FEASIBILITY OF HYDROGEN STORAGE IN POLYMER-LINED CONCRETE FACILITIES

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A study on repurposing local pre-existing concrete structures as hydrogen storage containers using restorative encapsulation materials and methods.

THE BACKGROUND PROBLEM

WHAT: Storage of hydrogen in existing concrete bunker structures could be a feasible option in Umatilla, Oregon by utilizing a polymer lining to improve the structure's hydrogen encapsulation, structural integrity, and reduce leakage.

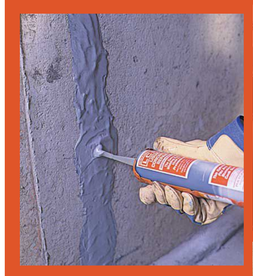
WHY: Hydrogen is an increasingly popular alternative fuel source to product clean green energy. An inexpensive, recycled, and versatile way to store hydrogen is desirable.

MATERIALS INVESTIGATED

RESIN: epoxy resin, pure or composite
- PRO: High compressible and tensile strength, Low permeability, Fills cracks
- CON: Slower application via liquid resin

SPRAY: spray polyurethane foam, sealer
- PRO: Low permeability, Easy and quick application, Inexpensive, Fills cracks
- CON: Very low compressible strength

PLASTIC: solid polymer sheets, HDPE
- PRO: High compressible and tensile strength, Low permeability, Inexpensive
- CON: Slow application, Less conformable



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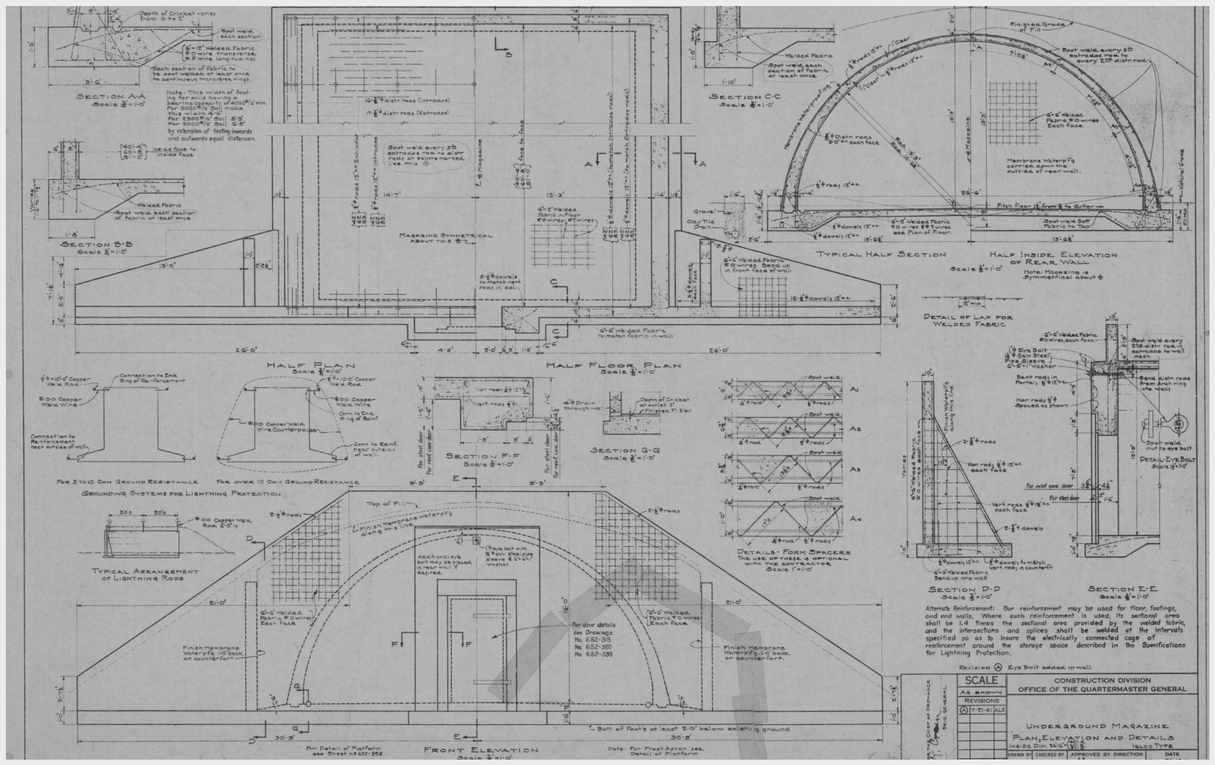


WHAT ABOUT CONCRETE?

- Aged concrete has a much lower strength and pressure integrity than fresh poured concrete
- Cracks could be filled with resin or concrete patches but this does not strengthen the surrounding aged concrete or the interior fill
- Typical life expectancy of reinforced concrete can be up to 100 years but requires maintenance
- How does tensile and compressive strength dictate how much pressure a vessel can hold?

IMAGE REFERENCES

"Epoxy Injection for Concrete Crack Repair." *Engineering Discoveries*, 2018, www.engineeringdiscoveries.net/2019/06/epoxy-injection-for-concrete-crack.html.

Gundle GeoSynthetics, Admin. "Products: GeoSynthetics; HDPE Liners & Other Enviroliners." Products; *Gundle Geo*, 18 Mar. 2020, www.gundlegeo.co.za/products/.

Houlton, Sarah. "Spray Polyurethane Foam Alliance Appoints Executive Director." *Rubber News*, 25 Sept. 2020, www.rubbernews.com/executive-action/spray-polyurethane-foam-alliance-appoints-executive-director.

Notarianni, John. "A New Life Awaits for the Umatilla Chemical Weapons Depot." *OPB*, 4 Mar. 2019, www.opb.org/news/article/oregon-umatilla-chemical-weapons-depot/.

United States, Congress, Office of the Quartermaster General, and Delaney Ferguson. *Underground Magazine Plan, Elevation and Details,* Igloos ed., 1941. *Plan 652-394.* via Obsidian Renewables.

EPOXY RESIN LINING

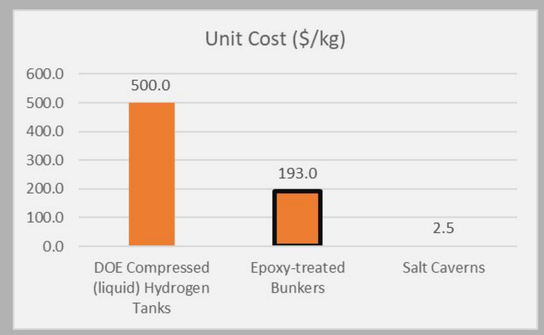
- Epoxy resin is an adhesive used for many purposes such as floor coatings and plumbing.
- Hydrogen gas is very small and has high permeability in many materials; however, hydrogen gas has a permeability through epoxy resin that is about one million times lower that its permeability through new concrete.
- Epoxy resin is used to repair cracks in concrete and 0.375 centimeters of epoxy resin was able to withstand an average of 400 psi when tested.
- Using 0.375 cm layer of solid epoxy resin to line the **entire** bunker; 82.5 kilograms of hydrogen gas compressed at 100 psi feasible per bunker.

RESIN LINING COSTING

Capital Cost per Bunker: $20,270.00

Payback period: 4 years*

* Profit estimates assume 12 bunkers storing 82 kg hydrogen with a 1-month cycle and a set value of hydrogen gas product at $19.52/GGE. Maintenance estimated every 5th year, and transportation costs estimated using 2023 gas prices in state.



- This epoxy resin treatment is a competitive option compared to other storage methods due to its lower cost and high versatility.

EPOXY APPLICATION

- Epoxy consists of two parts: an adhesive resin and a curing agent.
- When applying epoxy to concrete, the concrete must be cleaned of any grease or other residues. Power washing the concrete is a good way to achieve the necessary cleanliness.
- Epoxy can be brushed, injected, or poured onto a surface and takes 2-8 hours to set depending on the temperature.
- After 3-7 days, the epoxy will be fully cured and ready for use. Rapid curing is possible.

REFERENCES

Gajda, Dawid, and Marcin Lutyński. "Hydrogen Permeability of Epoxy Composites as Liners in Lined Rock Caverns—Experimental Study." *Applied Sciences*, vol. 11, no. 9, Apr. 2021, p. 3885. *Crossref*, https://doi.org/10.3390/app11093885.

Gajda, Dawid. *Epoxy Resin for Sealing the Underground Hydrogen Storage Reservoirs*, Silesian University of Technology, 21 May 2021, https://avestia.com/EHST2021_Proceedings/files/paper/EHST_103.pdf.

Elberry, A. M., Thakur, J., Santasalo-Aarnio, A., & Larmi, M. (2021). Large-scale compressed hydrogen storage as part of renewable electricity storage systems. *International Journal of Hydrogen Energy*, 46(29), 15671-15690. https://doi.org/10.1016/j.ijhydene.2021.02.080

Harries, Kent A, and Michael Sweriduk. *Hydrostatic Pressure Tests of Spray-Applied Epoxy Lining System*, Warren Environmental, 25 Mar. 2013, https://www.warrenenviro.com/wp-content/uploads/2020/07/Multi-ASTM-Hydrostatic-Pressure-Testing_Kent-A.-Harrie.pdf.

"Clean Cities Alterna ve Fuel Price Report - Alternative Fuels Data Center." *Alternative Fuel Price Report*, afdc.energy.gov/files/u/publication/alternative_fuel_price_report_january_2023.pdf. Accessed 14 May 2023.

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