

GROUTING OF ROCK AND SOIL

CHRISTIAN KUTZNER

Consulting Geotechnical Engineer

Honorary Professor, Technical University Darmstadt, Hofheim, Germany



A. A. BALKEMA / ROTTERDAM / BROOKFIELD / 1996



Contents

FORWORD	XI
PREFACE	XIII
ACKNOWLEDGEMENTS	XV
1 DEFINITION OF TERMS	1
2 HISTORY	4
3 GROUTING THEORY	9
3.1 Basic considerations	9
3.2 Flow and hardening behaviour of grouting materials	11
3.3 The grouting pressure	16
3.4 The effective radius	19
3.5 The grouting time	22
3.6 Range of application	22
3.6.1 Permeability and groutability	22
3.6.2 Lower limit for the application of solutions	24
3.6.3 Lower limit for the application of suspensions	25
3.6.4 Lower limit for the application of emulsions	27
3.6.5 Upper limits of application	27
4 DESCRIPTION OF SUBSOIL PROPERTIES	28
4.1 Introduction	28
4.2 Rock	28
4.2.1 Weathering	28
4.2.2 Discontinuities	31
4.2.3 Karsticity	37
4.2.4 Permeability	38

VI Contents

4.2.5	Water pressure test	39
4.2.6	Other permeability tests	47
4.3	Soil	
4.3.1	Grain size distribution	48
4.3.2	Stratification	48
4.3.3	Permeability	48
4.3.4	Other soil parameters	48
4.4	Ground and joint water	50
		50
5	DESIGN OF GROUTING WORKS	
5.1	Introduction	52
5.2	Sealing rock	52
5.2.1	Grouting criteria	53
5.2.2	Location of the grouting zone and direction of boreholes	53
5.2.3	Depth of the grouting zone	61
5.2.4	Arrangement of boreholes and number of rows	64
5.2.5	Grouting materials	66
5.2.6	Grouting pressure and grouting rate	67
5.2.7	Grouting and inspection gallery	70
5.2.8	Effectiveness of rock sealing measures	71
5.3	Stabilization of rock	76
5.3.1	The need for stabilization	80
5.3.2	Size and shape of the grouting zone	80
5.3.3	Arrangement of boreholes	81
5.3.4	Grouting materials	82
5.3.5	Grouting pressure	83
5.3.6	Effectiveness of rock stabilizing measures	84
5.4	Sealing of non-cohesive soil by fill grouting	85
5.4.1	Requirement of sealing	86
5.4.2	Location and dimensions of the grouting zone	86
5.4.3	Arrangement of boreholes and grouting pressure	87
5.4.4	Grouting materials	88
5.4.5	Effectiveness of sealing measures by fill grouting in non-cohesive soil	89
		89
5.5	Stabilization of non-cohesive soil by fill grouting	90
5.5.1	Requirement of stabilization	90
5.5.2	Location and dimensions of the grouting zone	91
5.5.3	Arrangement of boreholes and grouting pressure	94
5.5.4	Grouting materials	95
5.5.5	Effectiveness of stabilizing measures by fill grouting in non-cohesive soil	96
		96
5.6	Stabilization of cohesive soil by crack grouting	97
5.6.1	Requirement of stabilization	97

5.6.2	Arrangement of boreholes and sequence of grouting	99
5.6.3	Grouting pressure	99
5.6.4	Grouting materials	100
5.6.5	Effectiveness of soil stabilization by crack grouting	100
5.7	Compaction grouting	100
6	TEST GROUTING	102
6.1	Introduction	102
6.2	Rock grouting	102
6.3	Soil grouting	106
7	EXECUTION OF GROUTING WORKS	108
7.1	Overview	108
7.2	Drilling of boreholes	109
7.2.1	General	109
7.2.2	Drilling of rock	111
7.2.3	Drilling of soil	115
7.2.4	Drilling equipment	116
7.2.5	Core drilling	129
7.2.6	Borehole deviation	134
7.3	Grouting of substrata	136
7.3.1	Procedure	136
7.3.2	Grouting of rock	138
7.3.3	Grouting of soil	143
7.3.4	Grouting equipment	149
8	GROUTING MATERIALS	174
8.1	Overview	174
8.2	Cement based suspensions	176
8.2.1	Cement	176
8.2.2	Water	177
8.2.3	Flow properties	177
8.2.4	Sedimentation	180
8.2.5	Permeability	182
8.2.6	Strength	183
8.2.7	Fillers	185
8.2.8	Additives	187
8.2.9	Durability and erosion stability	188
8.2.10	Effect of temperature	189
8.3	Silicagels	191
8.3.1	Composition and flow properties	191
8.3.2	Properties of grouted media	192

VIII Contents

8.4	Chemical grout materials other than silicagels	202
8.4.1	Acrylamide and lignosulfonate	202
8.4.2	Phenoplasts and aminoplasts	203
8.4.3	Foaming materials	203
8.5	Bitumen	204
8.5.1	Emulsions of bitumen	204
8.5.2	Hot bitumen	205
9	QUALITY CONTROL	206
9.1	Boreholes	206
9.1.1	Borehole stability	206
9.1.2	Borehole deviation	206
9.1.3	Borehole television survey	208
9.2	Grouting materials	211
9.2.1	Suspensions	214
9.2.2	Silicagels	215
9.2.3	Other chemical materials	215
9.3	Grouting zone	216
9.3.1	Control during construction	216
9.3.2	Control after construction	217
10	JET GROUTING	221
10.1	Introduction	221
10.2	Description of procedures	222
10.3	Range of application	225
10.4	Procedure	226
10.4.1	Basic effects	226
10.4.2	Pressure and effective radius	227
10.4.3	Work progress	229
10.4.4	Supply of material	229
10.5	Equipment	230
10.5.1	General	230
10.5.2	Jet grouting rigs	230
10.5.3	Monitor and nozzles	231
10.5.4	Batching plant	232
10.5.5	High pressure pumps	232
10.6	Properties of the elements	232
10.6.1	Composition of the suspension	232
10.6.2	Compressive strength	233
10.6.3	Permeability	235
10.7	Examples of application	236
10.7.1	Arrangement of boreholes	236
10.7.2	Sealing measures	237

10.7.3	Stabilizing measures	237
10.7.4	Other applications	239
10.7.5	Quality control	239
11	TENDER DOCUMENTS AND CONTRACTING	242
11.1	General	242
11.2	Liabilities	244
11.3	Technical specifications	246
11.3.1	Drilling work	246
11.3.2	Water pressure tests	246
11.3.3	Grouting work	247
11.4	Working items	249
11.4.1	Site installation	249
11.4.2	Drilling work	250
11.4.3	Water pressure tests	251
11.4.4	Grouting work	252
11.5	Tendencies	253
	REFERENCES	256
	CONVERSION TABLES	263
	SUBJECT INDEX	267