ExcelPlas Independent Materials Testing

Danger of Carbon Black 'Windows' in HDPE Geomembranes

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ISO 17025 ACCREDITED LABORATORY

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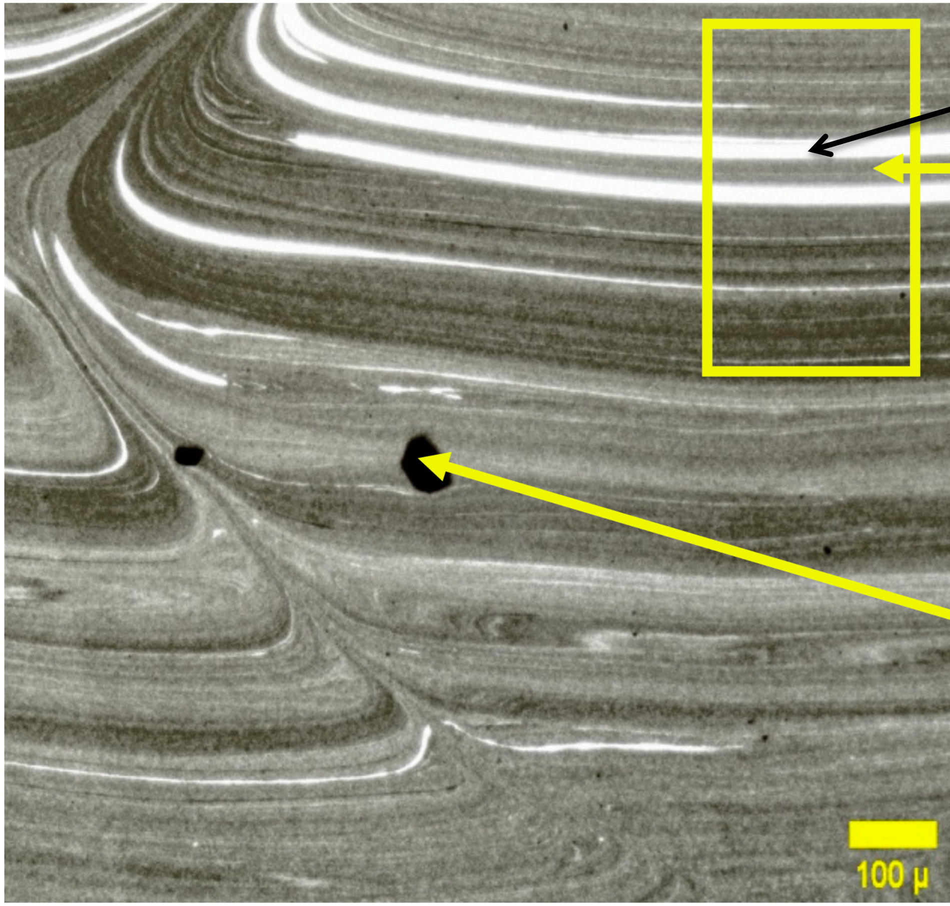
Carbon 'Windows'

- ExcelPlas Geosynthetic Testing Labs frequently observe 'windows' in the carbon black dispersion of HDPE geomembranes.
- These 'windows' are localised regions where there is inadequate or insufficient carbon back in the polymer usually due to poor dispersion of additives issues.
- Until recently it was thought that the poor dispersion of carbon black was only affecting UV stability in those areas. Now new work has shown that the mechanical properties of the product can be significantly altered by these carbon black 'windows'.

Poor Dispersion of Additives



Carbon black 'window'

Poor dispersion of additives

Agglomeration of carbon black

Fig.1. Poor dispersion of additives in polyethylene

Carbon Black ‘Windows’

- Insufficient dispersion and distribution of carbon black (CB) in HDPE geomembranes are likely to occur if CB and polyethylene base resin are insufficiently mixed during extrusion. This results in areas with lower CB contents appearing as light and dark swirls in microscopic images; these are commonly known as ‘windows’.
- These ‘windows’ are mostly a result of poor mixing of CB and natural polyethylene base resin in a single screw geomembrane extrusion line without a proper screw design and necessary mixing elements.
- To prevent this mixing problem, the use of black pre-compounded polyethylene material for geomembrane production. Recently, some brittle failures have been observed in HDPE geomembrane welds with insufficient CB distribution. The role of CB dispersion in the initiation and propagation of cracks in polyethylene has remained largely unknown until now.

Effect of Carbon ‘Windows’ on HDPE Geomembrane Properties

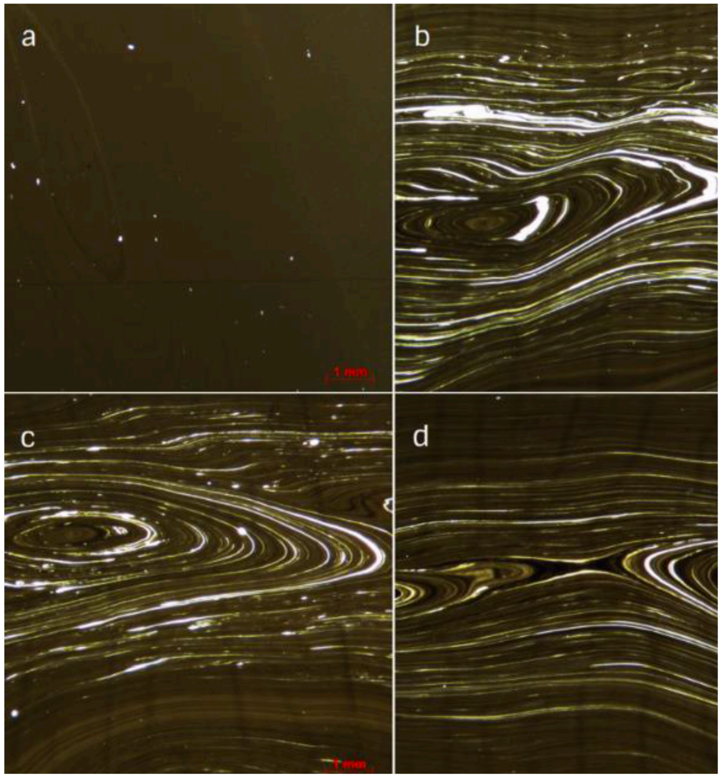


Figure **1:** Microscopy images of 15 μm slices (cross-flow) taken from GMB specimens: (a) Sample 1, (b) Sample 2, (c) Sample 3 and (d) Sample 4

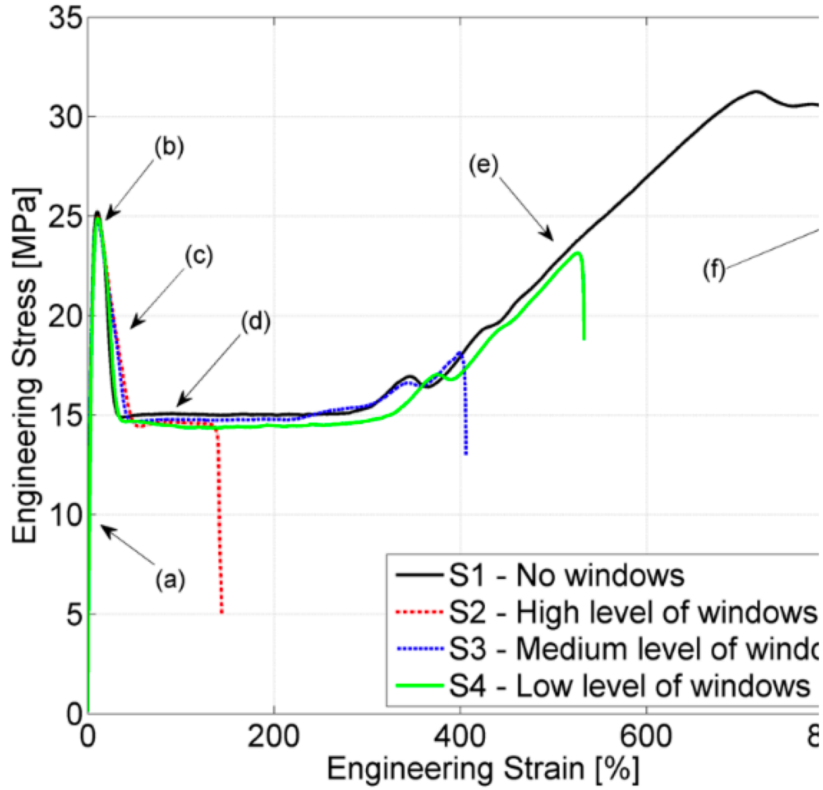


Figure 2: Engineering stress–strain curves of samples elongated to fracture at a test speed of 25 mm/min.

Effect of Carbon 'Windows' on HDPE Geomembrane Properties

Table 3 Tensile test (25 mm/min) on GMB samples.

Samples		Yield Stress	Yield Strain	Stress at Break	Nominal Strain at Break
		MPa	%	MPa	%
S1	Average	25.2	10	30.1	800
	Std. Dev	0.1	0.1	0.3	70
S2	Average	25	10	15.6	270
	Std. Dev	0.5	0.1	2.5	160
S3	Average	24.9	10	19.8	430
	Std. Dev	0.3	0.1	4.2	130
S4	Average	24.9	10	25.7	670
	Std. Dev	0.3	0.1	6.3	220

S1 = no 'windows'
S2 = high levels of 'windows'
S3 = medium level of 'windows'
S4 = low level of 'windows'

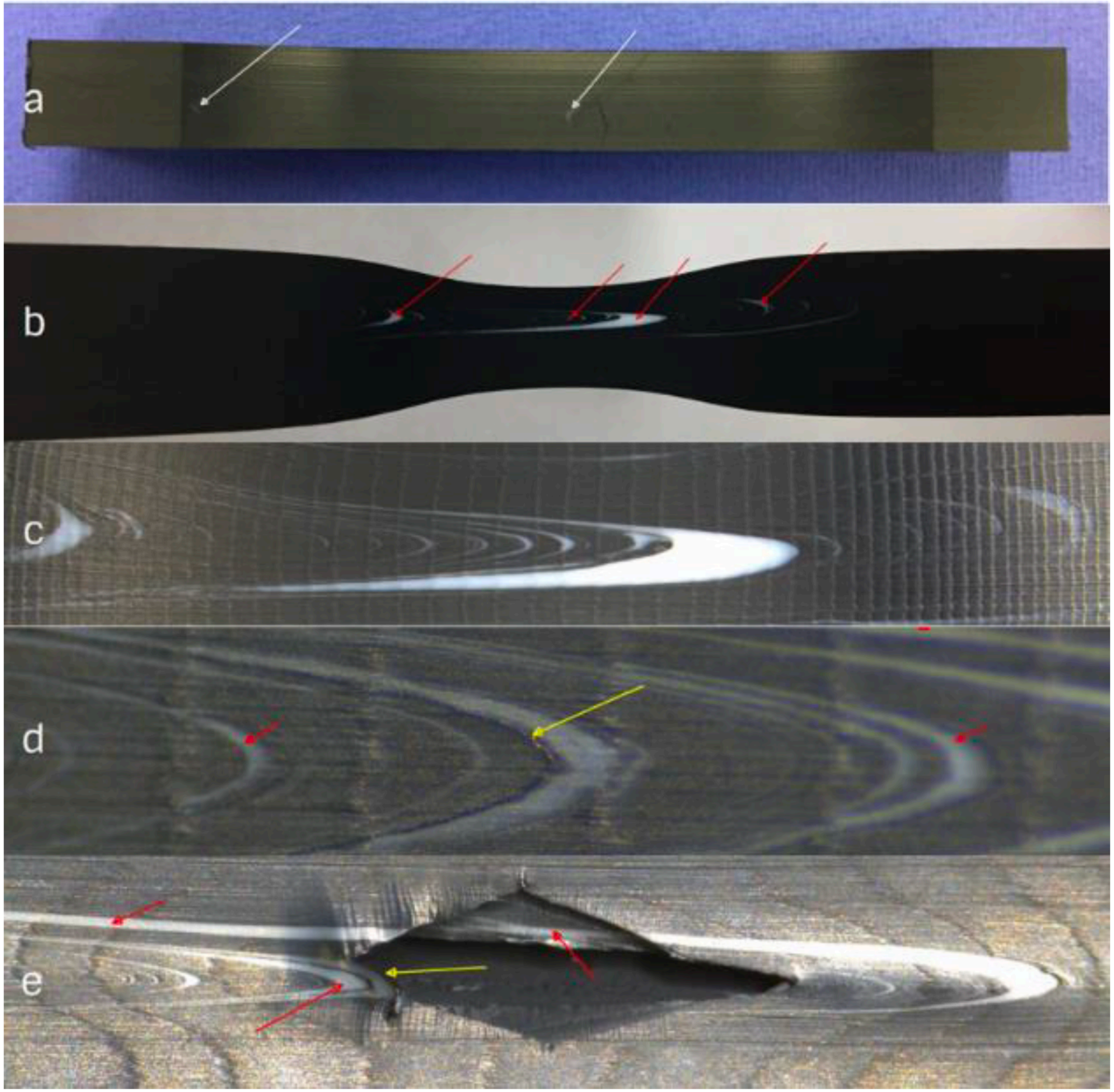


Figure 3: Propagation of windows to fracture: (a) tensile specimen before testing—white arrows indicate 'windows' visible to the naked eye; (b) tensile specimen after yield (20% elongated)—red arrows show windows curled towards the tensile direction; (c) tensile specimen (40% elongated); (d) interface separation at the edge of windows marked with a yellow arrow; (e) fracture occurrence at the interface separation (yellow arrow).

Fracture Surface Images

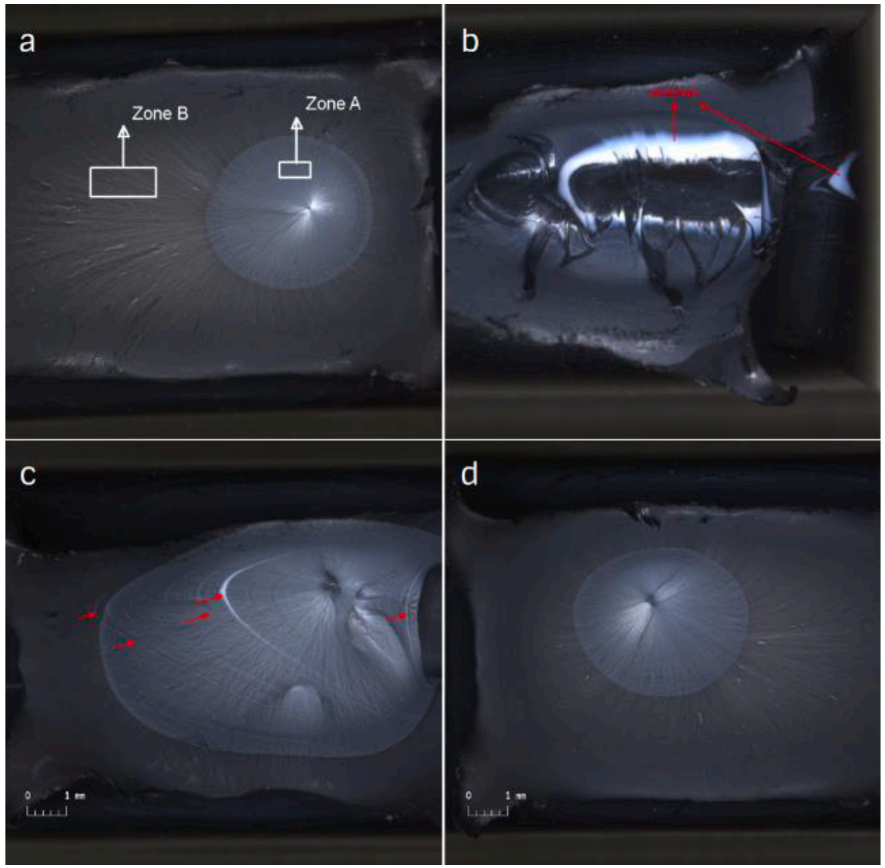


Figure 4: Optical images of fracture surfaces: (a) Sample 1, (b) Sample 2, (c) Sample 3 and (d) Sample 4.

SEM of Fracture Surfaces

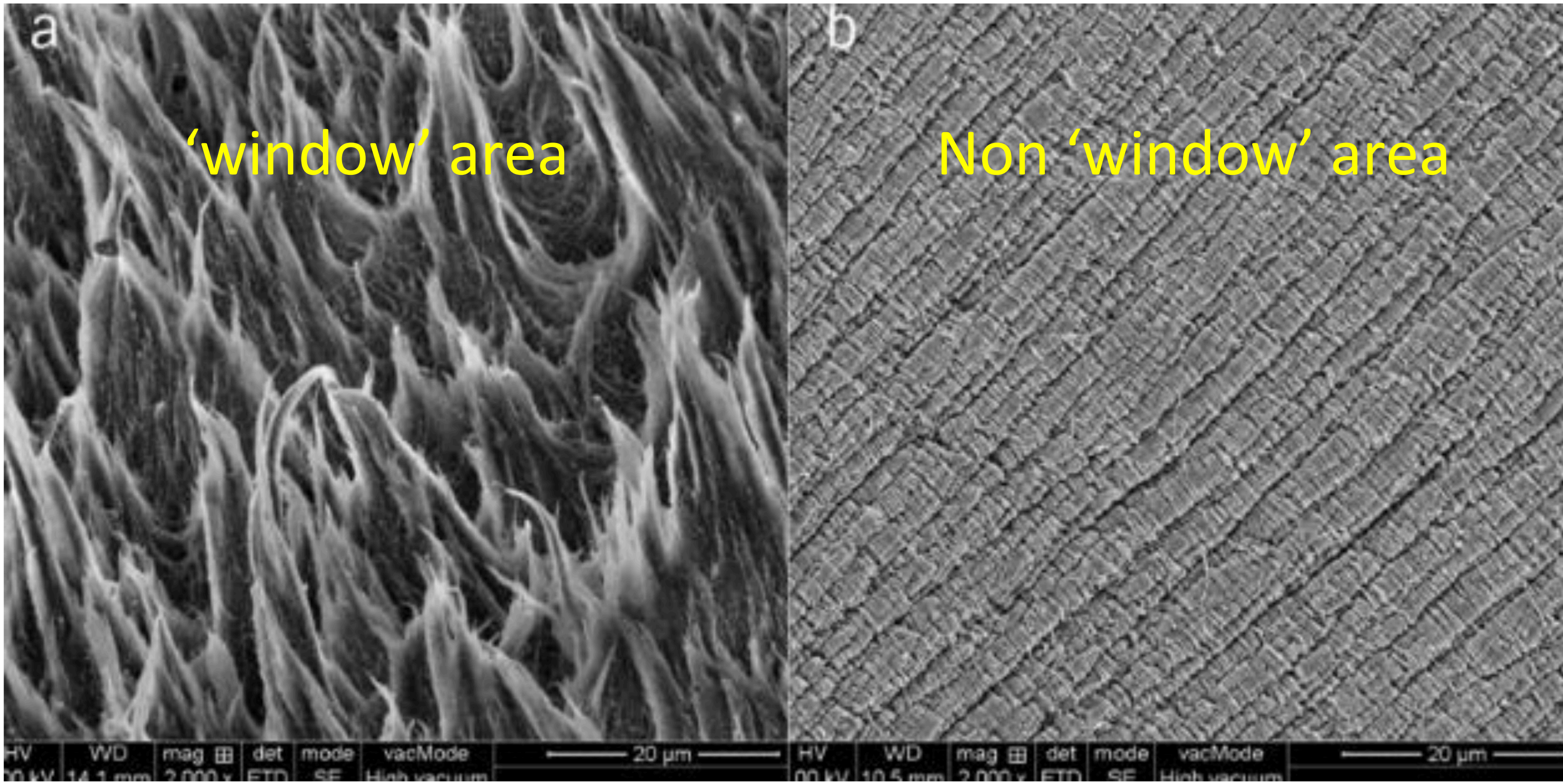


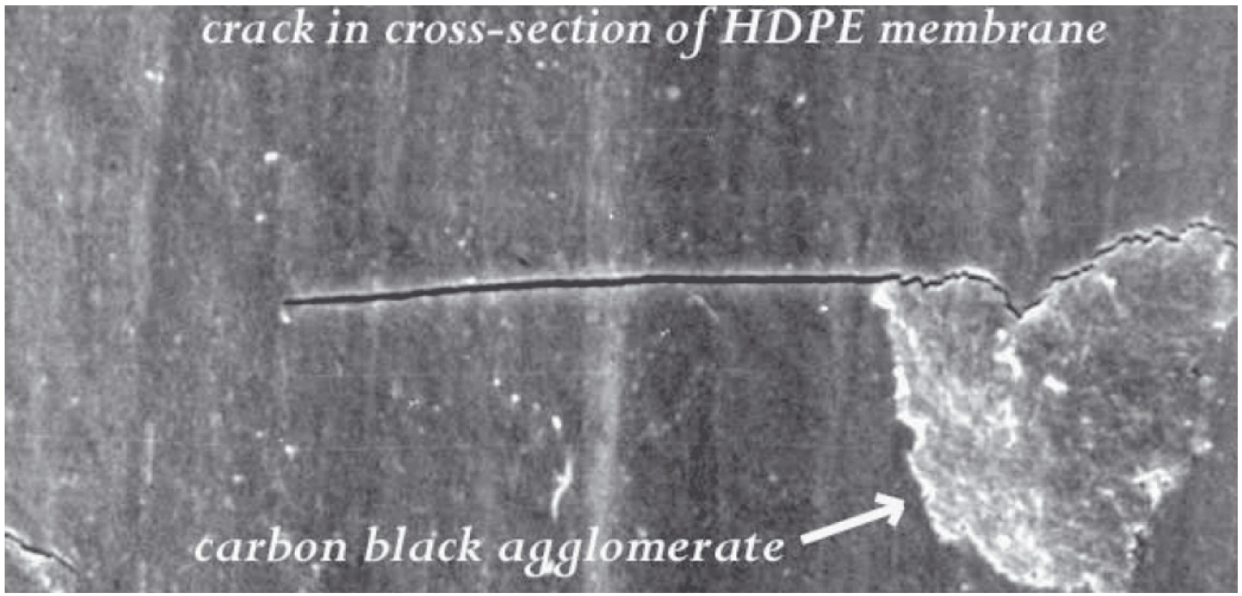
Figure 5: SEM images of fracture surfaces of (a) windowed area of Sample 2 and (b) black area of Sample 2.

Preventing Carbon Black 'Windows'

Good dispersion of the pigment and additives is essential for long-term geomembrane performance. It is particularly difficult to disperse 2 – 2.5% carbon black without large agglomerates using a standard single screw extruder. These agglomerates may provide an initiation site for a crack which can cause premature failure of the geomembrane (see figure below).

If the starting resin passes the Geomembrane stress crack resistance criteria, the final geomembrane may not as the masterbatch carrier material may reduce the stress crack resistance of the blend.

Crack Initiation from Carbon Black Agglomerates



Source: page 367, A Guide to Polymeric Geomembranes: A Practical Approach by John Scheirs (John Wiley & Sons)

Preventing Carbon Black 'Windows'

To reduce agglomeration we have observed that some geomembrane producers reduce the amount of carbon black but this means that the UV stability of the geomembrane will be sacrificed as a minimum level of 2% is required to protect the geomembrane over its lifetime.

Also to help improve dispersion and reduce costs some GMB manufacturers use carbon black with a larger particle size. This will also reduce the UV protection of the geomembrane as a carbon black with a particle size below 25 nm is required to achieve good UV stability (ref. Scheirs Geomembrane book p. 41).

Other Considerations

The correct choice of additives also requires considerable knowledge and extensive testing to ensure that the finished product meets the long-term performance requirements for HDPE geomembranes in particular the retained S-OIT and HP-OIT after 90 day oven ageing. Poor additive dispersion can results in a failure to meet the required retained S-OIT and HP-OIT values after 90 day oven ageing.

Clearly when using the barefoot resin and masterbatch approach it is the geomembrane manufacturer who takes over the complete responsibility for the geomembrane quality since it is they that are in control of all the above critical items.

References

WILEY

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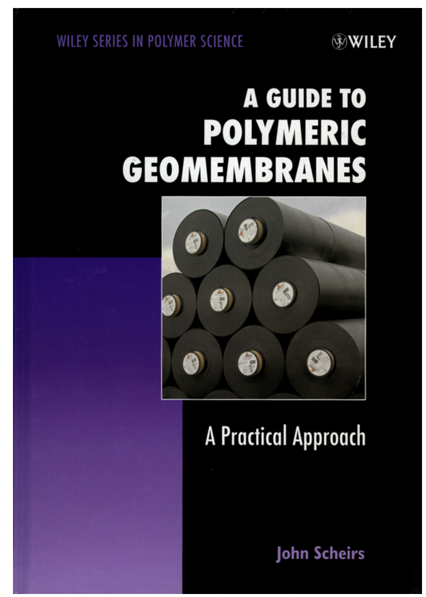

Courtesy: Borouge data