



LINERS AND COVERS FOR RESERVOIRS - EVALUATION AND REPLACEMENT

Mike Sadlier

Geosynthetic Consultants Australia

sadlierma@gmail.com

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A 15 year old fPP-R cover in poor condition

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Background 1

- Water reservoirs built or renovated in the last twenty years or so
- Liner and floating cover materials based on flexible polypropylene in both unreinforced and reinforced formats. fPP and fPP-R
- These materials have suffered over time mostly as a result of oxidation caused by aggressive sunlight exposure.

Background 2

- Older fPP materials have become difficult to weld
- Larger samples may require repairs by bolts and battens which compromise cover flexibility.
- Often we can only take very small samples from places like weld flaps.
- There may be limited scope for tensile or other mechanical testing and we may have to rely on analytical testing such as OIT and HPOIT

Testing – OIT and HPOIT

- OIT and HPOIT effectively assess the remaining antioxidant capacity provided by additives
- Most fPP materials used hindered amines such that HPOIT becomes relevant.
- Once antioxidant capacity is depleted the base polymer may be subject to oxidation.
- Comparing OIT or HPOIT of the unexposed material to the exposed material value can give a good assessment of the remaining service life.

Other Testing

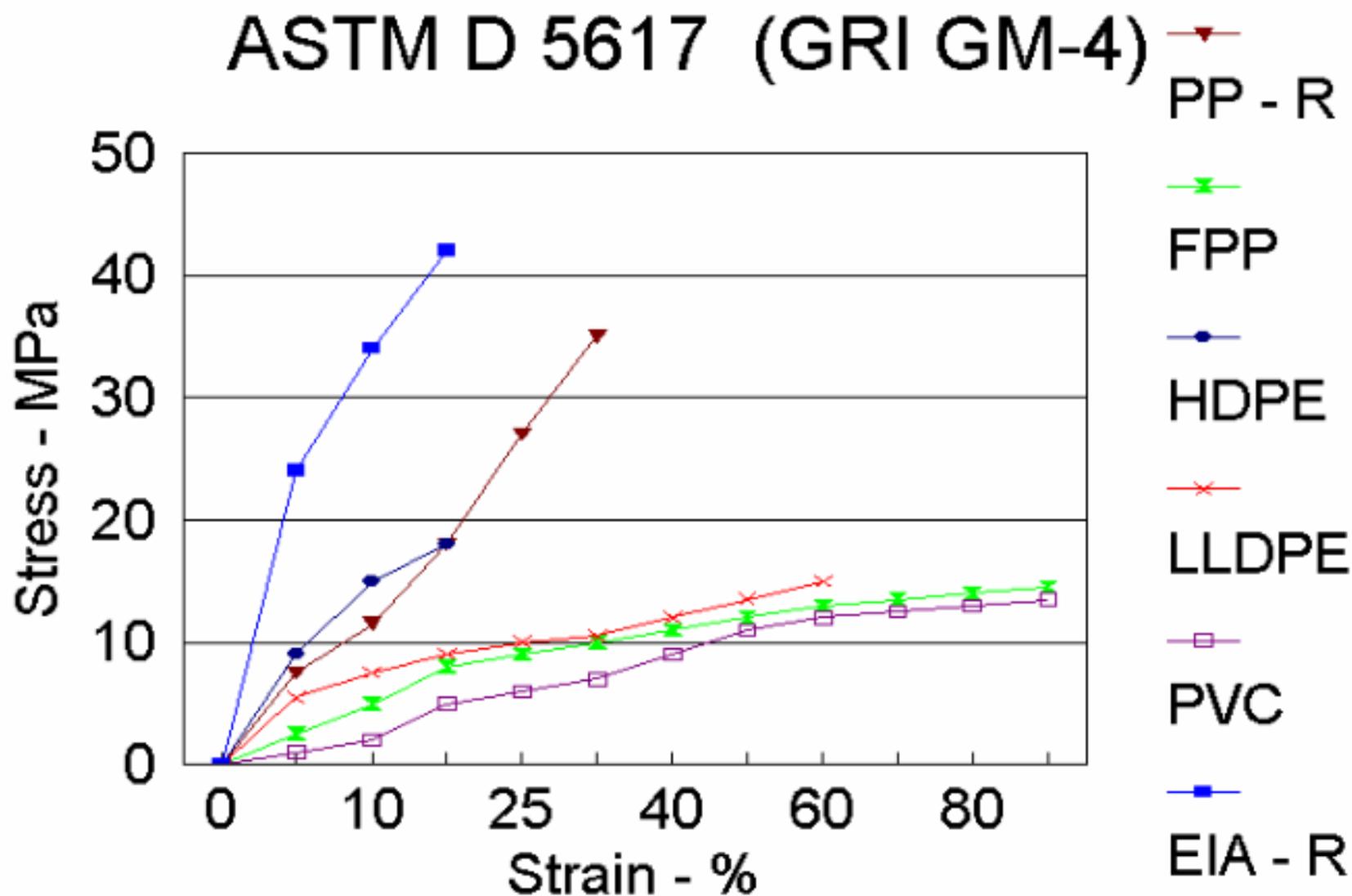
- Tensile and tear tests if samples can be obtained.
- Trapezoidal tear is especially useful for reinforced materials
- Carbonyl Index uses FTIR comparisons to help assess the extent of oxidation
- Microscopic examination of folded surfaces

Current Materials

- HDPE
- LLDPE
- PVC and PVC/EIA
- CSPE
- fPP and fPP-R

MULTIAXIAL BURST

ASTM D 5617 (GRI GM-4)



HDPE Development

Property	Test Method ASTM	GM 13 Value (1999)	GM 13 Value (2016)	GM 13 Value (2021)	“Enhanced” HDPE (2017)
Stress Crack Resistance	D 5397	200 hr.	500 hr.	500 hr	1000 hr. plus
Multiaxial bursting elongation at burst	D 5617	Not in GM13 ~15%	Not in GM13 ~15 to 20%	Not in GM13 ~15 to 20%	~45%
(a) Standard OIT	D 3895	100 min.	100 min.	100 min.	130 min.
(b) High Pressure OIT	D 5885	400 min.	400 min.	400 min.	700 min. plus

LLDPE Development

Tested Property	Test Method	Unit	LLDPE to GRI GM17	Fortified LLDPE
Density	ASTM D1505	g/cm (Min)	<0.939	<0.939
Notched Constant Tensile Load	ASTM D5397	hrs	N/A for LLDPE	1000 hrs
Multi-Axial Tensile Elongation	ASTM D5617	%	30%	80%
Strength Retained after 30,000 Hrs of QUV exposure	ASTM D4329	%	Not listed	90%
Oxidation Induction Time (OIT)	ASTM D3895	min	> 100	> 100
High Pressure Oxidation Induction Time (HPOIT)	ASTM D5885	min	>400	2000 min

Polyvinyl Chloride (PVC or PVC/EIA)

- PVC is a naturally stiff or brittle material eg pipes
- Requires use of plasticisers and associated stabilisers to achieve a flexible geomembrane material.
- Reinforced PVC from both America and Europe that uses proprietary ketone ethylene ester (KEE) polymeric plasticisers that enable long term flexible performance under exposed conditions
- Some manufacturers are calling this an ethylene interpolymer alloy (EIA or Elvalloy) and are trying to ignore the PVC origins of the material
- PVC/EIA geomembranes maintain the flexibility advantages of PVC but have good durability and chemical resistance especially with extreme temperature
- Thermal welding is easy and effective with automatic and hand operated equipment
- Can be a taste and odour issue with water supply

Chlorosulphonated Polyethylene (CSPE)

- Previously known as Hypalon.
- Scrim reinforced for dimensional stability and strength.
- Seaming by both solvent bonding and thermal methods but it crosslinks or cures with exposure such that thermal welding becomes more difficult
- Once cured, modifications or repairs must use solvent based adhesive.
- CSPE provides very good chemical resistance and excellent UV exposure performance
- Has provided good service in the past for floating membrane cover systems

Polypropylene fPP

- Appeared on the scene in the 1990's in both reinforced and unreinforced forms
- Offered great promise because it was competitive and easily installed and repaired.
- During the 2000's formulations appeared to change and there were many performance issues in Australia and the Americas.
- After the GeoAmericas Conference in 2008 the GRI GM18 Specification was re-issued with a requirement for 20,000 hours of QUV accelerated UV testing
- Several manufacturers have completed this testing and more but unfortunately facility owners have been reluctant to use the new fPP.

ACCESS ISSUES

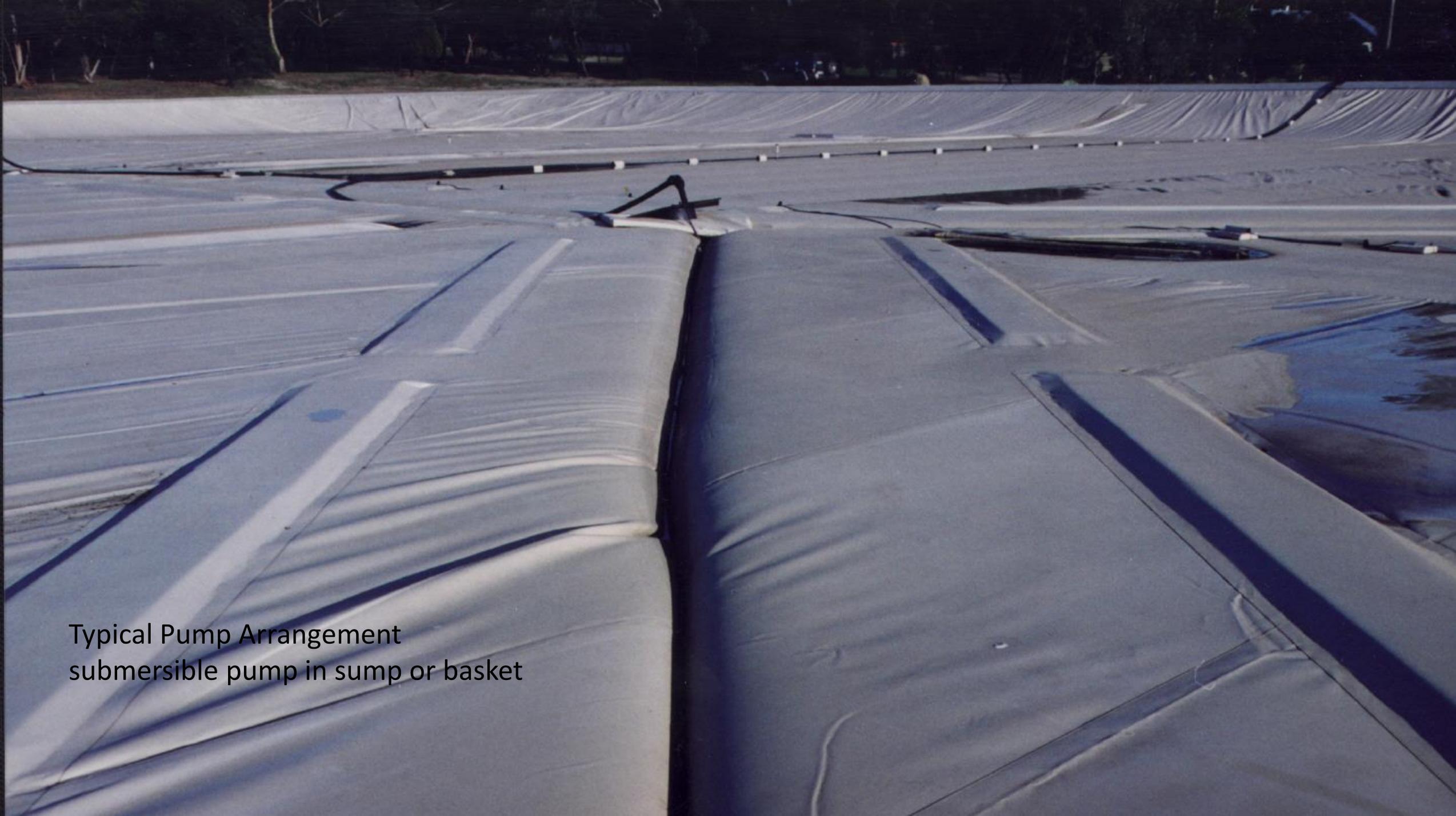
Sump with pump

Access to hatch



Pumps and Access

- Submersible pumps in floating sumps or baskets were common practice
- Safety concerns about access for maintenance and electrical safety have given rise to other solutions
- Some are using off cover pumps but long suction lines need help with priming
- Despite the installation of walkways there is a reluctance to have personnel working on floating covers



Typical Pump Arrangement
submersible pump in sump or basket

Off-cover pump
with header tank
for priming



Floating Cover Access

Is this the solution?



Water Reservoir Leakage Rates

- Based on North American data Peggs and Giroud (ICG10 Berlin 2014) suggested action leakage rates of around 2300 litres/hectare/day for a water depth of 4 m
- Several recent renovation projects have seen PVC/EIA liners installed over geocomposite drain systems with existing compacted clayey soils, concrete liner or old geomembrane retained as a de facto secondary liner
- Sizes have ranged from 3000 sqm to 10,000 sqm with effective depths of 4 to 8 m
- Some used conductive geotextile to facilitate leak location survey by the Arc method and others had water introduced to enable dipole leak location survey
- Observed leakage rates were all less than 150 litres/hectare/day
- Point of weakness was seen to be old concrete structures and liner fixings to old structures

A 22 year old cover built with a hybrid of reinforced mPE and coextruded HDPE/LLDPE. Reinforced component no longer available



Thank you

Especially to all those reservoir owners and operators who put up with extreme heat and cold, wild weather, bushfires and aggressive wildlife.