TECHNICAL PAPER

Case Study: Lake Forest Reservoir Relining & Floating Cover

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ABSTRACT

This paper highlights a very challenging geosynthetic floating cover project for the Seattle Public Utilities Forest Park Reservoir. The reservoir was first built in 1962 as an open top concrete lined 60-million-gallon containment facility for potable water storage. The reservoir perimeter has a vertical concrete parapet wall with a 2:1 interior reservoir side slope. In 2002, the owner constructed a 28-foot high (8.5 meter) vertical divider wall partitioning the reservoir into two operating cells. The existing geomembrane liner and floating cover material installed in 2002 were showing signs of aging and degradation and required replacement. The new geomembrane liner required a watertight mechanical attachment at the bottom of the parapet wall and extended to the top of the divider wall. The floating cover was anchored mechanically to the top of the perimeter parapet wall and divider wall. The vertical divider wall created specific design and installation challenges for the replacement floating cover and liner. This paper highlights the design challenges and the custom prefabrication and installation techniques needed for the geosynthetic liner and floating cover. In addition, a custom fabricated double trough system was designed and installed to handle the tensioning loads of the floating cover resulting from vertical divider wall. The paper also addresses the importance of the material selection process and the challenges for geosynthetic materials used in floating cover applications resulting from multiple factors including chemical disinfectants, UV exposure, and the need for material flexibility and folds.

Figure 1. Aerial view of the completed east cell (left side) completed in 2021 and west cell (right side) reservoir under construction in July 2022

INTRODUCTION

The Lake Forest reservoir was originally built in 1962 as an open-air drinking water reservoir with concrete lining on the reservoir floor and side slopes. In 2002, the reservoir underwent multiple modifications and improvements which included a 28-foot high vertical cast-in-place reinforced concrete center divider wall and the installation of a geomembrane liner and floating cover. With the divider wall the reservoir was separated into two independent operating cells; each approximately 288 feet wide by 671 feet long by 24 feet deep (87.8 m x 204.5 m x 7.3 m). The reservoir operates as a potable drinking water storage facility and provides emergency water supply. A 45 mil reinforced polypropylene geomembrane liner and floating cover were installed in 2002 and were experiencing problems that required replacement.

In May 2021, phase 1 construction began on the new replacement geomembrane liner and floating cover system for the east cell of the Lake Forest reservoir and was completed in September 2021. Phase 2 included the installation of a new geomembrane liner and floating cover system on the west cell. This construction was completed September 2022.

PROJECT CHALLENGES

The construction challenges included developing a revised floating cover design and installation to address the issues with the 28-foot high vertical divider wall as well as mechanically attached to the perimeter concrete parapet wall. To address the vertical wall configuration and shape of the reservoir, the design engineer selected a weighted tension cover system. This system uses a series of designed troughs in conjunction with surface floats and ballast weights to supply the required cover tensioning, buoyancy in the floating cover, and create rainwater collection troughs to drain surface water adjacent to the vertical divider wall. To handle the additional material slack developed in the floating cover from the 28-foot high vertical divider wall during the different reservoir operating levels, a special double trough system was designed and installed. The installation of this required large custom size panels be fabricated in the factory. These panels then needed to be lifted onto the vertical wall on site to be vertically welded together. The joining of the panels required 3-inch (7.62 cm) wide field seams. The perimeter parapet wall required each panel to be lifted above the parapet wall for deployment of the factory produced panels and anchorage to the top of the perimeter wall. The geomembrane liner was anchored at the base of the perimeter wall and the floating cover was anchored to the top of the perimeter wall. The mechanical attachment consisted of stainless steel concrete anchors and stainless steel batten bars with rubber gasket material. The welding on site was done primarily by thermal wedge and performed in compliance with the Geosynthetics Research Institute GM 19 standards and engineers specified field factory and seam strength requirements.

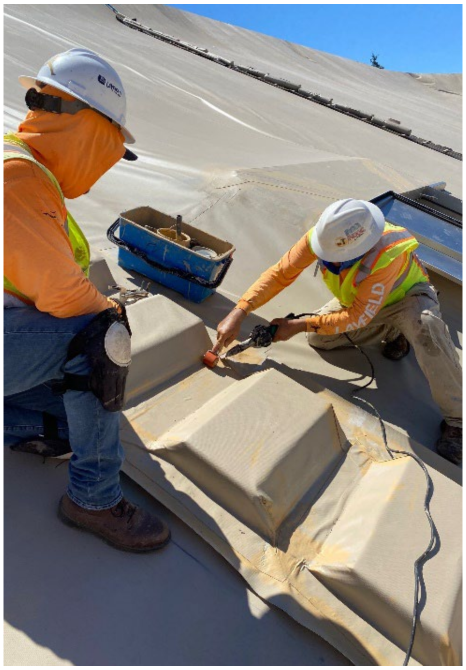
Figure 2. Installation underway of double trough system on 28-foot divider wall on west cell

The weight tensioned floating cover system in both reservoir cells also required various additional appurtenances including access hatches, air vents, access stairways, double material over existing concrete stairs on slope, and a pump surface water removal system. Figure 2 below shows the installation of the divider wall trough system on the west cell. Figure 3 shows the east cell wall trough system in application at close to full operating level of the reservoir.

Figure 3. East cell divider wall trough in full service

The rainwater removal system was designed for a 10-year, 24-hour duration and 25-year, 24-hour duration storm event. The number and size of the rainwater removal system pumps was based on a 48-hour and 72-hour removal capacity. Each cell has five submersible sump pumps housed in perforated aluminum sump cans located in the rainwater collection troughs. The surface water is pumped to the top of reservoir perimeter and discharge into pipes located outboard of the perimeter parapet wall. Figure 4 shows one of the aluminum sump cans located in the east reservoir cell. Figures 5 – 10 show additional installation and inflating testing performed during phase 2 on the west cell.

Figure 4. Rainwater Removal System



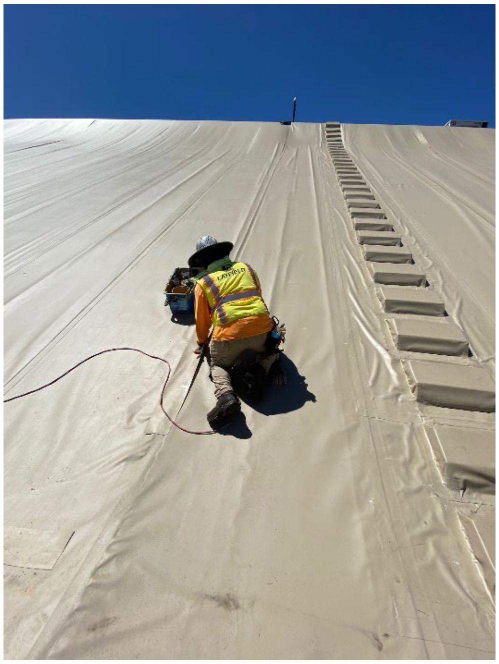


Figure 5 and 6. Crews installing fabricated entry stairways and welding floating cover seams

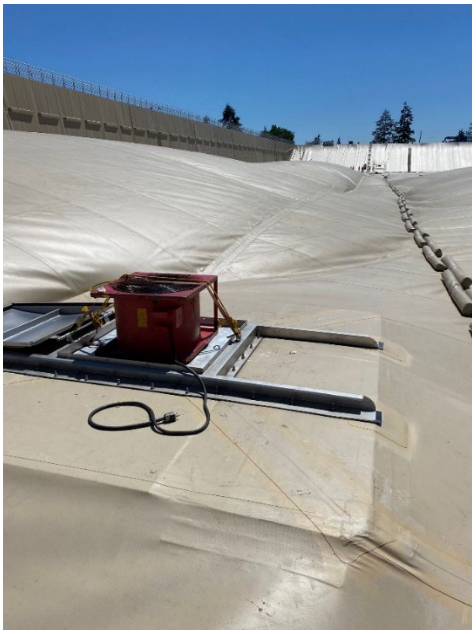



Figure 7 and 8. Inflation via access hatch and west cell cover undergoing inflation inspections.

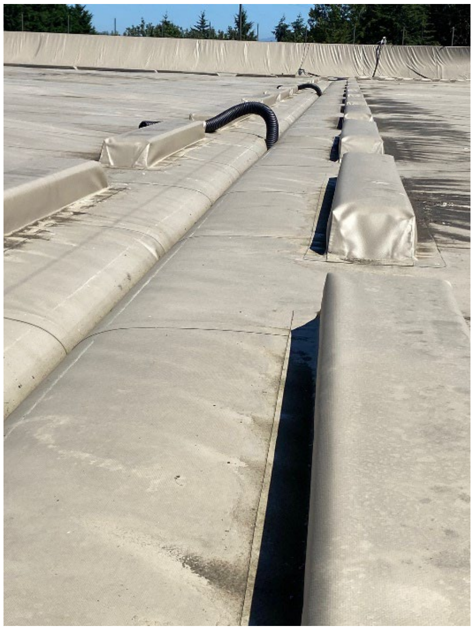


Figure 9. East cell trough & floats in service

Figure 10. Floating cover mechanical anchorage at parapet wall

GEOMEMBRANE FABRICATION

The Lake Forest reservoir required substantial prefabrication of the geomembrane liner, floating cover, and appurtenances. The project required approximately 850,000 ft^2 (79,000 m^2) of prefabricated geomembrane panels. This included a large amount of custom size fabricated panels to address the divider wall and various curves and slopes of the reservoir. In total the project required close to 120 days of equivalent plant fabrication time. The prefabrication of the geomembrane liner, cover and components resulted in substantial reduction in the amount of required field welding, construction time and installation cost. This was also important considering the highly inclement weather conditions typically experienced in the Seattle and Puget Sound region of Western Washington.

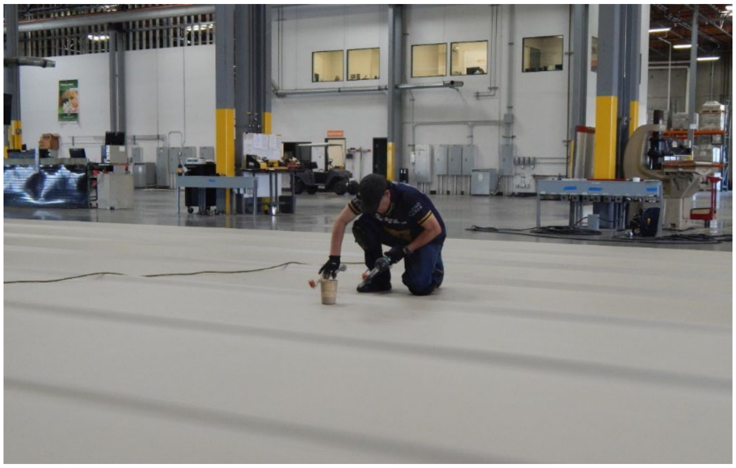


Figure 11. Factory fabrication of CSPE panels in our Lakeside, CA Plant

There are many recognized performance advantages of using factory fabricated panels for geomembrane liners and floating covers. The constant and favorable factory-controlled environmental conditions yield higher quality, better seams between individual geomembrane rolls, than field fabricated geomembranes and fewer opportunities for damage by field activities and personnel. The Fabricated Geomembrane Industries (Stark et al. (2020) has previously compared factory and field welded thermal geomembrane seams for a large off-stream water reservoir project. This comparison showed that factory welded seams exhibit higher seam peel and shear strengths, less variability, and more consistency than field welded thermal seams. The compiled test results showed that factory seams are about 10% stronger than field seams. Factory fabrication can typically result in about 75% less field seams on a project.

MATERIAL SELECTION

The material selection process was an important factor for the geomembrane liner and floating cover portion of the project. The current reinforced polypropylene (RPP) material had demonstrated signs of fatigue and premature degradation at approximately 16 years in service. This included various cracks located around folds and creases as per Figures 12 and 13 below. Also, the extent of damage on the geomembrane liner material could not be determined until the reservoir was taken out of service and the floating cover system was fully removed. The type of cracking in the material folds is often associated with multiple factors including prolonged UV exposure, continuous exposure to chlorine used for potable water disinfection, and stress concentrations at upstanding folds resulting from hydrostatic pressure. Chemicals used for disinfectants in municipal water treatment include chlorine and chloramines and can function as accelerators in breaking down or leaching out the protective antioxidant packages of certain geomembranes resulting in environmental stress cracking and premature material failure (Mills 2011).

After a detailed review process and consideration of available materials, the owner selected chlorosulfonated polyethylene (CSPE) for the replacement geomembrane material. CSPE is a highly flexible geomembrane which has been on the market for over 50 years with a long established history of proven performance in municipal water containment applications using chlorine and other

Figure 12 & 13. Surface cracks found in the RPP liner material folds and creases.

disinfectants. The CSPE geomembrane material is also noted to have excellent UV resistance and backed by a 30 year weathering warranty.

CONCLUSION

The relining and cover replacement of the Lake Forest project incorporated many of the current best practices outlined in the AWWA Manual M25, *Flexible Membrane Covers and Linings for Potable-Water Reservoirs.* As the owner required a 30-year service life for the liner and cover, the material selection of the CSPE material with its 50 year proven record in potable water reservoir was an important decision. The project also incorporated an important weighted tensioned floating cover design including strategically located custom troughs designed to manage the water service levels and center divider wall. Factory prefabrication of the materials and appurtenances was essential ensuring high quality as well as reduced installation risk and costs. With the integration of a site specific operations and maintenance program including regular planned inspections, all stakeholders involved are confident that the new Lake Forest reservoir liner and floating cover system will perform very well and achieve its expected 30-year service life.

REFERENCES

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Stark, T.D., Hernandez, M.A., and Rohe, D.S., (2020). "Geomembrane Factory and Field Thermally Welded Geomembrane Seams Comparison," *Geotextiles and Geomembranes Journal*, 48(4), August 2020, 454-467, https://doi.org/10.1016/j.geotexmem.2020.02.004.