

Contents

1	Introduction.....	1
1.1	General introduction	1
1.2	Advantages and disadvantages of arch bridges	12
1.3	Structure of the book	14
1.4	Terms	20
1.5	Classification of static bridge types	29
1.6	Types of arch geometry	33
1.7	History of stone arch bridges	36
1.8	Arch bridges from alternative material	47
1.8.1	Steel arch bridges	47
1.8.2	Wooden arch bridges	48
1.8.3	Concrete arch bridges.....	49
1.9	Number of arch bridges	50
	References	56
2	Loads.....	67
2.1	Introduction	67
2.2	Road traffic loads.....	67
2.3	Railroad traffic.....	82
2.4	Initial drive forces.....	86
2.5	Breaking forces.....	87
2.6	Wind loading	88
2.7	Impact forces	89
2.8	Settlements.....	89
2.9	Temperature loading	89
2.10	Snow loading	92
2.11	Dead load	92
	References	94
3	Computation of historical arch bridges	99
3.1	Introduction	99
3.2	Empirical rules.....	100
3.2.1	Historical rules.....	100
3.2.2	Modern rules.....	119

3.3	Beam models	125
3.3.1	Single beam models.....	125
3.3.2	Compound beam models	133
3.4	Finite element method (FEM)	136
3.5	Discrete element method (DEM).....	140
3.6	Comparison of testing and modelling.....	141
3.6.1	Load tests on arches.....	141
3.6.2	Comparison results	144
3.7	Transverse direction (effective width).....	148
	References	152
4	Masonry strength.....	165
4.1	Introduction	165
4.2	Masonry elements.....	166
4.2.1	Masonry stones.....	166
4.2.2	Mortar	172
4.3	Maximum centric masonry compression strength.....	176
4.3.1	Model according to DIN 1053-100	177
4.3.2	Model according to DIN 1053.....	178
4.3.3	Empirical exponential models	179
4.3.4	Model according to Hilsdorf	179
4.3.5	Model according to Mann	180
4.3.6	Model according to Berndt.....	181
4.3.7	Model according to Sabha.....	183
4.3.8	Model according to Ohler.....	183
4.3.9	Model according to Stiglat	184
4.3.10	Model according to Francis, Horman and Jerrems.....	184
4.3.11	Model according to Khoo and Hendry	184
4.3.12	Model according to Schnackers.....	185
4.3.13	Model according to Ebner	185
4.3.14	Further masonry compression models.....	185
4.4	Stress-strain relationship.....	186
4.5	Moment-Axial force diagrams.....	187
4.6	Additional-leaf masonry	188
4.6.1	Introduction	188
4.6.2	Model according to Warnecke.....	188
4.6.3	Model according to Egermann	188
4.7	Shear strength	190
4.8	Proof equations	191
	References	192

5 Investigation techniques	199
5.1 Introduction	199
5.2 Destructive tests	202
5.3 Semi-destructive test methods	205
5.4 Non-destructive test methods	205
5.4.1 Ultrasound	205
5.4.2 Impact-echo	206
5.4.3 Radar	207
5.4.4 Tomography	208
5.4.5 Thermography	208
5.4.6 Electrical conductivity	208
5.4.7 Experimental tests on bridges on site	208
5.4.8 Photogrammetry and lasercanning	209
References	210
6 Damages and repair	217
6.1 Introduction	217
6.2 Damages on historical arch bridges	218
6.2.1 Overview	218
6.2.2 Recent collapses of historical arch bridges.....	221
6.2.3 Weathering of the mortar.....	222
6.2.4 Spalling and contour scaling	223
6.2.5 Salt attack	224
6.2.6 Chemical weathering	226
6.2.7 Biological weathering.....	226
6.2.8 Mechanical and physical weathering.....	226
6.2.9 Deformations	227
6.2.10 Cracks	229
6.3 Repair and strengthening	235
6.3.1 Introduction	235
6.3.2 Strengthening techniques.....	241
6.3.3 Examples	254
6.4 Arch bridges of the second generation	256
References	257
7 Safety assessment	265
7.1 Definition of safety and safety concepts	265
7.2 Probabilistic safety concept	269
7.2.1 Introduction	269
7.2.2 FORM (First-order reliability method).....	270
7.2.3 SORM (Second-order reliability method)	274
7.2.4 Hypersphere division method.....	281
7.2.5 Response Surface Method	281

7.2.6 Monte Carlo Simulation	285
7.2.7 Combination of safety indexes	288
7.2.8 Limitation of the presented methods	293
7.2.9 Commercial programs	295
7.2.10 Goal values of safety indexes	297
7.3 Semi-probabilistic safety concept	301
7.3.1 Introduction	301
7.3.2 Partial safety factors	303
7.3.3 Characteristic values	310
References	323
8 Examples.....	333
8.1 Introduction	333
8.2 Examples in literature	333
8.3 Belonging examples	336
8.3.1 Bridge 1	336
8.3.2 Bridge 2	341
8.3.3 Bridge 3	345
8.3.4 Bridge 4	346
8.3.5 Bridge 5	348
8.3.6 Bridge 6	349
8.3.7 Summary	350
8.4 Further examples	351
8.4.1 Historical stone beam bridges	351
8.4.2 Anchoring chamber of the Blue Wonder Bridge	352
8.5 Conclusion	354
References	357
Index	361

Safety of historical stone arch bridges

Proske, D.; van Gelder, P.

2009, XII, 366 p., Hardcover

ISBN: 978-3-540-77616-1