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CSPE Performance & History in Open Top Reservoirs for long term Potable Water Storage Applications

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ABSTRACT
Open top reservoirs have been used for thousands of years for the storage of water. This paper covers the history and applications of open top reservoirs with geosynthetic floating covers. It discusses the design and performance functions of floating covers. The paper also addresses the notable economics of open top reservoirs using geosynthetic floating covers for the storage of large quantities of water compared to other common below and above ground structural storage methods used. It further discusses the proven performance of Chlorosulfonated polyethylene (CSPE) as a long-term material for floating covers.

This paper highlights the long history of CSPE floating covers in potable water storage and the material's outstanding UV performance and chemical resistance to chlorine and other chemicals disinfectants used in water treatment. The paper further profiles three larger floating cover projects located in hot, dry regions for potable water containment where the covers were used in exposed applications for an average of 30 years. With CSPE, the material goes through a unique polymer cross linking process where several of the product's mechanical and endurance properties improve as the material ages. The material can be repaired in floating cover applications as old as 37 years. With over forty years of documented applications, 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.LADWP, Santa Ynes Reservoir, CA. Floating Cover 2010

1. OPEN TOP RESERVOIRS

Open top reservoirs have been used for thousands of years for various water storage applications. The oldest known reservoir in the world is the Jawa Dam in what is now Jordan. It was built in about 3000 BCE to store water to use for irrigation, or watering crops. Today, open top reservoirs are still frequently used around the world for water storage including potable, reclaimed, recycled and waste water containment. These reservoirs are typically lined with a geomembrane synthetic water proofing barrier. A geomembrane is a low permeability synthetic membrane liner or barrier used with any geotechnical engineering related material to control fluid

migrating in a human made project, structure or system. Uncovered water reservoirs are often impacted by evaporation as a result of winds and warmer temperatures. Water losses can be substantial in hotter arid climates. Geosynthetic floating covers are a good method of protecting large volumes of water from evaporation. Floating covers are designed to eliminate evaporation as well can help to reduce odors while preventing dirt and debris from entering the main water source. An example of a floating cover is shown in Figure 1.

Reservoirs with geomembrane liners and floating covers can also be one of the most economical methods of storing larger volumes of water. As an 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 2) owned by the Santa Margarita Water Districts in Southern California, USA (Mills and Falk, 2013). The overall cost of the Upper Chiquita project including the construction of the earthen dam, 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 US.

In comparison, the Kelly Butte reservoir in East Portland, Oregon, USA (Figure 3) 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 projected surface area of these reservoirs is about 2.5 acres. The overall investment in the Kelly Butte project was about $90 million. The Kelly Butte reservoir took 4 years to complete and worked out to an average cost of $3.6 gallon.

The comparison between the Upper Chiquita and Kelly Butte projects shows how a floating cover on an open top reservoir can be substantially cheaper than a concrete potable water reservoir.

Figure 2. Upper Chiquita Reservoir

Figure 3. Kelly Butte Clearwell Reservoir

2. HISTORY OF CSPE AS A GEOMEMBRANE

Chlorosulfonated Polyethylene is a group of sulfur and peroxide cured elastomers created through a cross linking process with chlorinated polyethylene (CPE) and CSPE. This synthetic rubber was originally developed in the 1950's to address some of the limitations of polyvinyl chloride, polyisoprene, and butyl rubber. In the 1960's CSPE was developed into a sheet material using the calendaring process. CSPE was originally known by the tradename Hypalon®.

Beginning in the mid 1970's CSPE was introduced as a new liner material for water and wastewater containment applications. The initial markets and applications included potable water storage and wastewater treatment for municipalities and tailings ponds for the mining sector. The first floating covers on record using CSPE were installed in the late 1970's in Southern California for municipal potable water storage. The covers were designed and used for evaporation control as well as to prevent dirt and debris from contaminating the water storage supply. An example of a floating cover is shown in Figure 4.

In June of 2009 the developer of CSPE made the decision to exit the production of certain resin products including CSPE. This decision closed the only source of CSPE in North America. Fortunately, there was a qualified backup source of CSPE resin out of Japan. This Japanese source is now the primary resin being used in CSPE products today.

Since its inception as a liner grade product, the manufacturer has confirmed that over 46,000,000 m^2 (500,000,000 ft^2) of CSPE has been supplied into the market as either a geomembrane, a floating cover, or as single-ply roofing. The majority of this material is still in service.

Figure 4. MWDS Skinner Reservoir, CSPE Cover installed 2010

3. PROPERTIES OF CSPE

CSPE has many advantages over other commonly used polymers such as polyvinyl chloride (PVC), polyolefins and elvaloy ketone ethylene ester (KEE) resin technology. One of the primary differences is that CSPE is manufactured as a thermoplastic material that will vulcanize over time, becoming a thermoset material capable of surviving thermally stressful and 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. In standard exposed applications it demonstrates slow reduction of its mechanical and endurance properties.

The material's unique cross-linking properties provide it very good overall chemical resistance to several chemicals used as disinfectants in municipal water treatment. These include chlorine, sodium hypochlorite and chloramines. In water treatment these chemicals can often act as accelerators attacking and breaking down the antioxidant packages of a number of geomembrane types. This can result in environmental stress cracking and premature material failure (Mills 2011). No plasticizers are used in the formulation of CSPE geomembranes resulting in no issues relating to plasticizers that can leach out and cause embrittlement or cracking of plasticized liners. Its inherent low coefficient of thermal expansion and contraction provides excellent dimensional stability and lay-flat characteristics. CSPE also has a very low thermal expansion coefficient compared to that of rigid membranes such as HDPE, and so 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 geomembrane and floating cover applications, CSPE is typically factory fabricated. Fabricated geomembranes are lining materials that are flexible enough for panels to be joined in a factory environment to create large prefabricated panels of material that can be folded, rolled, and transported efficiently to a containment project site. From there these larger prefabricated panels are unrolled into position and field welded on site. Factory fabrication can significantly reduce the amount of field welding which reduces installation time and construction costs. It also provides consistent seam integrity and liner quality.

Standard reinforced CSPE geomembrane grade products are available in 0.91, 1.14, and 1.52 mm (36, 45, 60 mil) thicknesses and meet the Geosynthetic Institute standard GM28 "(Geosynthetic Institute)". This specification provides the specific test methods, properties and testing frequency for reinforced CSPE material. CSPE also has good overall thermal properties allowing it to be installed and handled in temperatures ranging from -30 C (-22 F) to 46 C (115 F). Another unique advantage of CSPE is the materials ability to be repaired or patched after

years of exposed application following specific repair procedures. CSPE materials have been successfully repaired on floating covers in application for over 37 years by certified industry installers.

4. PROJECT PROFILES

CSPE is one of a few industry materials where we have 40 years of confirmed history showing the performance as a liner and floating cover in potable water containment applications. There are several important factors that contribute to achieving long term performance of floating covers in any containment project. These include the initial cover design; selection of material; quality of the workmanship including factory fabrication and field installation. On the operations side, an important factor is the need for regular inspections and preventative maintenance of the cover systems recommended on an annual basis.

In the following section we highlight 3 projects where CSPE liner and floating covers have been used in longer term applications in hot, dry climates for municipal potable water storage. The profiles help to demonstrate the unique weathering ability of CSPE to withstand the elements of time, temperature, UV exposure and chemicals used for water disinfectant.

4.1 PROJECT PROFILE 1: HINKLE RESERVOIR - San Juan Water District

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

Figure 5. Hinkle Reservoir, 37-Year-Old CSPE Floating Cover Picture 2017

San Juan Water District's Hinkle Reservoir (Figure 5) had a 1.14 mm (45 mil) CSPE liner and floating cover installed in 1980. The cover has a defined sump design however with the floatation system installed on the bottom side of the cover. The water district initially chose an open top reservoir with a floating cover based on the substantial cost savings versus other storage options. When the reservoir was initially reconstructed, alternative such as steel and concrete tanks were considered. Being a municipal facility both cost and performance were equally considered in the determination of the storage facility. It was determined at the time that the cost of a 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, CSPE was specified and the material was designed, fabricated and installed as one of the first-generation larger scale floating covers at the time. Fully extended, the floating cover spans 5.7 hectares (14 acres). The Hinkle reservoir is located north east of Sacramento, CA. The region is known for its hot, arid summers and high UV

exposure. The winters are typically a bit cooler, wet, and partly cloudy. Over the course of the year, average temperature can vary from 4°C to 40°C (35°F to 104°F).

In 2016 when the CSPE material reached the 36-year mark, the material was tested by the manufacturer to determine its remaining life expectancy. The material tensile strengths and tensile elongation properties were shown to be above the original published material specifications. Further independent third-party testing was conducted by the water district. 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 41 years. A key to the outstanding success of this floating cover was the regular maintenance and servicing performed by the San Juan Water District. It is believed that the Hinkle Reservoir is one of the longest reported CSPE floating cover systems still operating.

4.2 PROJECT PROFILE 2: HAPPY VALLEY RESERVOIR

South Australia Water Corp, South Australia

- Happy Valley Reservoir
- 100 Million Liters (26,418,000-gallon) Capacity
- Potable Water Storage
- CSPE Liner & Cover originally installed in 1988

Figure 6. Aerial of Twin Happy Valley Reservoirs, Adelaide, AU

In the mid 1980's, SA Water Corp. was evaluating the feasibility of installing geomembrane liners and covers on two new 100 million liter (24.4 million-gallon) earth bank potable water storage reservoirs adjacent to the Happy Valley water treatment plant. This plant provides potable water for most of the southern Adelaide region. Ambient temperatures for the area can often reach as high as 44°C (114°F) and extreme high solar exposure in the summer months. Due to the proximity to the treatment plant, higher levels of chlorine were expected at the inlet stream. Extensive research and testing were carried out during the preliminary design stage on all liner materials available at the time. Significant focus was placed on the puncture resistance, flexibility, UV resistance and long-term durability of materials. This was due to the fact South Australia has some of the highest solar conditions in the developed world. Specific puncture resistance tests were conducted using material obtained from the site and HDPE, CSPE (Hypalon), EDPM and Butanol were all evaluated.

Resulting from the evaluation process, 1.14mm (45 mil) CSPE was selected as the most suitable material (Figure 6). Black material was selected for the liner while the cover material was black on the underside in contact with the potable water and a tan top surface to reduce surface temperatures and provide a more aesthetic appearance.

The Liner and cover for storage 1 were factory fabricated off-site. The twin storages were constructed using compacted cut and fill material with an underfloor drainage system. After final surface preparation, a heavy weight non-woven geotextile cushion layer was installed by the contractor before installation of the pre-fabricated CSPE liner panels. All field seams carried out on the liner were performed using CSPE adhesive. The covers were installed in the same manner. Storage 1 was completed in 1988 and storage 2 was completed a year later. Annual inflations of the CSPE floating covers were carried out to facilitate inspection and cleaning of the liners. Three years after installation during one of these regular inflations the cover on Storage 1 was torn open by a gust of wind resulting in large tear over halfway across the cover and displacing approximately 25% of the cover area. Over the following days the cover was manually pulled back into place and successfully repaired using the CSPE gluing process. The repairs carried out in 1991 on the cover on storage 1 remained for the full remaining life of the material.

Recently, a decision to replace the CSPE liners and covers. The planned 25-year asset life had been achieved and changes to flow were also necessary as water quality standards had changed over the previous 25 years. Short circuiting was an issue as the inlets & outlets were relatively close to each other. After 26 of service, the liner and cover on storage 1 was replaced in 2014. While the tan top surface of the cover was stained the CSPE material was still completely pliable and black underside surface appeared near new. The liner material when cleaned appeared to be in close to new condition. The 26-year-old CSPE liner and cover material was appeared to still have some life in it and were cut and re-used as drop in liners, evaporation pit liners, tarpaulins & haystack covers. In 2016, after 27 years of service, the liner and cover on storage 2 was replaced. The CSPE material was in the same near new condition as in storage 1 and was again recovered and re-used in other applications. The new replacement 45mil CSPE covers were constructed with integral CSPE baffle curtains to improve chlorine contact/residence time and eliminate short circuiting.

4.3 PROJECT PROFILE 3: UPPER RESERVOIR

- Otay Water District, Spring Valley, California
- Upper Reservoir
- 139 Million Liters (36,700,000 gallon) Capacity
- Potable Water Storage
- CSPE Liner & Cover originally installed in 1988

Figure 7. Aerial of Upper Reservoir CSPE Cover

Otay Water is a water, recycled water, and sewer service provider. The California State Legislator originally authorized the establishment of the Otay Water District in 1956 as a special district. The district today provides water services to customers within 200 km^2 (125 m^2) of the densely populated region of southeastern San Diego County. The district's facilities service the water and sewer needs of customers residing in several southern communities of San Diego Country up to the border of Mexico. This region has a very not hot arid climate with summer average temperatures ranging for 20C to 38C (70F to 100F). Winter average temperature can range for

7C to 16C (45F to 60F). The San Diego County is known for a very high to extreme UV index through most months of the year.

The original cover and liner material for the Upper Reservoir were installed in 1988 using a 1.14 mm (45 mil) CSPE. A special aqua skin color was chosen for the skin layer of the CSPE for its aesthetic. The Upper Reservoir is used for portable water reservoir servicing a rapidly growing population base in San Diego County. A weighted tension cable system was initially chosen for the cover design based on its lower maintenance cost primarily the result of not having any surface floats or sumps required to tension the cover. It also allows the operator to use the existing hardware when replacing the cover at the end of its life representing a measurable cost savings during replacement (Figure 8).

In 2018 the existing cover and liner needed to be replaced to allow for mechanical pipe and pump upgrading requirements (Figure 7). At the time of relining the Upper Reservoir floating cover had been in operation for 30 years with no reported major problems encountered during its long operational life. Both the CSPE manufacturer and liner installer were of the opinion after physical inspection of the material that it was still in overall good condition and would have functioned for a few more years. An important part of the cover longevity can be contributed to Otay Water's regular inspection and maintenance programs and the quality design and workmanship of the original installation. The new CSPE cover system incorporated most of the existing hardware a benefit to using the mechanical tension cable system. In terms of industry records, Otay Water's Upper Reservoir was one of the longest performing CSPE floating cover projects for potable water storage in Southern California.

Figure 8. Mechanical Tensioning Tower System on Upper Valley

5. CONCLUSION

This paper points out the potential major cost advantages of using open top reservoirs combined with a geomembrane and floating covers compared to structural above ground steel tanks or underground concrete clearwell water storage systems. The paper further highlights CSPE as a proven material for long term exposed floating cover system in reservoirs. The geomembrane industry has seen several products introduced and promoted into potable water storage however to date, few materials have consistently demonstrated the successful long-term performance for water storage when compared with CSPE. CSPE is supported by a 30-year manufacturers weathering warranty. It is one of the few materials that has truly passed the test of time.

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