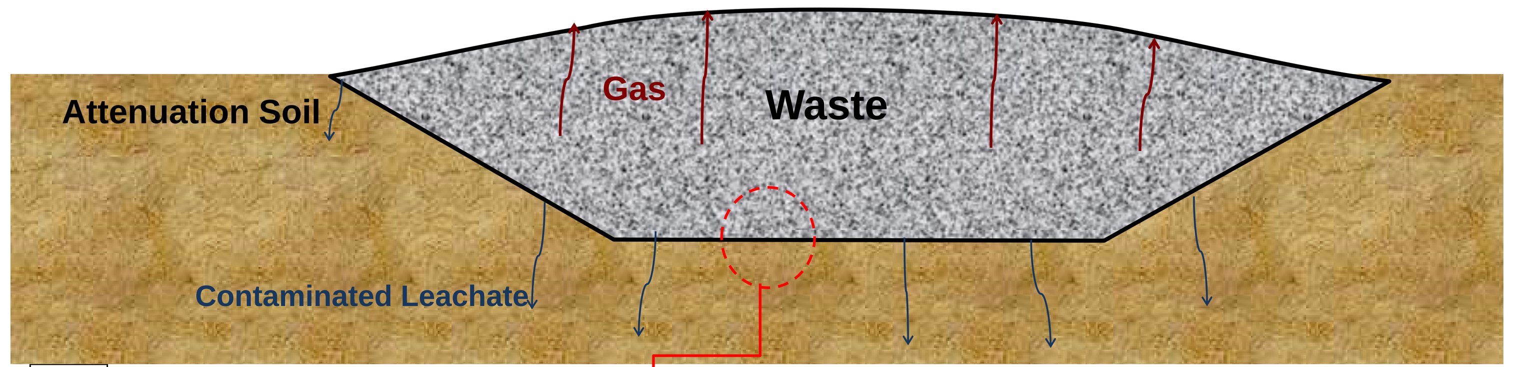
Durability of HDPE Geomembranes

Amr M. R. Ewais, *MSc., PhD, P.Eng.,*
Research Associate at University of California Berkeley.

Polyethylene Geomembrane (GMB)



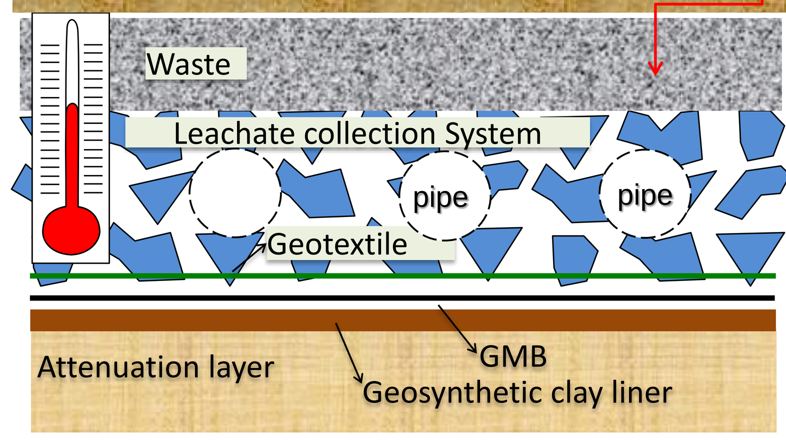


Fig1. Landfill Composite liner.

GMBs are widely used in *preserving earth's integrity while promoting engineering earth's development.* used as part of base liners or covers in different waste disposal (e.g., landfills Fig1), oil, gas, and mining applications (e.g. Fig2).

Fig2. Water Dam at Alumbrera mine in northwest Argentina [10].

Challenges facing the use of GMBs

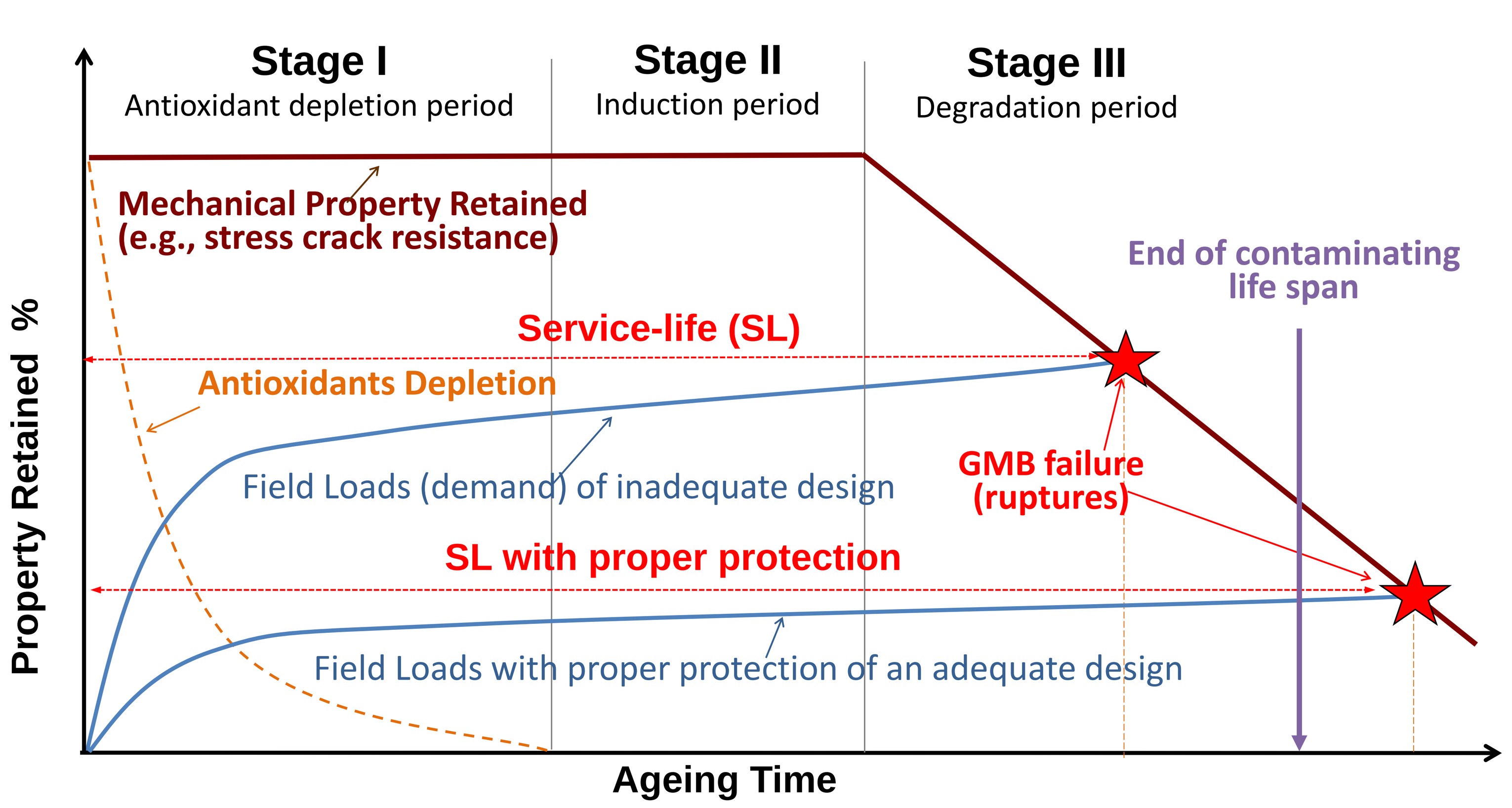


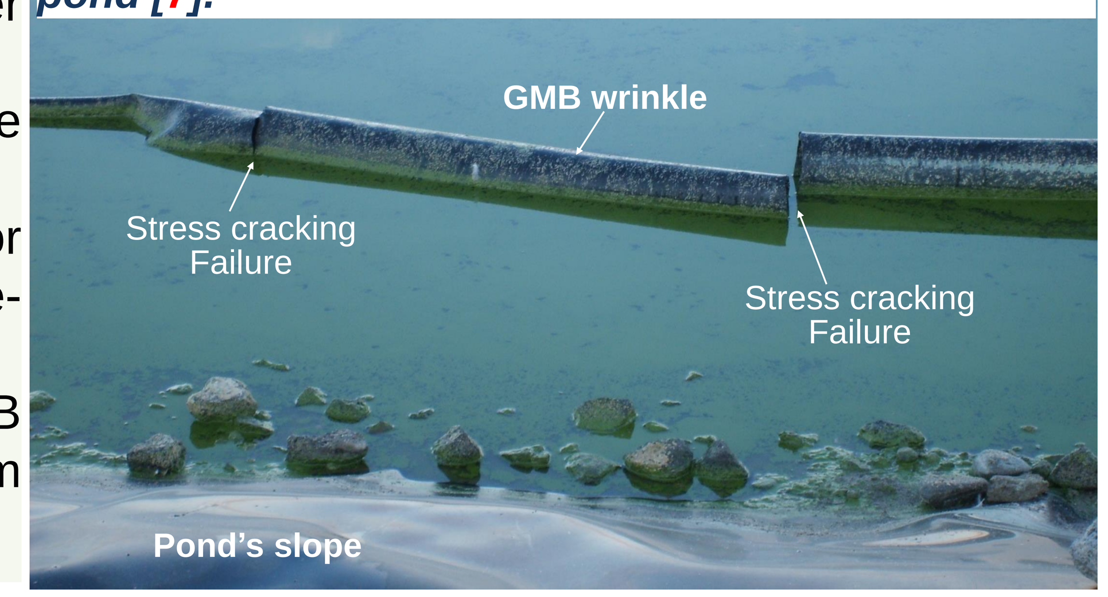
Fig3. Classical degradation model [6] vs load demand

1. A GMB will degrade with time and lose its engineering properties (Fig3) until ruptures signal the end of its service-life (SL) (Figs 4&5) **[2,4,5,6,7,10]**.
2. Different load demands and exposure conditions from one application to another **[4,7,10]**.
3. The properties of the GMB differ from one manufacturer to another and even within the same manufacturer **[2,3]** .

Research Objectives

1. Enhancing the criteria in practice of selecting the proper polyethylene GMBs.
2. Estimating the service-life polyethylene GMBs in the field.
3. Developing a protocol for assessing the remaining service-life of existing GMBs.
4. Investigate the effect of GMB properties on the long-term performance of the GMB.

Fig4. GMB failure at wrinkle at the base of water pond [7].



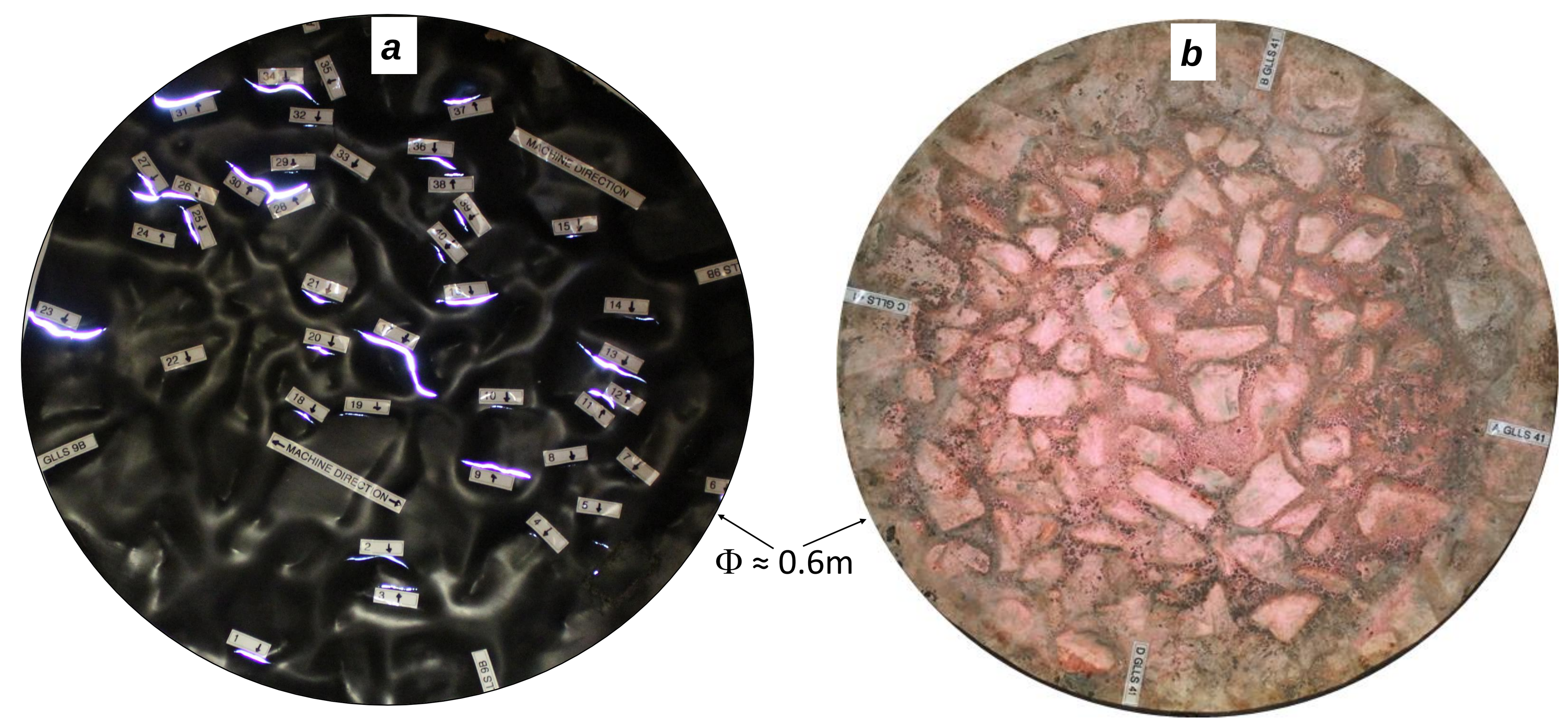


Fig5. photos for: (a) half of ruptured GMB samples with light shining through raptures and (b) half of geotextile protection sample that was rested on the GMB samples after being aged in GLLS (Fig5) [5].

Testing procedure

Field conditions (Ideal) [10]*:* the degradation behaviours of GMBs' samples exhumed from the field (Fig2) were investigated for three different facilities.
B) Simulated Conditions:
i. ***GLLS (Fig5):*** simulate landfill composite liner (>70 Cells were built) [5,14].
ii. Oven Immersion (Fig6) [5, 9, 12, 13].
iii. Exposed to the elements (Fig6) [11].

.

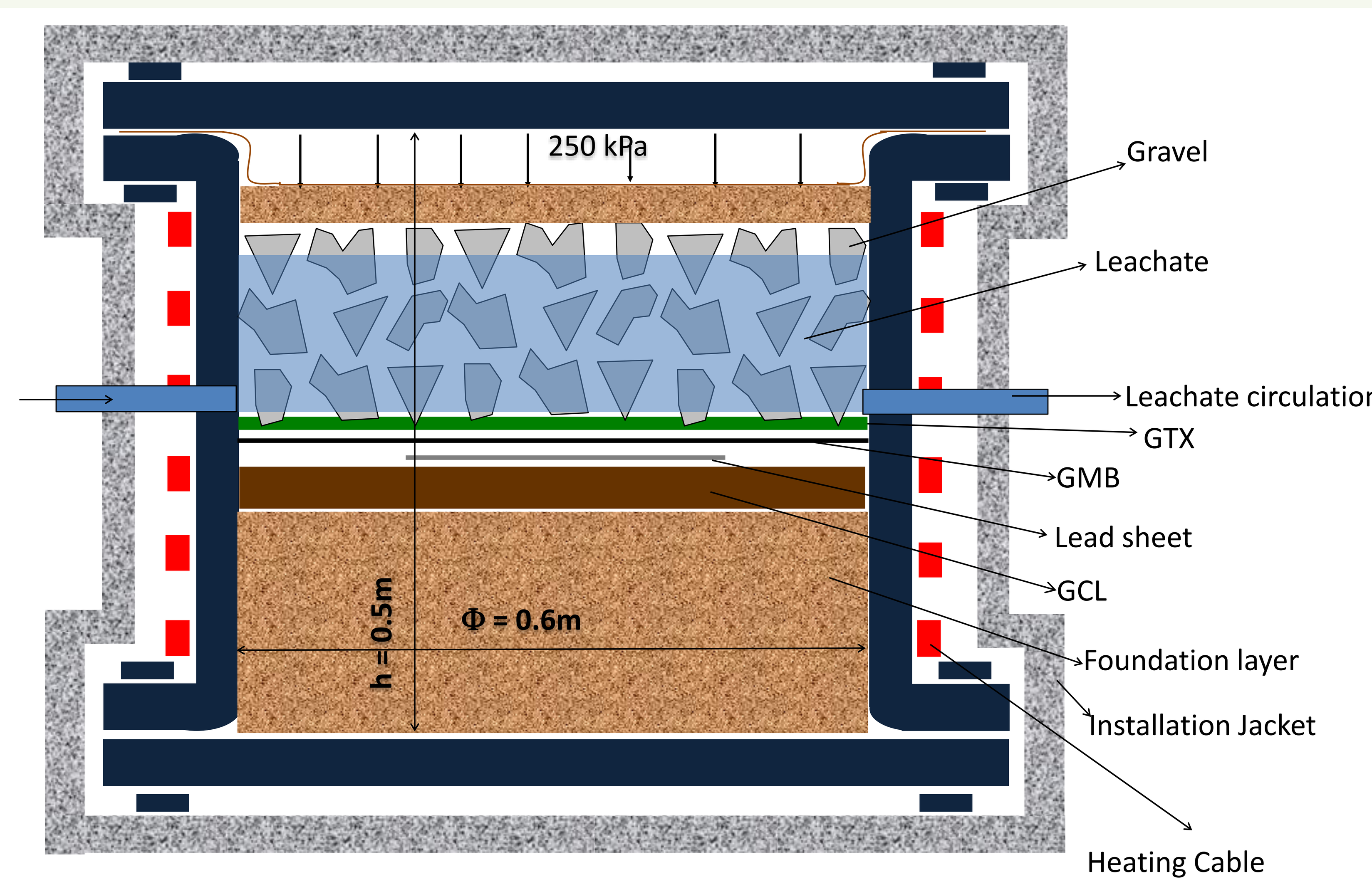


Fig.6 Geosynthetic Liner Longevity Simulator (GLLS)[1].

Summary and conclusions

a) The current practice of selecting the GMBs based on their initial properties might be misleading. The reasons and proposed enhancements for the selection criteria are discussed [3,5,9].

b) Catastrophic failures for GMBs after short service periods may be caused by the significant decrease in GMB's stress crack resistance due to morphological changes in the GMBs structure that may begin to take place shortly after a GMB is manufactured such that ***classical degradation model (Fig3) is no longer applicable***. Discussion and a proposal for mitigating catastrophic failures are proposed in [3]. For exposed GMBs, White GMBs are less prone to catastrophic failure than black GMBs [11].

c) Thicker GMBs have: slower degradation rates but not as much as expected, and higher initial stress crack resistance if they are from the same resin [2,9].

d) The GMB aged in landfill liner configuration (GLLS, Fig5) at 85ºC is shown to have service-life as little as three years with 30,000 to >2.0 million ruptures/hectare at failure (Fig3a). Thus, more proper protection (than GTX of 580 g/m², Fig3b) will be required for GMBs used in similar landfill liner configuration at high temperatures (>55ºC) [4,14].

e) A protocol for testing and inferring the long-term performance of already installed GMBs in the field were developed [10].

f) Service-life for different GMBs were presented to help the designer in selecting the proper GMBs [4,5,8,910,11,12,13,14].

Fig7. Immersion tests.

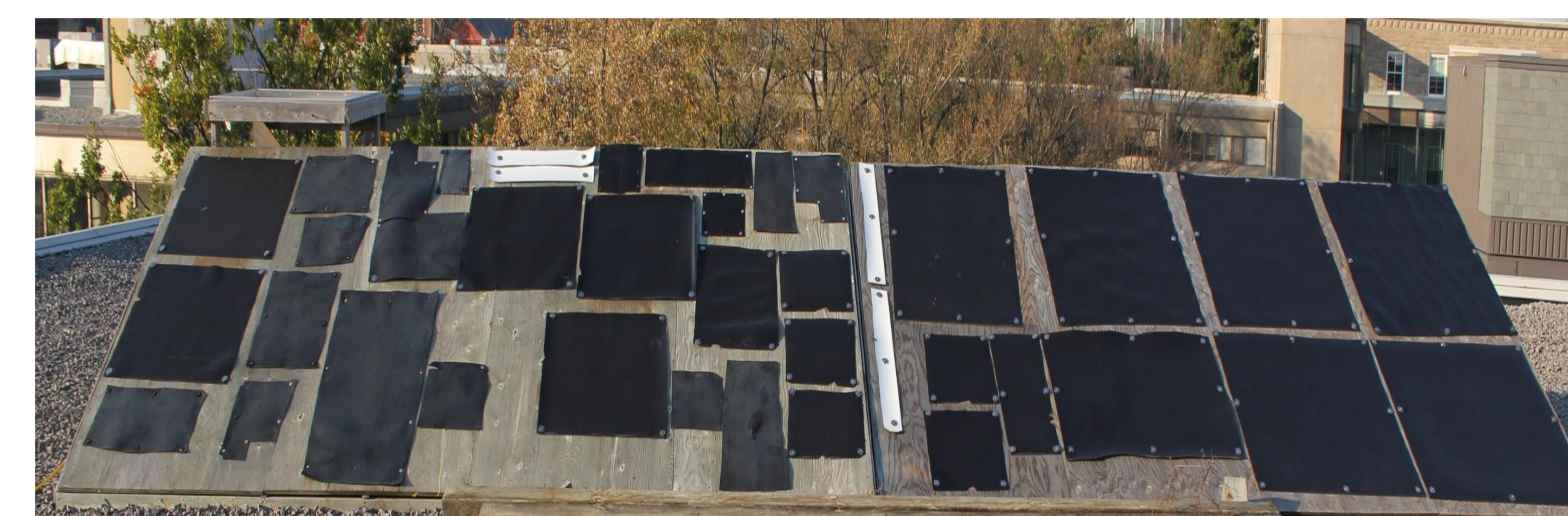


Fig8. Exposed samples of 16 different GMBs at Queen's University [11].

References

[1] Brachman, R.W.I., Rowe, R.K., Arnepalli, D.N., Dickinson, S., Islam, Z. and Sabir, A. (2008). "Development of an apparatus to simulate the ageing of geomembranes under chemical exposure", Elevated Temperatures and Applied Stresses, GEOAMERICAS 2008, Cancun, Mexico, March, pp. 444-451.
[2] Ewais, A.M.R. and Rowe, R.K. (2014). Effect of blown film process on initial properties of HDPE geomembranes of different thicknesses. Geosynthetics International, 21(1), pp. 62-82.
[3] Ewais, A.M.R and Rowe, R.K. (2014). Effect of ageing on the stress crack resistance of an HDPE geomembrane. Journal of polymer degradation and stability, Vol. 109, pp. 194-208.
[4] Ewais, A.M.R, Rowe, R.K., Brachman, R.W.I. and Arnepalli, D.N. (2014). Service-life of a HDPE GMB under simulated landfill conditions at 85ºC. Journal of Geotechnical and Geoenvironmental Engineering (ASCE), Vol. 140(11), 04014060.
[5] Ewais, A.M.R., Rowe, R.K. and Scheirs J. (2014). Degradation behavior of HDPE geomembranes with high and low initial high pressure oxidative induction time. Geotextiles and Geomembranes, 42 (2), pp. 111-126.
[6] Hsuan, Y. G. and Koerner, R. M. (1998). Antioxidant depletion lifetime in high density polyethylene geomembranes. ASCE Journal of Geotechnical and Geoenvironmental Engineering, Vol. 124, No. 6, pp. 532-541.
[7] Peggs ID. Eliminating geomembrane stress cracking. Technical note at geosynthetica. net; 2013., http://www.geosynthetica.net/geomembrane-stresscracking/.
[8] Rowe, R.K., Islam, M.Z., Brachman, R.W.I., Arnepalli, D.N. and Ewais, R. A. (2010). "Antioxidant depletion from an HDPE geomembrane under simulated landfill conditions", ASCE Journal of Geotechnical and Geoenvironmental Engineering.
[9] Rowe, R.K. and Ewais, A.M.R. (2014). Antioxidant depletion from five geomembranes of same resin but of different thicknesses immersed in leachate. Geotextiles and Geomembranes, Vol. 42(5), pp. 540–554.
[10] Rowe, R.K. and Ewais, A.M.R. (2015). Ageing of exposed HDPE geomembranes at locations with different climatological conditions. Canadian Geotechnical Journal.
[11] Ewais, A.M.R. and Rowe, R.K. (2014). Effect of resins and thicknesses on OIT depletion for geomembranes exposed to the elements (In preparation).
[12] Rowe, R.K., Ewais, A.M.R. and Rimal, S. (2018). Seventeen years of ageing for HDPE geomembranes incubated in air, water and leachate, Geosynthetic international (accepted).
[13] Ewais, A.M.R. and Rowe, R.K. and (2018). Antioxidant depletion time for five geomembranes of same resin but of different thicknesses immersed in air and water (In preparation).
[14] Rowe, R.K, Ewais, A.M.R., Brachman, R.W.I. (2018). Service-life of an HDPE GMB under simulated landfill conditions (In preparation).

Acknowledgments: Drs. R. Kerry Rowe, Kenichi Soga, Richard Brachman, John Scheirs, Grace Hsuan, Zahirul Islam, Dali Naidu Arnepalli, Edwin Safari and Santosh Rimal. Foundation for Innovation, the Ontario Innovation Trust, Queen's University, NSERC, the Ontario Ministry of the Environment. Industrial partner: Solmax International, GSE Lining Technology Inc., Terrafix Geosynthetics and Golder Associates.