

Contents

Members of the Working Party	xii	2.6.3 Metamorphic rocks	47
Acknowledgements	xiii	2.6.3.1 Petrography	47
Foreword 1	xv	2.6.3.2 Fabric	48
Foreword 2	xvi	2.6.3.3 Classification	49
Foreword 3	xvii	2.6.3.4 Occurrence of metamorphic rocks	49
Preface	xxiii	2.7 Igneous rocks as building stones	50
Chapter 1 Introduction	1	2.7.1 Granites and porphyritic granites	50
1.1 Stone	1	2.7.2 Other igneous rock types	51
1.1.1 Production statistics	1	2.7.3 Summary	52
1.1.2 A future for building stone	1	2.8 Sedimentary rocks as building stones	52
1.1.2.1 Europe	3	2.8.1 Previous studies	52
1.2 Objectives of the Working Party	3	2.8.2 Discontinuities: joints and bedding planes	53
1.3 The Working Party and the Report	4	2.8.3 Facies and trade names	54
References	5	2.8.4 Cross bedding: from quarry to building stone	54
Chapter 2 Geology	7	2.8.5 Polishable limestones (trade marbles)	54
2.1 Introduction	7	2.8.6 Weathering	54
2.2 Stratigraphy and historical geology	7	2.8.7 Summary	56
2.2.1 Stratigraphic unit	7	2.9 Metamorphic rocks as building stones	56
2.2.2 Stratigraphic nomenclature	9	2.9.1 Marbles	56
2.2.3 Geological time-scale	9	2.9.2 Metamorphic quartzites	58
2.3 Structural geology	11	2.9.3 Slates	58
2.3.1 Folds	12	2.9.4 Summary	58
2.3.2 Faults and thrusts	12	2.10 Conclusions	59
2.3.3 Joints	13	2.11 References	60
2.3.4 Bedding planes and unconformities	13	Appendix 2A Mineralogy	62
2.3.5 Metamorphic cleavage and foliation	14	Chapter 3 Exploration	65
2.4 Weathering	16	3.1 The aims and objectives of exploration	65
2.4.1 Mechanical weathering	16	3.1.1 Aim	65
2.4.2 Chemical weathering	17	3.1.2 The stages of proving a mineral reserve	65
2.4.3 Biological weathering	20	3.2 Feasibility studies	68
2.4.4 Classification schemes	20	3.2.1 Literature search and desk-top studies	68
2.5 Geomorphology and physical geology	23	3.2.1.1 Sources of data	69
2.5.1 Deep-seated Earth processes	23	3.2.1.2 Historical sources	69
2.5.2 Surface processes	24	3.2.1.3 Remote sensing techniques	69
2.5.3 Erosional landforms	25	3.2.1.4 Aerial photography	69
2.5.4 Depositional landforms	26	3.2.1.5 Other aircraft-borne sensors	69
2.6 The main rock divisions	27	3.2.1.6 Satellite-borne sensors	70
2.6.1 Igneous rocks	27	3.2.2 Field reconnaissance	70
2.6.1.1 Grain size, texture and classification	27	3.2.2.1 Use of the built environment	71
2.6.1.2 Composition and petrography	31	3.2.2.2 Geomorphological information	72
2.6.1.3 Fabric	32	3.2.2.3 Potential environmental factors	72
2.6.1.4 Igneous rock forms	33	3.2.2.4 Infra-structure	73
2.6.1.5 Occurrence of igneous rocks	35	3.2.2.5 Secondary products	73
2.6.2 Sedimentary rocks	36	3.2.3 Preliminary assessment and report	73
2.6.2.1 Origin, composition and classification	36	3.3 Detailed field investigations	74
2.6.2.2 Diagenesis	37	3.3.1 Aim	74
2.6.2.3 Terrigenous siliclastic sediments	37	3.3.2 Field mapping	74
2.6.2.4 Carbonate rocks	41	3.3.2.1 The base map	74
2.6.2.5 Other sedimentary rocks	46	3.3.2.2 Exposures	76
2.6.2.6 Occurrence of sedimentary rocks	47		

vi		CONTENTS		
3.3.2.3	Methods of recording field data	76	3.7 Sample preparation	101
3.3.2.4	Recording discontinuity data	77	3.7.1 Sample size	101
3.3.2.5	Photographic recording	79	3.7.2 Sample reduction	101
3.3.2.6	Interpretation	79	3.8 Overview of testing requirements	102
3.4	Sampling	79	3.8.1 Petrography	102
3.4.1	Aim of the sampling	79	3.8.2 Density of the stone	103
3.4.2	Sample and population size	80	3.8.3 Water absorption	104
3.4.3	Sampling theory	80	3.8.4 Strength	104
3.4.4	Sampling schemes	80	3.8.5 Abrasion and slip resistance	104
3.4.5	Surface sampling	82	3.8.6 Durability	104
3.4.6	Pitting and trenching	83	References	105
3.4.6.1	Machine excavation	83	Chapter 4 Assessment	107
3.4.6.2	Hand excavation	83	4.1 Introduction	107
3.4.6.3	Sampling	83	4.2 Determination of the suitability and grade of the stone	107
3.4.7	Borehole drilling	83	4.2.1 The use of sample data	109
3.4.7.1	The size of the drilling programme	84	4.2.2 Sampling errors	109
3.4.7.2	Design of the drilling programme	84	4.2.3 Variation in the stone	110
3.4.7.3	Drilling methods	84	4.2.3.1 Variation in petrography	110
3.4.7.4	Choice of core size	85	4.2.3.2 Variation in discontinuities	110
3.4.7.5	Core recovery	86	4.2.3.3 Colour and fabric variations	116
3.4.7.6	Choice of drilling fluid	86	4.2.4 Estimation of grade	116
3.4.7.7	Angle drilling	87	4.2.4.1 The relationship between samples and blocks	116
3.4.8	Core logging	87	4.2.4.2 Area of influence of a sample	118
3.4.8.1	Logging methods	88	4.2.4.3 Modelling using isolines	121
3.4.8.2	Contents of the log	88	4.2.4.4 Trend Surface Analysis	122
3.4.8.3	Sampling borehole core	89	4.2.4.5 Moving average	122
3.5	Shallow geophysics	89	4.2.4.6 Geostatistics	122
3.5.1	Overview	89	4.2.5 The size of the grade block	124
3.5.2	Electrical resistivity/conductivity and electromagnetic methods	90	4.2.5.1 Practical quarrying requirements	124
3.5.2.1	Principles	90	4.2.5.2 Grade estimation with limited data	126
3.5.2.2	Resistivity/conductivity	90	4.3 Determination of the quantity of stone available	126
3.5.2.3	Induced polarization	92	4.3.1 Estimation of the size of the deposit	126
3.5.2.4	Electromagnetic methods	92	4.3.1.1 Volume	126
3.5.3	Seismic	93	4.3.1.2 Density and tonnage	128
3.5.3.1	Principles	93	4.3.1.3 Specialized quantity considerations for building stone	128
3.5.3.2	Applications	93	4.3.2 Overburden	128
3.5.4	Gravity	94	4.3.3 Calculation of the quantity of stone product	128
3.5.4.1	Principles	94	4.3.3.1 Losses due to cavities	129
3.5.4.2	Applications	94	4.3.3.2 Extraction losses	129
3.5.5	Magnetic	94	4.3.3.3 Processing losses	129
3.5.5.1	Principles	94	4.4 Resource or reserve?	129
3.5.5.2	Applications	94	4.4.1 Economic aspects	130
3.5.6	Radar	96	4.4.1.1 Markets	130
3.5.6.1	Principles	96	4.4.1.2 Extraction costs	130
3.5.6.2	Applications	96	4.4.1.3 By-products	133
3.5.7	Borehole geophysical logging	96	4.4.2 Financial evaluation	134
3.5.7.1	Principles	96	4.4.2.1 Cash flow and discounted cash flow	134
3.5.7.2	Applications	99		
3.6	Field analysis	100		
3.6.1	Chemical and mineralogical analysis	100		
3.6.2	Physical analysis	101		

CONTENTS

vii

4.4.2.2	Present Value	134	5.3.7	Production of rock fill	179
4.4.2.3	Internal Rate of Return	136	5.3.7.1	General	179
4.4.2.4	Pay-back period	137	5.3.7.2	Fragmentation blasting	180
4.4.2.5	Sensitivity analysis	137	5.3.8	Production of armourstone	180
4.4.2.6	Monte Carlo simulation	138	5.3.8.1	Introduction	180
4.4.3	Surface or underground extraction	138	5.3.8.2	Blasting to produce armourstone	181
4.5	The assessment report	140	5.3.9	Quarrying of dimension stone	182
	References	140	5.3.9.1	Introduction	182
Chapter 5	Extraction	143	5.3.9.2	Superficial deposits	183
5.1	Aims and Content	143	5.3.9.3	Block production	183
5.2	Design and Planning	144	5.3.9.4	Wedges	184
5.2.1	Extraction methods	144	5.3.9.5	Plug and feathers	186
5.2.1.1	Introduction	144	5.3.9.6	Channelling	186
5.2.1.2	Mining and quarrying	144	5.3.9.7	Drilling	187
5.2.2	Planning considerations	145	5.3.9.8	Saws	187
5.2.3	Environmental and safety considerations	146	5.3.9.9	Wire saws	187
5.2.3.1	Vehicle traffic	146	5.3.9.10	Flame jet cutting	189
5.2.3.2	Noise	147	5.3.9.11	Explosives	190
5.2.3.3	Visual intrusion	149	5.3.9.12	Expanding powders	193
5.2.3.4	Blasting vibration	149	5.3.9.13	Mobile equipment	195
5.2.3.5	Dust	151	5.3.9.14	Other methods	195
5.2.3.6	Hydrogeology	152	5.3.9.15	Transport	195
5.2.3.7	Loss of wildlife habitat	152	5.3.10	Underground mining of dimension stone	197
5.2.3.8	Loss of amenity	152	5.3.10.1	Introduction	197
5.2.3.9	Archaeology	153	5.3.10.2	Access	197
5.2.3.10	Restoration	153	5.3.10.3	Ventilation	197
5.3	Extraction	153	5.3.10.4	Room and pillar method	197
5.3.1	Introduction	153	5.3.10.5	Mining of gently dipping strata	198
5.3.2	Rock mechanics	154	5.3.10.6	Mining of steeply dipping strata	199
5.3.2.1	Introduction	154	5.3.11	Storage	200
5.3.2.2	Discontinuities	154	5.3.12	Waste disposal	201
5.3.2.3	Block size distribution	158		References	202
5.3.2.4	Rock masses	159	Appendix 5.1		203
5.3.2.5	Slope stability	160	A5.1.1	Derrick crane	203
5.3.2.6	Reinforcement	162	A5.1.2	Rope excavator	204
5.3.2.7	Presplitting	164	A5.1.3	Hydraulic face excavator	204
5.3.2.8	Cleavage	165	A5.1.4	Hydraulic backhoe	205
5.3.2.9	Rippability	165	A5.1.5	Wheeled loader	205
5.3.3	Blasting and explosives	168	A5.1.6	Dragline excavator	205
5.3.3.1	Introduction	168	A5.1.7	Crawler tractor	206
5.3.3.2	Explosives	169	A5.1.8	Motor scraper	206
5.3.3.3	Detonators	169	A5.1.9	Articulated dump truck	206
5.3.3.4	Blasting	169	A5.1.10	Rigid body dump truck	206
5.3.3.5	Fragmentation blasting	171	A5.1.11	Trolleys and scows	206
5.3.3.6	Block production	171	A5.1.12	Ropeways, cableways and inclines	207
5.3.3.7	Overburden blasting	174	A5.1.13	Quarry bar	208
5.3.3.8	Safety and Regulations	174			
5.3.4	Drilling	175	Chapter 6	Processing	205
5.3.4.1	Introduction	175	6.1	Introduction	209
5.3.4.2	Blastholes	175	6.2	Rock fill	209
5.3.4.3	Drills	175	6.2.1	Introduction	209
5.3.5	Overburden removal	176			
5.3.6	Quarry and mining machinery	178			
5.3.6.1	Equipment application and selection	178			

6.2.2	Secondary breaking	209	Chapter 7 Rock fill	257
6.2.3	Sizing	209	7.1 Introduction	257
6.3	Armourstone	209	7.2 Functions and required properties	257
6.3.1	Introduction	209	7.2.1 Applications	257
6.3.2	Selection	209	7.2.2 Slope stability	258
6.3.3	Sizing	213	7.2.3 Deformations	258
6.3.4	Picking rip-rap	213	7.2.4 Dynamic behaviour	260
6.3.5	Handling	213	7.2.5 Permeability	260
6.3.6	Transport	214	7.2.6 Gabions	261
6.4	Dimension stone	214	7.3 Laboratory testing	262
6.4.1	Introduction	214	7.3.1 General	262
6.4.2	Masonry design and detailing	215	7.3.2 Index and classification tests	262
6.4.3	Stone selection	218	7.3.3 Shear strength tests	263
6.4.4	Splitting	218	7.3.4 Compressibility tests	263
6.4.5	Primary saws	218	7.4 Excavation	264
6.4.6	Secondary saws	221	7.4.1 General	264
6.4.7	Planers	223	7.4.2 Instability induced by excavation using explosives	264
6.4.8	Lathes	224	7.4.3 Presplit blasting	264
6.4.9	Routers	224	7.4.4 Fragmentation blasting	265
6.4.10	Milling	224	7.4.5 Ripping	266
6.4.11	Work centres	224	7.4.6 Assessment of excavatability by blasting or ripping	266
6.4.12	Surface finishes	224	7.4.7 Treatment of instability of cutting slopes	268
6.4.12.1	Sawn	225	7.4.7.1 Removal of unstable rock	268
6.4.12.2	Rubbed	225	7.4.7.2 Strengthening of rock face	268
6.4.12.3	Dolly pointed	225	7.4.7.3 Support of rock face	268
6.4.12.4	Grit blasted	225	7.4.7.4 Containment of falling rock	268
6.4.12.5	Flame textured	226	7.4.8 Environmental impact	269
6.4.12.6	Honed	226	7.5 Placement and compaction	269
6.4.12.7	Polished	226	7.5.1 General	269
6.4.12.8	Ashlar	229	7.5.2 Low grade rock fill	270
6.4.13	Roofing slate	229	7.5.3 Trial fill placement	271
6.4.14	Tiles	233	7.5.4 British practice for specification and control	271
6.4.15	Setts	234	7.5.5 Other national practice for specification and control	273
6.4.16	Carving and hand dressing	234	7.6 Case studies	273
6.4.17	Artificial and reconstituted stone	235	7.6.1 Scammonden dam	273
6.4.17.1	Coade stone	236	7.6.2 Roadford dam	274
6.4.18	Process water	236	7.6.3 Queen's Valley dam	275
6.5	Quality systems	236	7.6.4 Loch Lomondside A82 highway	277
6.6	Examples of British stone quarries and mines	237	7.6.5 Llanddulas to Glan Conwy section of the A55 highway	279
6.6.1	Coombeheld limestone quarry, Portland, Dorset	237	7.6.6 New Hong Kong airport	279
6.6.2	Monk's Park Mine, Bathstone mine, Wiltshire	241	References	286
6.6.3	De Lank granite quarry, Cornwall, UK	243	Chapter 8 Armourstone	289
6.6.4	Kirkby slate quarry, Cumbria, UK	244	8.1 Introduction	289
6.6.5	Penrhyn slate quarry, Bethesda, Gwynedd, north Wales	247	8.1.1 Objectives	289
6.6.6	Aberllefeni slate mine, Powys, Wales	250	8.1.2 Marine structures	289
6.6.7	Slate mines and quarries of Blaenau Ffestiniog, Gwynedd, Wales	251	8.1.3 Non-marine structures	292
6.6.8	Birchover gritstone quarry, Derbyshire	253	8.1.4 Materials requirements	292
References		255	8.1.5 Material quality evaluation	293

8.2	Definitions	293	9.2.1.4	Facing, bonded and/or cramped to backing masonry or <i>in situ</i> concrete	332
8.2.1	Introducing armourstone terminology	293	9.2.1.5	Mortar, its function and influence on masonry properties	333
8.2.2	Terminology used for rock in marine structures	296	9.2.2	Masonry facades to framed buildings	335
8.3	Functions and Required Properties	305	9.2.2.1	Facing bonded and/or cramped to backing brick or blockwork, supported floor-by-floor on steel frame	336
8.3.1	The coastal defence and breakwater environment	305	9.2.2.2	Facing bonded and/or cramped to backing brick or blockwork, supported floor-by-floor on reinforced concrete frame	336
8.3.2	Required rock properties for coastal engineering	307	9.2.3	Cladding and lining to framed buildings	336
8.3.3	Design requirements, rock weight and grading	309	9.2.3.1	Cladding- and lining-slabs, individually fixed	336
8.3.4	Durability	310	9.2.3.2	Stone faced pre-cast panels	338
8.4	Extraction, processing and placing	312	9.2.3.3	Sub-frame mounted stone facings	338
8.4.1	Introduction	312	9.2.3.4	Veneer panels	340
8.4.2	Quarry production	312	9.2.4	Internal flooring and stairs	341
8.4.3	Handling and transportation	314	9.2.4.1	Internal floor paving and stair treads	341
8.4.4	Placing	314	9.2.4.2	'Cantilever' stairs and landings	341
8.5	Testing and evaluation	317	9.2.5	Roof cladding	341
8.5.1	Petrography	318	9.2.5.1	Limestone and sandstone roofing tiles	342
8.5.2	Size, shape and grading	319	9.2.5.2	Metamorphic slates ('true slates')	343
8.5.3	Density and water absorption	319	9.2.6	Miscellaneous	344
8.5.4	Strength related tests	319	9.2.6.1	Foundations and plinths	344
8.5.4.1	Block integrity drop test	320	9.2.6.2	Lintels, jambs, sills, padstones, cornices, quoins and ornamental bands	344
8.5.4.2	Fracture toughness (K_{Ic})	320	9.2.6.3	Sills and copings	345
8.5.4.3	Point load strength	320	9.3	Forms of construction and uses in civil engineering	346
8.5.4.4	Aggregate impact strength tests	320	9.3.1	Structural uses	346
8.5.4.5	Resistance to abrasion	321	9.3.1.1	Arch bridges	346
8.5.4.6	Sonic velocity	321	9.3.1.2	Solid bridge piers, abutments and parapets	347
8.5.5	Durability tests	321	9.3.1.3	Through-thickness dams, retaining walls, dock and quay walls	347
8.5.6	Field tests	321	9.3.2	Facing and cladding	347
8.6	Specifications	322	9.3.2.1	Facing to bridge piers, abutments and parapets	347
8.6.1	Gradings	322	9.3.2.2	Facings to dams, intake structures and spillways	347
8.6.2	Shape	322	9.3.2.3	Tunnel linings and portals	347
8.6.3	Density and water absorption	322	9.3.2.4	Facing to precast concrete cladding panels	349
8.6.4	Durability	323			
8.6.5	Block integrity	323			
8.6.6	Impact resistance	323			
8.6.7	Abrasion resistance	325			
8.7	Case histories of coastal protection projects	325			
8.7.1	St Paul's Island, Alaska	325			
8.7.2	Morecambe Bay, England	325			
	References	325			
Chapter 9 Stone for buildings and civil engineering		327			
9.1	Introduction	327			
9.2	Forms of construction and uses of stone in buildings	327			
9.2.1	Load-bearing and self-supporting masonry	328			
9.2.1.1	Through-thickness walls, piers and arches	329			
9.2.1.2	Dressed stone leaves with rubble-and-mortar core	330			
9.2.1.3	Outer leaf of external walls	332			

x	CONTENTS			
9.3.3	Hard landscaping	349	9.6.3 Programme of testing	369
	9.3.3.1 External paving	349	9.6.4 Future testing – European standards	370
	9.3.3.2 Kerbs, bollards, etc.	349	References	371
9.4	Design methodology	349	Chapter 10 Stone repair and restoration	373
9.4.1	Strategy	350	10.1 Introduction	373
	9.4.1.1 Briefing	350	10.2 Defects requiring repair or restoration	373
9.4.2	Specification/selection	352	10.2.1 Need for repair or restoration	373
	9.4.2.1 Specification	352	10.2.2 Failures caused by construction,	
	9.4.2.2 Selection	353	detailing and use	373
	9.4.2.3 Special considerations for		10.2.2.1 Construction and design	373
	the selection of slate	354	10.2.2.2 Selection of materials	374
	9.4.2.4 Quality control	354	10.2.2.3 Detailing	374
9.4.3	Design	355	10.2.2.4 Use	375
	9.4.3.1 General design of facades	355	10.2.2.5 Maintenance	375
	9.4.3.2 Structural design of load-		10.2.3 Failures caused by the effects of	
	bearing masonry	355	weather	376
	9.4.3.3 Structural design of facade		10.2.3.1 Introduction	376
	cladding	355	10.2.3.2 Wind erosion	378
	9.4.3.4 Design of roof cladding	356	10.2.3.3 Frost	378
	9.4.3.5 Design of fixings	357	10.2.3.4 Thermal cycles	380
	9.4.3.6 Joints	358	10.2.3.5 Biochemical weathering	380
9.4.4	Workmanship	358	10.2.3.6 Chemical weathering	381
9.5	Functional requirements of stone for		10.2.3.7 Rain and water	
	different uses	360	weathering	381
9.5.1	Structural properties	360	10.2.3.8 Salt crystallization	383
	9.5.1.1 Compressive strength	360	10.3 Masonry condition evaluation	385
	9.5.1.2 Bending and shear		10.3.1 Introduction	385
	strength	362	10.3.2 Building history	385
	9.5.1.3 Tensile (pull-out) strength	362	10.3.3 Visual assessment	386
	9.5.1.4 Modulus of deformation		10.3.4 Non-destructive testing	386
	(elastic modulus)	363	10.3.5 Semi-destructive testing	388
	9.5.1.5 Thermal and moisture		10.3.6 Destructive testing	388
	movements	363	10.3.7 Monitoring structural movements	389
9.5.2	Weathering and wear resistance	365	10.3.8 Preparing for remediation	390
	9.5.2.1 Chemical resistance	365	10.3.9 Final decisions: repair, restore or	
	9.5.2.2 Frost resistance	365	leave alone	390
	9.5.2.3 Abrasion resistance	365	10.3.10 Factors and financial influences	
	9.5.2.4 Slip resistance	365	on nature and extent of remedial	
9.6	Testing requirements and regimes for the		works	390
	different uses	366	10.4 Stone cleaning	391
9.6.1	Testing for structural properties	366	10.4.1 Introduction	391
	9.6.1.1 Compressive strength	366	10.4.2 Cleaning trials	391
	9.6.1.2 Flexural strength	367	10.4.3 Cleaning methods	393
	9.6.1.3 Strength around fixings	367	10.4.3.1 Water washing	393
	9.6.1.4 Modulus of elasticity	368	10.4.3.2 Mechanical and air	
	9.6.1.5 Thermal and moisture		abrasive cleaning	394
	movements	368	10.4.3.3 Chemical cleaning	397
9.6.2	Testing for weathering and wear		10.4.3.4 Special cleaning methods	402
	resistance	368	10.4.3.5 Removal of algae, lichen	
	9.6.2.1 Petrographic description	368	and moss	403
	9.6.2.2 Density and porosity	368	10.4.4 Stains and their removal	403
	9.6.2.3 Water absorption	368	10.4.4.1 Metallic stains	403
	9.6.2.4 Durability	368	10.4.4.2 Smoke and soot	404
	9.6.2.5 Abrasion resistance	369	10.4.4.3 Tar, asphalt and bitumen	404
	9.6.2.6 Slip resistance	369	10.4.4.4 Oil and grease	404
	9.6.2.7 Impact resistance and		10.4.4.5 Timber stains	404
	surface hardness	369		

CONTENTS

xi

10.4.4.6	Cement and mortar deposits	404	B2	Sampling	443
10.4.4.7	Bird fouling and anti-pigeon gel	404	B3	Repeatability and reproducibility	444
10.4.4.8	Paint	404	B3.1	Repeatability (<i>r</i>)	444
10.4.4.9	Graffiti	405	B3.2	Reproducibility (<i>R</i>)	444
10.5	Methods of repairing stone buildings and surface treatments	405	B4	Physical tests	444
10.5.1	Introduction	405	B4.1	Particle size and shape	444
10.5.2	Replacement	405	B4.2	Density	445
10.5.3	Indentation	410	B4.3	Water absorption	445
10.5.4	Dressing back	410	B4.4	Petrographic description	445
10.5.5	Mortars for repair and pointing	410	B5	Mechanical tests	445
10.5.6	Repair with mortar (plastic repair)	413	B5.1	Strength	445
10.5.7	Grouting	417	B5.1.1	Introduction	445
10.5.7.1	Gravity systems	417	B5.1.2	Particle strength	446
10.5.7.2	Hand/pumped systems	417	B5.1.3	Aggregate crushing test	446
10.5.7.3	Vacuum	417	B5.1.4	Compressibility tests	446
10.5.8	Surface treatments	418	B5.1.5	Compressive strength	446
10.5.8.1	Water repellants	418	B5.1.6	Shear strength testing	446
10.5.8.2	Consolidants	418	B5.1.7	Flexural strength	447
10.5.8.3	Brethane	418	B5.1.8	Strength around fixings	447
10.5.8.4	Treatments based on lime	418	B5.1.9	Modulus of elasticity	447
10.6	Case studies of repair and restoration	418	B5.2	Durability	447
10.7.1	St. Margaret's Church, Westminster	418	B5.2.1	Slake durability test	448
10.7.2	All Hallows staining and crypt of Lambe's chapel	418	B5.2.2	Abrasion resistance	448
References		421	B5.2.3	Slip resistance	448
Appendix A	Glossary	425	B5.2.4	Thermal and moisture movement	448
Appendix B	Details of test methods	441	B5.2.5	Impact resistance and surface hardness	448
B1	Introduction	441	References		448
B1.1	General	441	Appendix C	Stone and rock properties	451
B1.2	Exploration and assessment	441	C1	Properties of some British building stones	451
B1.3	Rockfill	441	C2	Generalized properties of building stones	467
B1.4	Armourstone	443	C3	Effect of weathering	469
			C4	Scale of rock strength	469
			C5	References	470