

CONTENTS

<i>Acknowledgments</i>	v
<i>Preface</i>	vii
Chapter 1 Introduction	1
1.1. General	1
1.2. Maintainability Analysis	3
1.3. Maintainability Website (http://www.hpbc.bdg.nus.edu.sg/)	6
1.3.1. Defect Library	7
1.3.2. Material Manual	8
1.3.3. Maintainability Grading System	10
1.4. Integrated Approach to Maintainability	14
1.4.1. Performance Mandates	14
1.4.2. Performance Benchmarks	15
1.4.3. Temporal Perspective	15
References	18
Chapter 2 Wet Area	21
2.1. General	21
2.2. Systems and Components Selection	21
2.2.1. Waterproofing System	22

2.2.2. Screed	24
2.2.3. Tile	25
2.2.3.1. Man-Made Tiles	25
2.2.3.2. Natural Stone Tiles	27
2.2.4. Tile Bedding	27
2.2.5. Grout	29
2.2.6. Paint	33
2.2.7. Service Pipe	33
2.3. Common Defects in Wet Areas	34
2.3.1. Waterproofing	34
2.3.1.1. Design Aspects	34
2.3.1.2. Construction Aspects	35
2.3.2. Screed	49
2.3.2.1. Design Aspects	49
2.3.2.2. Construction Aspects	52
2.3.3. Tiling	55
2.3.3.1. Design Aspects	55
2.3.3.2. Construction Aspects	56
2.3.4. Ventilation and Air Circulation	70
2.3.4.1. Plumbing	73
2.3.4.2. Sanitary Fittings	74
2.4. Maintenance	82
References	91
Chapter 3 Façade	95
3.1. General	95
3.2. Environmental Aspects	97
3.2.1. Rain	98
3.2.2. Wind	98
3.2.3. Sunlight	99
3.2.4. Pollution	99

3.3. Common Defects on Façades	101
3.4. Exposed Brick	106
3.5. Concrete	126
3.6. Plaster and Paint Surface Coatings	126
3.7. Tile	131
3.8. Cladding and Curtain Wall Façades	135
3.8.1. Natural Stone	135
3.8.2. Metal	142
3.8.3. Glass	149
3.8.4. Sealant Failures	158
3.9. Façade Access Systems	164
3.9.1. Permanent Systems	165
3.9.1.1. Trolley Unit	166
3.9.1.2. Monorail Track	167
3.9.1.3. Traversing Trolley	167
3.9.1.4. Personal Unit	168
3.9.1.5. Fixed Davit	169
3.9.1.6. Powered Traveling Davit	171
3.9.1.7. Traveling Ladders and Platforms	172
3.9.2. Temporary Access	173
3.9.2.1. Temporary Installed Gondolas	173
3.9.2.2. Counterweighted Suspension Beam	173
3.9.2.3. Suspended Platform	173
3.9.2.4. Parapet Clamp	174
3.9.2.5. Scaffolding	175
3.9.2.6. Boomlifts	175
3.9.2.7. Façade-Cleaning Robots	175
3.9.3. Building Forms	178
References	181

Chapter 4 Basement	185
4.1. General	185
4.2. Water Seepage	185
4.3 Risk Factors	188
4.3.1. Design Risk	191
4.3.1.1. Inappropriate Waterproofing System	191
4.3.1.2. Poor Drainage Design Detailing	192
4.3.1.3. Lack of Waterproofing Detailing	193
4.3.2. Building Profile Risk	194
4.3.3. Environmental Risk	196
4.3.4. Material Risk	196
4.3.5. Construction Quality Risk	197
4.3.5.1. Insufficient Compaction	198
4.3.5.2. Improper Installation of Construction Joints	198
4.3.5.3. Improper Installation of Waterproofing	200
4.3.5.4. Damage of Waterproofing During Construction	200
4.3.5.5. Insufficient Curing of Waterproofing	200
4.3.6. Maintenance Practice Risk	201
4.3.6.1. Lack of Regular Inspection to Defect Detection	202
4.3.6.2. Delayed Repair to Initial Defect	203
4.3.6.3. Deterioration of Waterproofing	204
4.4. Common Defects in Basement	205
4.5. Case Study	206
4.5.1. Seepage Through Joint	206
4.5.1.1. Problem	206
4.5.1.2. Good Practices	206
References	221

Chapter 5 Roof	223
5.1. General	223
5.2. Common Defects in Roof	223
5.3. Roof Decking	226
5.3.1. Drainage	237
5.3.2. Concrete Cracking	237
5.3.3. Ponding	238
5.3.4. Biological Growth	240
5.3.5. Sealant Failure	241
5.3.6. Secondary Roof	241
5.4. Roof Waterproofing	243
5.4.1. Blistering	244
5.4.2. Alligatoring of Membrane	244
5.4.3. Delamination of Membrane	246
5.4.4. Ridges of Membrane	248
5.4.5. Water Ponding	250
5.4.6. Service Penetration Through Membrane	251
5.4.7. Adhesion Failure of Membrane	252
5.5. Good Practices	254
5.5.1. Surface Preparation	254
5.5.2. Application of Preformed Membrane	256
5.5.3. Lapping	258
5.5.4. Application of Liquid-Applied Membrane	258
5.6. Membrane Roof	261
5.7. Green Roof	263
References	265
Chapter 6 M&E	267
6.1. General	267
6.2. Sanitary-Plumbing System	267
6.2.1. General	267

6.2.2. Maintainability of Sanitary-Plumbing System	268
6.2.3. Common Defects	269
6.3. HVAC System	269
6.3.1. General	269
6.3.2. Maintainability of HVAC Systems	280
6.3.3. Common Defects	281
6.4. Elevators/Lifts	282
6.4.1. General	282
6.4.2. Mechanized Transportation System	293
6.4.2.1. Elevators	293
6.4.2.2. Elevator Operation and Control	293
6.4.2.3. Elevator Service Requirements	294
6.4.3. Codes and Standards	294
6.4.4. Maintainability of Mechanized Transportation System	295
6.4.5. Common Defects	296
6.5. Electrical System	309
6.5.1. General	309
6.5.2. Maintainability of Electrical System	309
6.5.3. Common Defects	310
6.6. Fire Protection System	311
6.6.1. General	311
6.6.2. Maintainability of Fire Protection System	324
6.6.3. Common Defects	325
References	336
Chapter 7 Material Selection	345
7.1. General	345
7.2. Interface of the Material Manual	345
7.3. Durability	348
7.3.1. Adjustment Factors for Durability of Material	349

7.4. Properties	353
7.5. Maintenance and Cleaning	353
7.6. Defect and Repair	405
References	409
Chapter 8 Nondestructive Tests	415
8.1. General	415
8.2. Vibration	416
8.2.1. Accelerometer	416
8.2.2. Tiltmeter	418
8.3. Stress and Strain	419
8.3.1. Strain Gauges	420
8.3.2. Load Cells	424
8.3.3. Vibrating Wire Strain Gauge	424
8.4. Optical and Mechanical	425
8.4.1. Fiberscope	425
8.4.2. Glossmeter and Colormeter	427
8.4.2.1. Glossmeter	428
8.4.2.2. Color Meter/ Spectrophotometer	428
8.4.3. Liquid Penetrant Testing	429
8.4.4. Elastic Recovery Tester	431
8.4.5. Rebound Hammer	431
8.5. Sonic and Ultrasonic	432
8.5.1. Ultrasonic Pulse Velocity Measurement	432
8.5.2. Impact-Echo Test	434
8.6. Thermal and Infrared	435
8.7. Electromagnetic, Electronics and Radiography	437
8.7.1. Electromagnetic Cover Measurement	437
8.7.2. Leak Detection	438
8.7.3. Environmental and Holidays Test for Paint	438

8.7.3.1.	Environmental Paint Test	438
8.7.3.2.	Holiday Test	440
8.7.4.	Moisture Meter	440
8.7.5.	Ground Penetrating Radar (GPR)	441
	References	444
Chapter 9 Maintainability Grading System		447
9.1.	General	447
9.2.	Grading System — State of the Art	447
9.2.1.	First Generation: Pass–Fail Systems	448
9.2.1.1.	R-2000, Canada	448
9.2.1.2.	P-Mark Certification System, Sweden	448
9.2.1.3.	ELO and EM Schemes, Denmark	451
9.2.1.4.	Energy Star, USA	451
9.2.2.	Second Generation: Simple Additive Systems	451
9.2.2.1.	LEED, USA	452
9.2.3.	Third Generation: Weighed Additive Systems	452
9.2.3.1.	BREEAM, UK	453
9.2.3.2.	BEPAC, Canada	454
9.2.3.3.	Green Globes Rating System, USA	455
9.2.3.4.	GEM, UK	455
9.2.3.5.	Go Green and Go Green Plus, Canada	456
9.2.3.6.	HQAL, Japan	456
9.2.3.7.	MSS, Singapore	457
9.2.3.8.	Green Star Rating, Australia	457
9.2.3.9.	NABERS, Australia	458
9.2.3.10.	HK-BEAM, Hong Kong	459
9.2.3.11.	GBTool 2005, International	460

9.2.4. Other Examples	462
9.2.4.1. CASBEE, Japan	462
9.3. Maintainability and Management	463
9.3.1. Risk Identification and Primary Risk Factors	464
9.3.2. Risk Analysis	465
9.4. Maintainability Prediction and Integration	467
9.4.1. Defect Analysis	468
9.4.2. Benchmarking for Design, Construction and Maintenance	469
9.4.3. Integration of Subsystems Based on Maintainability Parameters	470
9.4.4. Overview of Scoring of All Subsystems	470
References	513
<i>Index</i>	517