TECHNICAL PAPER

The Economics of Open Top Reservoirs and Geomembrane Floating Covers

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ABSTRACT

Open top reservoirs have been used for thousands of years for the storage of water for municipal, natural resource and agricultural applications. While these reservoirs are still presently utilized, restrictions have been instituted over time to regulate the protection of these water storages. As a result, geosynthetic floating covers have been developed as a method of providing protection to meet these regulations. Floating covers are designed to eliminate water loss from evaporation and to protect the water source from dirt, debris and other contamination sources. Floating covers have consistently demonstrated their ability to be a long-term solution and are increasingly being used as an economical method to protect water supplies. This paper will cover the history and performance of geosynthetic floating covers over time and their economic advantage compared to other common below and above ground structural alternatives. Lastly, this paper will highlight the long history of chlorosulfonated polyethylene (CSPE) as the primary material for floating covers in potable water storage resulting from its outstanding UV performance and chemical resistance to chlorine and other disinfectants used in water treatment. With over forty years of documented use, CSPE has proven to be one of the best performing materials for floating covers and geomembranes in long term potable water storage applications.

Figure 1. Ramona Water District. CSPE Tensioned Cable Systems installed in 2020.

Figure 2. MWDS Skinner Reservoir. CSPE Defined Sump 2013.

INTRODUCTION

Open top reservoirs have been used for thousands of years for various water storage applications, with the oldest known reservoir in the world being the Jawa Dam in present-day Jordan. It was built in about 3000 BCE to store water for irrigation (National Encyclopedia 2011). Today, open top reservoirs are still frequently used worldwide for many applications, including potable, reclaimed, recycled and wastewater storage. These reservoirs are often lined with a geomembrane waterproofing barrier to prevent seepage. A geomembrane is a low permeability synthetic membrane liner or barrier used to control fluid migration in an earthen containment project, structure or system. Uncovered water reservoirs are often impacted by evaporation, which can be substantial in hotter, arid climates. Geosynthetic floating covers are an excellent method of protecting large volumes of water from evaporation. Additionally, floating covers can help to reduce odors while preventing dirt and debris from contaminating the water being stored. An example of a floating cover is shown in Figure 1 and 2 above.

ECONOMICS OF FLOATING COVERS

Reservoirs with geomembrane floating covers are an economical method of storing larger volumes of water. For example, in 2009, an 18-acre, 244 million-gallon, (923 ML) water reservoir designed with a geomembrane liner and floating cover was completed for the Upper Chiquita Reservoir (Figure 3) owned by the Santa Margarita Water District in Southern California, USA (Mills and Falk, 2013). The overall cost of the Upper Chiquita project, including the construction of the earthen dam and installation of the liner and floating cover, was approximately $53 million US dollars and took 1.5 years to complete. Based on the cost to construct the reservoir, the average price per gallon of water was $0.22 USD.

Figure 3. Upper Chiquita Reservoir

In comparison, the Kelly Butte reservoir in East Portland, Oregon, USA (Figure 4) was completed around the same time period. The Kelly Butte project involved the replacement of two older 10 million-gallon covered storage reservoirs. The original reservoirs, covered by a steel enclosure, were replaced with two 12.5 million-gallon (47.3 ML) storage reservoirs covered by a rectangular concrete structure. The surface area of these reservoirs is about 2.5 acres. The overall investment in the Kelly Butte project was an estimated $90 million taking about 4 years to complete and working out to a cost of $3.60 USD per gallon. The comparison between the Upper Chiquita and Kelly Butte projects shows how a floating cover on an open top reservoir can be substantially more economical.

Figure 4. Kelly Butte Clearwell Reservoir

Another economic advantage of floating covers is evaporation control. In many hot arid regions of the Southern United States, evaporation rates can reach 90” annually. The cost of water in these regions can also be very high, making water losses expensive. This has applications in particular in West Texas where upstream oil and gas producers require large volumes of water for hydraulic fracturing. In the Permian Basin region, producers have reported water costs ranging from $0.50 to $1.00 USD per barrel ($42 USD per gallon) (Fraser and Killian 2015). For the hydraulic fracturing process, this water is stored in frac water pits or structural above ground storage tanks.

Figure 5. Evaporation Control Cover. Permian Basin, Texas, in 2014

These frac pits or tanks can incorporate the use of floating covers to eliminate all evaporation loss. Figure 5 shows a 250,000 ft2 (23,200 m2) frac pond reservoir with a floating cover installed in West Texas in 2014. The producer was losing the equivalent of 13 million gallons annually at an estimated cost of $310,000. The floating cover in this project was supplied and installed for $325,000 and eliminated all evaporation, providing a return on investment period of approximately 13 months. A total of 8 of these floating covers were installed for the operator in this region.

CSPE HISTORY & PROPERTIES

Chlorosulfonated polyethylene (CSPE) was first introduced in the United States in the 1970's as a geomembrane material for water and wastewater containment applications. Initial applications included potable water and wastewater storage for municipalities and tailings ponds for the mining sector. The first floating covers on record using CSPE were installed in the late 1970s in Southern California for municipal potable water storage (Fraser, et al, 2017). The covers were designed and used for evaporation control as well as to prevent dirt and debris from contaminating the water storage supply.

CSPE has many advantages over other commonly specified materials. CSPE is manufactured as a thermoplastic material that will vulcanize over time, becoming a thermoset material capable of surviving thermally stressful, high-temperature environments and UV exposure. When formulated and calendared into a lining grade material, it provides outstanding UV resistance and weathering properties, allowing it to be used for long term exposed containment applications. It also demonstrates a slow reduction of its mechanical and endurance properties over time. The material's unique cross-linking properties provide exceptional resistance to several chemicals used as disinfectants in municipal water treatment, including chlorine, sodium hypochlorite and chloramines, which act as accelerators in breaking down the antioxidant packages of many geomembranes, resulting in environmental stress cracking that causes premature material failure in other geomembrane materials (Mills 2011). CSPE also has a low coefficient of thermal expansion and contraction, providing excellent dimensional stability and lay-flat characteristics in the field. Expansion and contraction problems caused by temperature changes are virtually nonexistent.

CSPE's synthetic rubber properties also provide it with a unique combination of flexibility and durability. In floating cover applications, CSPE is flexible enough to be factory fabricated in large prefabricated panels that can be folded, rolled, and transported efficiently to a containment project site. These larger prefabricated panels are unrolled into position and field welded on site, significantly reducing installation time and construction costs. It also provides consistent seam integrity and liner quality by using shop seams. CSPE is produced in accordance to the Geosynthetic Research Institute GM 28 standards (GRI GM 28).

PROJECT PROFILES

The following section highlights two projects where CSPE floating covers have been installed in hotter and dryer climates for potable water storage and protection. These profiles demonstrate the unique ability of CSPE to withstand weathering and UV exposure, as well as common water treatment chemicals.

PROJECT PROFILE 1: HINKLE RESERVOIR - San Juan Water District

- Granite Bay, California
- Hinkle Reservoir
- 62 million Gallon (238 Million Liters) Capacity
- Potable Water Storage
- CSPE Liner & Cover installed in 1980

Figure 6. Hinkle Reservoir. 40-year-old cover installed in 1980.

San Juan Water District's Hinkle Reservoir (Figure 6) had a 45 mil (1.14 mm) CSPE liner and floating cover installed in 1980. The water district chose a floating cover based on the substantial cost savings versus other storage options. When the reservoir was initially constructed, alternatives such as steel and concrete tanks were considered. After evaluating the costs of each option, the CSPE liner and floating cover system was approximately 60% to 80% less than alternative storage systems considered. This also factored in lifecycle cost for maintenance and servicing.

As a result, a CSPE floating cover was selected and installed as one of the first-generation larger scale floating covers at the time. It is located northeast of Sacramento, CA, spanning 5.7 hectares (14 acres) in a region known for hot, arid summers and high UV exposure. The winters are typically a bit cooler, wet, and partly cloudy. Over the course of the year, the average temperature can vary from 4°C to 40°C (35°F to 104°F).

The reservoir is currently scheduled to have a new liner and cover installed over the next couple of years. At that time, the original installed liner and cover materials will have been in service for over 42 years. The Hinkle Reservoir is believed to be one of the longest reported CSPE floating cover systems still operating.

PROJECT PROFILE 2: Upper Stone Canyon LADWP

- Los Angeles Department of Water & Power (LADWP) Upper Stone Canyon
- Beverly Hills, CA
- Upper Stone Canyon Reservoir
- 139 Million Gallon (526 ML) Capacity
- Potable Water Storage

Figure 7. 45 mil CSPE Defined Sump Cover installed in 2019.

The Upper Stone Canyon reservoir is owned and operated by Los Angeles Department of Water & Power (LADWP). In 2019 a new 700,000 ft2 (65,000 m2) floating cover was installed as part of an initiative to protect and preserve the city's drinking water supplies. This 139 million-gallon-reservoir was first constructed in 1954 for water storage in the Bel Air, CA region. The reservoir provides water to approximately 450,000 residents in the areas of West Los Angeles, Pacific Palisades, Marina Del Rey, and the UCLA campus.

The large reservoir was covered to comply with State and Federal laws. The cover material installed was 45 mil CSPE manufactured with a distinctive green color to better match the surrounding environment. Beverly Hills, CA, is a warm Mediterranean climate known for its dry, arid summers and high UV exposure. Prior to construction, LADWP conducted an environmental impact assessment to investigate the impact of different methods to cover the Upper Stone Canyon Reservoir (Los Angeles Department of Water & Power, 2011). The two main options considered were a concrete roof and a geomembrane floating cover. Looking at the overall cost of the concrete roof option, the LADWP estimated a $140 million expenditure over a 60-year life cycle. Also noted in this study was that most of that cost would be the up-front capital for construction.

The construction timeline was estimated to be 4-5 years. The floating cover option was estimated to be $35 million in overall costs and would only take an estimate 1.5 years to complete installation. The estimated lifespan of a floating cover is in excess of 30 years (Fraser 2019), and even with scheduled cover replacements would still be significantly less expensive than the overall cost of the concrete roof structure. This highlights the cost advantage of using a floating cover, with savings being observed in both the initial purchase and installation and over the lifespan of the cover.

The floating cover replaced the use of plastic HDPE balls, which were used temporarily until a more permanent floating cover system could be installed. The main project challenges were primarily the large scale of the cover system and tight access in the conjected Beverly Hills region. To address the tight space constraints, the floating cover system had to be prefabricated and installed on site in sections. Upon completion, the installed floating cover eliminated all evaporation losses and prevented dirt and debris from entering the potable water storage to comply with state and federal regulations.

CONCLUSION

This paper points out several cost advantages of using open top reservoirs combined with a geosynthetic floating cover compared to structural above ground steel tanks or underground concrete clearwells water storage systems. Floating covers are able to provide the same coverage as traditional water storage methods at a fraction of the costs. Floating covers have consistently demonstrated their ability to perform as long-term exposed covers and are increasingly being used as an economical method to protect valuable water supplies.

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