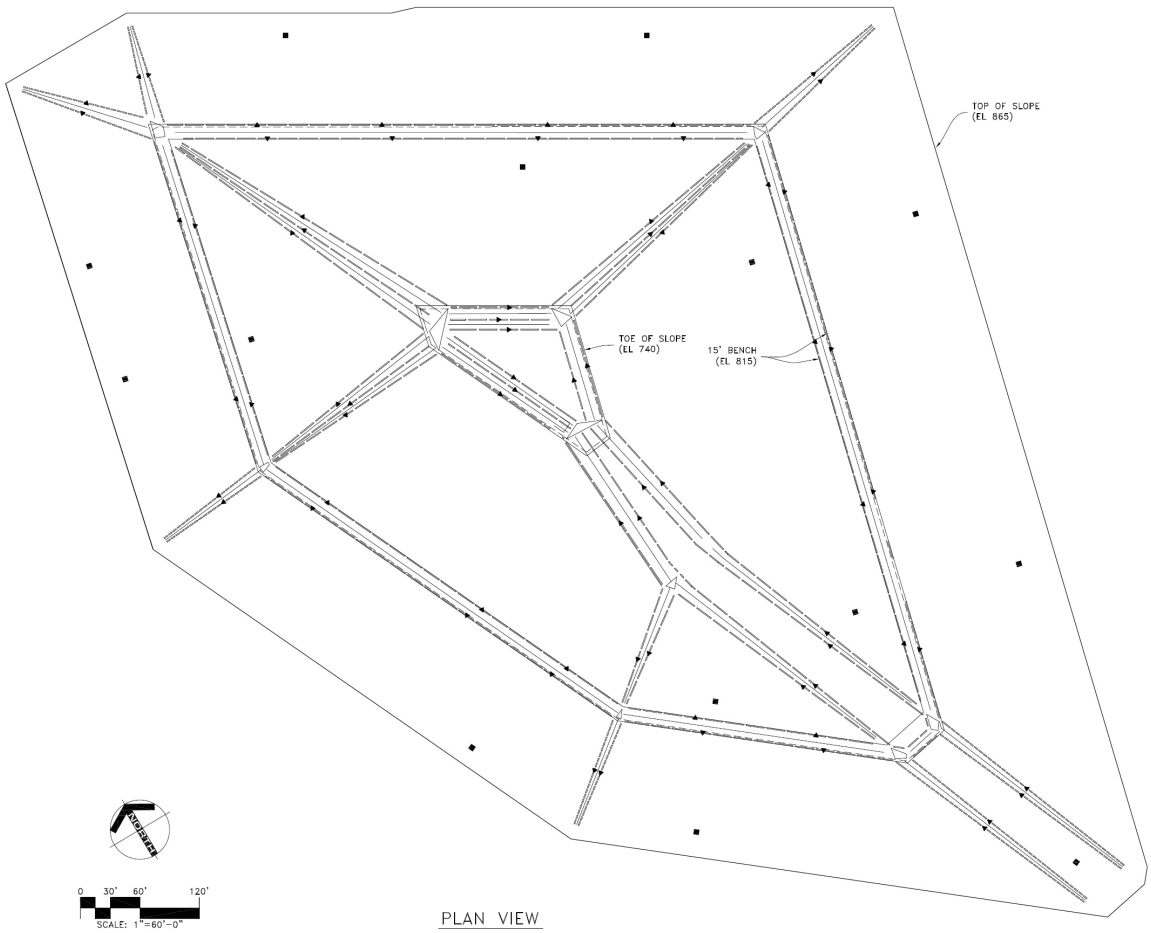

Figure 5: Plan view of cover system showing location of sump channels. Vents are indicated by black squares.

4. THE PROJECT

The Upper Chiquita Reservoir project had actually been started nearly 20 years earlier as part of the long range plans for the water district. There were a number of sites located that were deemed suitable for a large reservoir and environmental studies were begun. These environmental and planning studies started in the 80's and took many years to work their way through the system until the this site was selected and approved for a reservoir.

The design of the reservoir has a number of interesting features. The first is the large earth-fill dam that encloses the canyon to create the containment. This dam is designed for stability in the strong earthquake environment of California. The other noticeable detail is the bench about half-way down the slopes. This bench and a road to access the bench was a design feature to improve access for maintenance. The bench lets the operators reach much of the reservoir surface without having to drain the reservoir completely. Part of the design was a concrete trough over 400 feet long from the top of the slope to the toe of the slope. This trough held the pneumatic lines that were used to operate the valves in the bottom of the reservoir. A final feature of the project was consideration given to the construction of the berms so that the reservoir is not normally visible from the nearby busy highway.

The construction of the reservoir started in the summer of 2009 and progressed well until the winter of that year. The winter of 2009/2010 was very rainy and there were many project delays. The large volumes of water kept the base of the reservoir very wet so that the earthworks could not be completed and the lining could not cover the base of the reservoir. The winter of 2010/2011 was even wetter with one particular week seeing over 10 inches of rain. "The rain gauges overflowed three days in a row" said Bart Lantz, project manager for SMWD. This rain event washed out a portion of the subgrade underneath the liner and a large section of liner had to be removed and the subgrade repaired. Over 200,000 ft^2 of liner was pulled back to access this repair area. It took more than a month for the earthworks contractor to dry out the site after this rain event.

Finally after many weather delays and significant effort in repairs the liner and cover were complete. The reservoir went into service in October 2011.

Figure 6: Subgrade damage after a significant rainfall event.

5. LEAKAGE

As soon as the reservoir started to fill there was leakage observed in the leak detection system. The leakage started as soon as the reservoir had been filled to the 2 ft level and increased in intensity as the water head increased. The leak was approximately 90 gallons a minute which was higher than the specified leakage rate for this structure. The reservoir was put into service while the leak was evaluated.

The first steps were to send divers into the reservoir to see if they could spot any obvious leakage. Immediately they detected leakage in the concrete trough area that carried the pneumatic lines to the base of the pond. Using underwater epoxy the divers attempted to stop the leaks however there appeared to be too many leaks to stop effectively with this technique.

Figure 7: Pneumatic tubing in concrete trough

At this point the reservoir was needed in service and the leakage repairs had to wait for a suitable opportunity.

6. REPAIR

The opportunity to repair the reservoir occurred in 2012 when the Metropolitan Water District did a week-long shut-down of the Diemer Filtration Plant. This type of shut-down is precisely why the Upper Chiquita Reservoir was built and it supplied water to the region throughout this time. Once the shut-down was completed the reservoir was at a very low level so this was the opportunity to make repairs.

The reservoir was drained and the cover and the liner were cut back to expose the concrete trough. The trough was completely filled with additional concrete and then matched to the surrounding the subgrade. The geocomposite and liner materials were then extended over this sealed trench. The operators of the facility were concerned about the maintenance implications of sealing the pneumatic lines in concrete so a secondary set of pneumatic lines were placed on top of the liner in case they are needed in the future. The facility will operate with the encapsulated pneumatic lines until they malfunction and then a diver can switch the lines over to the newer lines on top of the liner using valves in the reservoir. Once the new lines were completed the cover was repaired and the reservoir brought back into service.

Since the repair the leakage rate fallen to between 9 and 10 gallons per minute which is within the design limits for a project of this size.

7. CONCLUSION

The Upper Chiquita Reservoir is the culmination of a long range plan to ensure water security to Santa Margarita Water District and area users. The reservoir is operating as designed and is not experiencing any further issues. The reservoir is an excellent example of a large covered potable water reservoir typical of the California area.

Figure 8: The Upper Chiquita Water Reservoir of the Santa Margarita Water District filled and in service.

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