

Table of contents

Foreword	1
1 Earth building today	3
1.1 The state of the art of earth building materials	3
1.2 Reasons for using earth building materials	4
2 The raw material – soils for construction	7
2.1 Introduction	7
2.2 Types of soils and their formation	8
2.3 Clay minerals – the binding agent	8
2.3.1 Structure and cohesion	8
2.3.2 Two layer clay minerals	11
2.3.3 Three layer clay minerals	12
2.4 Testing the suitability of earth mixtures	14
2.4.1 In-situ soil testing	14
2.4.2 Laboratory testing of earth mixtures	16
2.4.2.1 Grain size distribution	16
2.4.2.2 Binding force test (figure-8-shape test)	17
2.4.2.3 Determining the compressive strength and shrinkage of earth mixtures	19
2.4.2.4 Qualitative determination of the natural lime content	19
2.4.2.5 Determining soil salinity	20
2.5 Processing	21
2.5.1 Natural processing of earth mixtures	22
2.5.2 Mechanical processing	22

3	Earth building materials – composition and properties	25
3.1	Aggregates and additives	25
3.1.1	Aggregates	25
3.1.2	Additives	29
3.2	Mixing	31
3.3	Properties	32
4	Earth plasters	37
4.1	The application of earth plasters	37
4.1.1	Reasons for using earth plasters	37
4.1.2	Application areas of earth plasters	38
4.1.3	Aspects of long-term use	39
4.2	Constitution of earth plaster mortars	40
4.2.1	General composition of earth plaster mortars	40
4.2.2	Kinds of earth plaster mortars	41
4.2.3	Grades of earth plaster mortar	42
4.3	Substrates for earth plasters	43
4.3.1	Plaster substrates in general	43
4.3.2	Common plaster substrates	45
4.3.3	Primers and absorption sealers	48
4.3.4	Plaster laths	49
4.3.5	Special considerations for substrates for coloured plasters	50
4.3.6	Surface quality levels of plaster substrates for subsequent plastering	51
4.4	Earth plaster systems	59
4.4.1	Earth plaster systems in general	59
4.4.2	Shrinkage cracks in undercoat layers	59
4.4.3	Reinforcement fabric	61
4.4.4	Earth plaster on surfaces subject to thermal fluctuation	63
4.5	Processing and application	63
4.5.1	Mortar preparation	63
4.5.2	Mortar application	67
4.5.3	Corner profiles, plaster beads and junctions	68
4.5.4	Surface finishing	70
4.5.5	Special considerations for coloured earth plaster surfaces	71
4.5.6	Drying	71

4.5.7	Crack repairs and additional surface finishing	77
4.6	Paints and wall coverings for earth plasters	78
4.6.1	Painting and surface stabilisation	78
4.6.2	Wallpaper	79
4.6.3	Lime skim coat plaster	80
4.6.4	Wall tiles on earth plasters	80
4.7	Requirements of earth plasters	80
4.7.1	Mechanical properties	80
4.7.2	Building biology requirements	83
4.7.3	Moisture sorption capacity requirement	85
4.7.4	Visual requirements	85
4.8	Guaranteeing material properties	85
4.8.1	Basic testing procedures and declarations	85
4.8.2	Supplementary testing procedures and declarations	86
4.8.3	Quality control	87
4.9	Building material and building element properties	88
4.9.1	Mechanical properties	88
4.9.2	Thermal insulation and protection against moisture	88
4.9.3	Sound insulation and acoustics	89
4.9.4	Fire performance	90
5	Paints and finishes	91
5.1	Terminology, composition and applications	91
5.2	Substrate preparation	91
5.3	Priming	92
5.4	Mixing and application	92
5.5	Renovation coats	93
6	Dry earth construction	95
6.1	Introduction	95
6.2	Clay panels	95
6.3	Dry stacked walling	98
6.3.1	Dry stacked wall infill	99
6.3.2	Dry stacked wall lining	99
6.4	Ceiling overlays and ceiling and roof infill	100
6.5	Material and building element properties	103

6.5.1	Mechanical properties	103
6.5.2	Thermal insulation, thermal capacity and vapour diffusion resistance	104
6.5.3	Sound insulation	104
6.5.4	Fire performance	106
7	Internal insulation with earth materials	109
7.1	Internal insulation in general	109
7.1.1	Introduction and background	109
7.1.2	Requirements of building materials for internal insulation	110
7.1.3	Suitability of earth building materials for internal insulation	111
7.1.4	Dimensioning internal insulation	111
7.1.5	Preparing existing walls for internal insulation	113
7.1.6	Junctions with walls and ceilings, and window and door reveals	114
7.1.7	Bearings for timber joists	115
7.1.8	Minimising air leakages with internal plastering	116
7.2	Light earth wall linings (wet construction)	117
7.2.1	Description of the internal insulation	117
7.2.2	Constructing light earth walls	117
7.2.3	Types of light earth and specific aspects of their construction	120
7.2.4	Building duration and drying	121
7.2.5	Fixing items to the light earth wall lining	122
7.3	Light earth masonry wall linings	123
7.3.1	Description of the internal insulation	123
7.3.2	Constructing masonry wall linings and appropriate materials	123
7.4	Insulation board wall linings	125
7.4.1	Description of the internal insulation	125
7.4.2	Mortar layer, application and fixing of the insulation	126
7.4.3	Kinds of insulation boards	127
7.5	Material and building element properties	129
7.5.1	Thermal insulation and protection against moisture	129
7.5.2	Sound insulation	130
7.5.3	Fire performance	131
8	Earth block masonry	133
8.1	Introduction	133
8.2	Earth blocks	134

8.2.1	Base material and manufacturing methods	134
8.2.2	Requirements of earth blocks	134
8.2.2.1	Usage Classes	134
8.2.2.2	Inner and outer geometry	135
8.2.2.3	Bulk density and bulk density classes	138
8.2.2.4	Compressive strength and deformation of earth blocks under load	138
8.2.2.5	Moisture and frost resistance	139
8.2.2.6	Fire performance	142
8.3	Earth masonry mortar	143
8.4	Non-loadbearing earth block masonry with & without timber studs ...	144
8.5	Loadbearing earth block masonry	146
8.5.1	General aspects	146
8.5.2	Construction principles	147
8.5.3	Loadbearing structure and dimensioning	147
8.5.4	Physical performance of loadbearing earth block walls	149
8.6	Material and building element properties	149
9	Rammed earth construction	151
9.1	Introduction	151
9.2	Rammed earth	152
9.2.1	Raw materials and manufacture	152
9.2.2	Properties	153
9.2.2.1	Bulk density	153
9.2.2.2	Measure of shrinkage	153
9.2.2.3	Compressive strength and modulus of elasticity	153
9.2.2.4	Moisture and frost	154
9.2.2.5	Fire performance	154
9.3	Constructing rammed earth walls	155
9.3.1	Introduction	155
9.3.2	Building material preparation	155
9.3.3	Shuttering and formwork	156
9.3.4	Material insertion and compaction	158
9.3.5	Removal of formwork and touching up	160
9.3.6	Drying	160
9.4	The design of rammed earth walls	161
9.4.1	Constructional measures for weather protection	161

9.4.2	Embedded elements	163
9.4.3	Reinforcement	164
9.4.4	Installations	166
9.4.5	Internal finishes of rammed earth wall surfaces	166
9.5	Non-loadbearing rammed earth walls	167
9.6	Loadbearing rammed earth walls	167
9.7	Rammed earth floors	168
9.8	Physical properties of rammed earth	170
9.9	Building element properties	171
10	Renovation – historical earth buildings	173
10.1	Introduction	173
10.2	Solid earth wall constructions	174
10.2.1	Weller earth construction	174
10.2.1.1	Weller earth and its properties	177
10.2.1.2	The construction of weller earth buildings	179
10.2.2	Historical rammed earth construction	187
10.2.2.1	Rammed earth and its properties	190
10.2.2.2	The construction of rammed earth buildings	191
10.2.3	Earth brick construction	194
10.2.3.1	Earth bricks and earth masonry mortar	196
10.2.3.2	The construction of earth brick buildings	197
10.2.4	Damages and repair of massive earth constructions	199
10.2.4.1	Material damage and reduced cross-section as a result of rising damp ...	200
10.2.4.2	Damages to plaster and render, weathering and washing out	203
10.2.4.3	Cracks	206
10.2.4.4	Pest infestation	208
10.2.5	Thermal insulation	208
10.2.6	Building material and building element properties	209
10.2.6.1	Mechanical properties	209
10.2.6.2	Selected physical properties	210
10.3	Timber-frame panel infill	211
10.3.1	Panel infill techniques	214
10.3.1.1	Wattle with straw-clay daub	214
10.3.1.2	Staves with straw-clay	218
10.3.1.3	Panel infill with earth brick masonry	220

10.3.1.4 Internal and external facing coats	220
10.3.2 The repair of external timber-frame panels	223
10.3.2.1 The repair of panels made of wattle & daub or staves & straw-clay	223
10.3.2.2 The repair of panels made of earth brick masonry	225
10.3.3 New panel infill	226
10.3.3.1 New panel infill with wattle and daub or staves and straw-clay	226
10.3.3.2 New panel infill with earth brick masonry	227
10.3.4 External render	231
10.3.4.1 Exposed timber-frame constructions and weathering	231
10.3.4.2 Rendering timber-frame panels	233
10.3.4.3 Rendering and cladding entire façades	237
10.3.5 Building material and building element properties	238
10.3.5.1 Mechanical properties	238
10.3.5.2 Thermal insulation and water vapour diffusion resistance	239
10.3.5.3 Sound insulation	240
10.3.5.4 Fire performance	240
10.4 Timber beam ceiling infill	242
10.4.1 Traditional ceiling infill techniques	242
10.4.1.1 Staves with straw-clay infill	242
10.4.1.2 Earth reels	244
10.4.1.3 Ceiling insert with loose or compacted earth infill	246
10.4.2 Repair of old ceiling infill	248
10.4.2.1 Repair of ceiling infill made of staves and straw-clay or earth reels	248
10.4.2.2 Repair of timber boarding with loose or compacted fill material	248
10.4.3 New ceiling infill	248
10.4.3.1 New ceiling infill made of staves and straw-clay or earth reels	248
10.4.3.2 New ceiling inserts with earth mass or earth loose fill material	249
10.4.4 New ceiling plaster	250
10.4.4.1 New ceiling plaster on ceilings with staves & straw-clay or earth reels	250
10.4.4.2 New ceiling plaster on ceiling inserts with earth fill material	252
10.4.5 Building material and building element properties	252
10.4.5.1 Mechanical properties	252
10.4.5.2 Thermal insulation	252
10.4.5.3 Sound insulation	253
10.4.5.4 Fire performance	254
10.5 Earth floors	255
10.5.1 Historical earth floors	255

10.5.2	The repair of historical earth floors	256
10.6	Historical earth plasters	257
10.6.1	Description of historical earth plaster methods	257
10.6.2	The repair of historical earth plasters	259
10.6.3	Building material and building element properties	260
11	Building legislation and business practice	261
11.1	Earth building regulations	261
11.2	Building trades and earth building qualifications	263
11.3	Calculating the cost of earth building works	264
11.3.1	Typical work times	265
11.3.2	Calculating typical constructions	272
	Bibliography	275
	Index	283