

# Contents

<b>1 Technical Regulations.....</b>	<b>1</b>
References .....	8
<b>2 HDPE Materials and Geomembrane Manufacture.....</b>	<b>11</b>
2.1 Materials .....	11
2.2 Morphology .....	21
2.3 Manufacture .....	23
References .....	32
<b>3 Testing of HDPE Geomembrane Properties .....</b>	<b>35</b>
3.1 Overview .....	35
3.2 Test Methods .....	41
3.2.1 External Appearance, Homogeneity, Skew and Waviness....	41
3.2.2 Thickness.....	42
3.2.3 Carbon Black Content and Distribution .....	43
3.2.4 Melt Mass-flow Rate and Density .....	48
3.2.5 Dimensional Stability .....	50
3.2.6 Permeation.....	55
3.2.7 Thermal Analysis and Measurement of Oxidation Stability .	59
3.2.8 Tensile Test .....	68
3.2.9 Multi-Axial Tension Test (Burst test).....	71
3.2.10 Relaxation Test.....	75
3.2.11 Resistance to Chemicals .....	77
3.2.12 Resistance to Thermal-Oxidative Degradation.....	84
3.2.13 Stress Crack Test: Pipe Pressure Test and NCTL Test.....	88
3.2.14 Weathering Resistance .....	98
3.2.15 Resistance to Biological Effects .....	103
3.2.16 Long-Term Tensile Test .....	108
3.2.17 Friction Properties .....	110
3.2.18 Long-term Shear Strength Test.....	116
3.3 Other Tests.....	120
References .....	123

<b>4 Deformation Behaviour .....</b>	<b>129</b>
4.1 Stress Relaxation and Creep .....	129
4.2 Phenomenological Dynamical Model.....	135
4.3 Deformation Behaviour in Tensile and Burst Testing .....	139
4.4 Determination of Local Strain from the Contour Line .....	140
References .....	144
<b>5 Long-term Behaviour .....</b>	<b>147</b>
5.1 Ageing .....	147
5.2 Oxidative Degradation.....	155
5.2.1 Auto-Oxidation of Non-Stabilised Polyolefins .....	156
5.2.2 Chemical Stabilisation.....	161
5.2.3 Structural Stabilisation .....	168
5.3 Stress Crack Formation .....	169
5.3.1 Description of Crack Phenomena and Terms .....	169
5.3.2 Test Method for Stress Crack Resistance .....	173
5.3.3 Excursion into Fracture Mechanics .....	179
5.3.4 Models for the Description of Stress Crack Formations .....	188
5.4 Service Lifetime of HDPE Geomembranes.....	206
5.4.1 Stress Cracking.....	206
5.4.2 Oxidative Degradation of HDPE Geomembranes .....	211
References .....	231
<b>6 HDPE Geomembranes with Textured Surface .....</b>	<b>235</b>
6.1 Type and Manufacture of Surface Textures .....	235
6.2 Tests on Textured Geomembranes .....	240
6.3 Properties of Textured Geomembranes, Slope Stability of Liner Systems.....	244
References .....	249
<b>7 Mass Transport .....</b>	<b>251</b>
7.1 Introduction .....	251
7.2 Mass Transport in Geomembrane.....	252
7.3 Mass Transport in Soil Materials (Geomembrane Subgrade) .....	266
7.4 Mass Transport in Composite Liners.....	275
7.5 Influence of Holes in Geomembranes .....	283
References .....	300
<b>8 Requirements for Protective Layers .....</b>	<b>303</b>
8.1 Function of Protective Layers.....	303
8.2 Types of Protective Layers .....	305
8.2.1 Overview .....	305

---

8.2.2 Mineral Protective Layers .....	308
8.2.3 Geosynthetic Protective Layers .....	310
8.3 Design and Testing of Protective Layers.....	314
8.3.1 Indentations in the Geomembrane .....	314
8.3.2 Protective Efficiency Test .....	317
8.3.3 Testing for Puncturing of the Geomembrane .....	323
References .....	329
<b>9 Installation of HDPE Geomembranes.....</b>	<b>333</b>
9.1 Introduction: HDPE Geomembranes in Landfill Engineering.....	333
9.2 Installation Planning .....	338
9.3 Installation .....	341
9.3.1 Excursion: Development and Effect of Waves in Geomembranes .....	348
9.3.2 Anchoring Technique (Riegelbauweise) .....	353
9.4 Quality Assurance.....	360
9.4.1 Conditions placed on Installation Companies .....	368
9.4.2 Conditions for Third-Party Inspectors .....	372
References .....	375
<b>10 Welding of HDPE Geomembranes.....</b>	<b>379</b>
10.1 Welding Machines, Devices and Weld Seams .....	379
10.2 Testing Seams.....	389
10.3 Process Model for Quality Assessment of Dual Hot Wedge Seams .....	404
References .....	418
<b>11 Leak Detection and Monitoring Systems .....</b>	<b>421</b>
11.1 Methods for Monitoring Geomembrane Liners .....	421
11.2 Types of Electrical Leak Detection Systems for CQA .....	431
11.3 Requirements on Leak Monitoring Systems.....	435
11.3.1 Efficacy and Assessment of Leak Monitoring Systems .....	436
11.3.2 Permeability of Liners with Leak Monitoring Systems.....	438
11.3.3 Long-term Behaviour and Handling of Leak Monitoring Systems.....	438
11.4 Types and Frequency of Faults.....	441
11.5 Leak Monitoring and CQA of Geomembrane Liners .....	444
References .....	447
<b>Appendix 1.....</b>	<b>451</b>
Requirement Tables .....	451

<b>Appendix 2.....</b>	<b>467</b>
Index of Standards, Guidelines and Recommendations .....	467
<b>Index .....</b>	<b>479</b>