White HDPE Geomembranes – Performance Benefits beyond Temperature?

INTRODUCTION

High Density Polyethylene (HDPE) Geomembranes have been used in containment applications for the past 50 years. Over this period, Polyethylene Geomembrane recipes have changed markedly with a design need to contain higher risk contaminants stored in more challenging environments.

One of the major product developments has seen the emergence of "White Top Layer" Geomembranes. These are not a recent trend. Recently at the ACIGS GEOANZ #1 Conference, Boyd Ramsey presented a "Gundle Road Facility" installation from the mid-1980s and a number of other sites with varying service lives and conditions. Boyd's conclusion was clear, *"Exposed White Geomembrane lasts longer than Black Geomembrane"(Ramsey 2022).*

Atarfil would concur, and our most recent immersion and exposure data is compelling. It is not simply the thermal behaviour that is beneficial, the additive types required to meet the challenges of stabilizing white layers, also serve significantly better protection when subjected to UV and Immersion Testing. This is translating to significantly longer predictions of Geomembrane performance life.

LASTING LONGER

Geomembrane Liner performance is fundamentally the measure of leaks. The key to establishing the Geomembrane leakage rate risk is to ensure that the polymer properties of the sheet remain the same over the life of the containment, but in reality in all applications we are trying to establish an acceptable loss of properties over time. Establishing the performance of the sheet, allows an assumption that the liner is effectively "impermeable" for the life of the project (it isn't but close) and leakage expectations can match historical design thinking eg. 4-5 holes per Hectare caused by onsite factors.

The key condition that threatens this assumption, is whether the liner is exposed or buried. When the Geomembrane is covered, the impacts of air and UV are removed, stresses are more easily quantified, temperature is "consistent" and chemical impacts are the key performance parameter.

For exposed Geomembranes, the synergistic impacts of Temperature, Oxygen, UV, Stress and Chemistry all serve to accelerate liner degradation and cannot be easily measured together. The impact of heat alone causes wrinkles, resulting in increased stresses that are difficult to model and known to accelerate degradation. In general, the options for testing must isolate one or two of these degradation mechanisms and make assumptions as to the impact of other factors onsite. Modern laboratory testing is getting closer to applying multiple site conditions but elevated temperature is a consistent factor that always accelerates rates of degradation.

White Geomembranes were developed to limit heat stress by reflecting solar radiation.

Cadwallader et al (1993) highlight a temperature reduction of 24ºC in the White Geomembrane surface in clear skies at an ambient temperature of 30ºC. This finding has been corroborated by other research in the public domain, with examples observing similar ranges of temperature benefits.

The fundamental benefits of limiting heat absorbance when compared to a Black Geomembrane are reduced wrinkling and sheet deformation, and lower temperatures reaching the GCL or soil subgrade below. This lowers both stress cracking risk of the liner, and limits moisture changes that can impact composite liner performance. If the predictive models apply this reduction in temperature to the Geomembrane Lifetime Prediction, there is a significant benefit to both HDPE liner performance and subgrade performance, which will logically provide an improved composite liner over time.

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Boyd Ramsey at GEOANZ (Ramsay 2022), elaborated further on this with forensic field evaluations undertaken of White Geomembranes. The results confirm the literature, that white will have a longer lifespan than equivalent black.

PROPERTIES OF WHITE GEOMEMBRANES

Historically, White Geomembranes have been comprised of a thin white skin layer covering a black HDPE layer co-extruded to comprise approx. 97% of the thickness. This provides potential added benefit to identify holes, that reveal the black layer below if the surface damage is deep enough.
In essence, the Geomembrane is using the White Skin as a means to reflect radiation at the surface, and the traditional Black HDPE formulation still provides the "chemical protection" function.

HDPE FORMULATION BLACK vs WHITE

The HDPE Resin source itself remains the same for both layers. The fundamental difference in manufacturing White Geomembranes has been the need to substitute the Carbon Black component, which has resulted in fundamental changes in the types and quantities of additives in the "Masterbatch" with greater challenges to achieve stabilization.

UV BEHAVIOUR

In Black HDPE Geomembranes, it is the Carbon Black that provides critical UV resistance and gives the liner it's black colour. For White layers, Titanium Oxide is the White Pigment that serves "similar" function. The need to ensure Carbon Black type, source and distribution for Black HDPE, remains the same with the Titanium Oxide source. There are a range of Titanium Oxide rutile grades, it is important to select a durable source that has key additives to protect the rutile itself and is compatible with the polymer (See ExcelPlas Technical Note Ep-50).

OXIDATION BEHAVOUR

The most broadly used tests for assessing the resistance of PE geomembranes to oxidation is to evaluate the quality and interaction of the antioxidants and stabiliser packages that remain post manufacturing. Oxidation causes structural polymer changes and is a key measure to understand performance loss in both the atmosphere and chemical immersions. This is quantified generally by measuring the oxidative induction time at varying temperatures (OIT and HPOIT values).
The results for White Geomembranes can differ markedly to Black, and there are implications for specifications and testing timeframes. It is extremely important to test both OIT and HPOIT to understand the Masterbatch used in White Geomembranes. An overall increase in the total mass of additives is observed with increased standard OIT values, and often there is significantly higher quantities of Hindered Amine Light Stabilisers observed in elevated HPOIT results.

KNOW THE TESTING PROCEDURES AND RESULT RISK

For certain White Masterbatch designed for specific high risk applications, it is not unusual to observe White Layer OIT values in excess of 1000 mins, and HPOIT values beyond 10,000mins. This will impact testing timeframes markedly. It is also critical to appreciate the test methods themselves. When the White and Black Layers are homogenized (ground and mixed), there is an inherent risk of test variability if the ratio of White to Black is not clearly managed. This has important implications when trying to measure a percentage retained across multiple samples. Our advice here is at minimum know the expected test values for each layer (have separate values for White/Black) so that anomalous results can be evaluated. Most importantly ensure the Geosynthetic Laboratory undertaking the test is ensuring consistent ratios of White/Black for homogenised samples.

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IMMERSION DATA

The fundamental challenge in using historic project data for Geomembranes, is that conditions are difficult to replicate across different sites. The performance measures implemented were very different even a decade ago, and the Geomembranes installed are vastly different to the liners available in 2022.
It is certainly difficult to evaluate modern Geomembrane projects using historic applications that have been buried and not measured in terms of leakage.
There is a better case for exposed Geomembrane applications to suggest that if the HDPE formulation was considered "of lower quality" when compared to today's resins and additives, that it must represent conservative performance. This is a sound argument, but only if leak rates on the site have been well understood. There fundamentally remains a perception that Geomembranes have been installed without issue and this is not founded in reality. The refreshing aspect to the majority of faults found, is that they link to a rational explanation that forms part of today's best practice recommendations and EPA Guidelines.

However, in an industry that is approximately 50 years old, with significant projects that are buried without further thought, Atarfil would advocate a need for immersion testing or at least possession of representative historic data in critical applications. If a site observes increasing temperature, Oxygen, UV, Stress and Chemistry risk it is impossible to account for these factors together, so applying data to any of the key modes of degradation (immersion is critical) provides a key measure of long term risk.

Recent developments in immersion testing also enable the client to better understand whether modern Geomembrane recipes can contain their contaminants. Thin Film Accelerated Immersion Testing (weeks) can be benchmarked to Long Term Pot Immersions that would historically take 12+ months and together provide a powerful model to establish a lifetime prediction.

IMMERSION BEHAVIOUR OF WHITE GEOMEMBRANES

Over recent years, Atarfil have conducted multiple immersions of White Geomembranes in excess of 12 months for a range of immersion chemistry that includes actual site and synthesized laboratory liquors.
The studies began with a fundamental aim to demonstrate that White Geomembrane Formulations are comparable to Black Geomembranes in a range of site chemistry. Black HDPE has a much larger project database in terms of project volumes.
The benefit of having both White and Black Layers in the single Geomembrane being tested, is that a direct representation of black vs white layers can be established. The results indicate categorically, that when the formulation is designed specifically to the immersion liquor, white performance exceeds black layers in terms of Additive retention. The key additives that were introduced to address the challenges of white layer stabilization, are demonstrating better performance long term.
Immersions have been carried out for the following project types;

ALUMINIUM = BAUXITE BAYER PROCESS RESIDUE PONDS (RED MUD)
GOLD/COPPER/BASE METALS – SULFURIC PROCESSING/AMD CONTAINMENTS
CONCENTRATED BRINE APPLICATIONS – CSG AND OFFSHORE GAS

CONCLUSION

White Geomembranes were developed for their thermal benefit to limit the detrimental impacts of wrinkles and improve composite liner performance. Substituting Carbon Black for Titanium Oxide presented a range of challenges to stabilise, but has resulted in specific White Geomembrane formulations that are demonstrating key benefits for UV performance and resistance to chemical degradation. If we combine these factors it results in significant long term performance benefits when using White Geomembranes.

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