

Contents

1	Masonry Strength and Deformability	1
1.1	Brief Notes on the History of Masonry Constructions.....	1
1.2	The Masonry of Historic Buildings	4
1.3	Compression Strength of Brick and Stone Elements	7
1.3.1	Bricks.....	7
1.3.2	Stone Blocks	7
1.4	Mortars.....	9
1.4.1	Binders.....	9
1.4.2	Aggregates	10
1.4.3	Mortars of Lime	10
1.5	Tests on Rock and Mortar Specimens.....	12
1.5.1	Tests on Rock Specimens	12
1.5.2	Uniaxial Compression Tests on Mortar Specimens	15
1.5.3	Stress-Strain Diagrams for Stone and Mortar Materials	15
1.6	Formulation of a Triaxial Failure Criterion for Stone Materials.....	16
1.6.1	Preliminary Considerations.....	16
1.6.2	Porosity Effects: Micro-macro Stress States.....	17
1.6.3	Micro-macro Failure Condition: Tensile and Compression Test: Reasons Why Stone and Mortar Materials Have Different Tensile and Compression Strengths	20
1.6.4	Evaluation of the Pores Shape Irregularity Factor	24
1.6.5	Failure Interaction Domains.....	25
1.7	Masonry Compression Strength.....	28
1.7.1	Features of Compressed Masonry Failure.....	28
1.7.2	Evaluation of Masonry Compression Strength	29
1.8	Masonry Tensile Strength.....	36
1.9	Masonry Shear Strength.....	37
1.10	Masonry Strength in Tension-Compression States with Varying Course Inclinations	39
1.11	Masonry Deformations	41
1.11.1	Masonry Elastic Modulus	41
1.11.2	Mortar Creep Deformation.....	44

1.11.3	Recalls of the Concept of Memory in Constitutive Creep Models	45
1.11.4	Mortar Shrinkage	48
References	48
2	Fundamentals of Statics of Masonry Solids and Structures.....	51
2.1	Introduction.....	51
2.2	No-Tension Masonry Models	52
2.2.1	No-Tension Assumption	52
2.2.2	The Problem of Elastic Compressive Strains.....	53
2.3	The Rigid No-Tension Model.....	57
2.3.1	The Unit Resistant Cell: Heyman's Assumptions.....	57
2.3.2	Material Properties.....	64
2.4	The Masonry Continuum.....	66
2.4.1	Local Compatibility Conditions on Loads.....	67
2.4.2	Local Compatibility Conditions on Stresses.....	68
2.4.3	Consequences of the No-Tension Assumption	69
2.4.4	Impenetrability Condition for the Displacement Fields.....	70
2.4.5	Compatibility Conditions for Strains and Detachments.....	71
2.4.6	The Boundary of a Cracked Body.....	72
2.4.7	Coupled Conditions between Stresses-Strains and Stress Vectors-Detachments	75
2.4.8	Specifications for One-Dimensional Masonry Systems.....	76
2.4.9	Indeformable Masonry Structures.....	78
2.5	Equilibrium and Compatibility	79
2.5.1	Principle of Virtual Work	79
2.5.2	Variational Inequality for the Existence of the AE State	83
2.5.3	Nonexistence of Self-equilibrated Stresses in Deformable Masonry	86
2.5.4	Indeformable Structures: Statically Indeterminate Behavior.....	87
2.5.5	Admissible Equilibrium States in One-Dimensional Masonry Systems	88
2.5.6	Weight and Live Loads.....	90
2.5.7	Mechanism States	92
2.6	Collapse State	94
2.6.1	Definitions	94
2.6.2	The Static Theorem.....	96
2.6.3	The Kinematic Theorem	98
2.6.4	Uniqueness of the Collapse Multiplier.....	99
2.6.5	Indeformable Systems: Lack of Collapse	100
2.7	Geometry and Strength: The Theory of Proportions in the Past Architecture	101
2.8	Settled States.....	106

2.8.1	Definitions	106
2.8.2	Properties of Settled States	108
2.8.3	Statically Admissible Thrusts: The Static Theorem of Minimum Thrust	109
2.8.4	Kinematically Admissible Thrusts: The Kinematic Theorem of Minimum Thrust	111
2.8.5	Uniqueness of the Settlement Multiplier	112
2.8.6	Conclusions	112
2.8.7	An Example Application of the Kinematic Approach to the Evaluation of Minimum Thrust	113
2.8.8	Static Analysis of Masonry Structures in Their Actual State	117
	Appendix A.1 Lessons from the Failure of Cathedral of Noto (1996).....	119
	References	125
3	Masonry Arches.....	129
3.1	Definitions and History	129
3.2	The Birth of the Statics of Arches and Its Evolution	134
3.3	Internal Equilibrium	148
3.3.1	Shear Force in Arches	149
3.4	Limit Analysis	151
3.5	Minimum and Maximum Thrust	152
3.5.1	Effects of the Elastic Deformation on the Thrust of the Arch	153
3.5.2	Cracking	156
3.5.3	Minimum Thrust State	156
3.5.4	Minimum Thrust in the Round Arch	157
3.5.5	Minimum Thrust in the Depressed Arch	160
3.6	Coupled Systems of Arches of Different Spans	162
3.7	Masonry Arches Loaded by Horizontal Forces	162
3.8	Some Experimental Results and Comments on Failure Tests of Masonry Arches	167
3.8.1	Test Description	167
3.8.2	Comments on Test Results	171
	References	172
4	Masonry Vaults.....	175
4.1	General Introduction	175
4.1.1	Brief Historical Notes	175
4.1.2	The Implemented Static Approach	180
4.2	Domes	183
4.2.1	The Membrane Equilibrium of Rotational Shells	183
4.2.2	Meridian Cracking: Definitive Stress State of Masonry Domes	190

4.2.3	Mycenaean Tholos	203
4.2.4	Roman Concrete Vaults: Do They Push on Their Supports ?	208
4.2.5	The Pantheon	209
4.2.6	Brunelleschi's Dome in Florence.....	218
4.2.7	St Peter's Basilica Dome by Michelangelo: The Static Restoration by Poleni and Vanvitelli	241
4.3	Barrel Vaults	269
4.3.1	Introduction.....	269
4.3.2	Membrane Stresses in Cylindrical Vaults	270
4.3.3	Transition from the Uncracked to the Cracked State: The No-Tension Model of the Barrel Vault.....	275
4.3.4	Composite Systems Made Up of Vaults and Walls	276
4.4	Cross and Cloister Vaults	287
4.4.1	Geometric Generation of Cross and Cloister Vaults	287
4.4.2	Historical Notes on Cross Vaults	289
4.4.3	Statics of Cross Vaults	292
4.4.4	Cloister Vaults	320
5	The Colosseum.....	343
5.1	The Original Colosseum	343
5.2	Static Analysis of the Colosseum's Original Configuration	350
5.2.1	Pier Stresses	350
5.3	Limit Analysis	357
5.3.1	Preliminary Remarks	357
5.3.2	The Collapse Load	362
5.4	Damage and Subsequent Repairs	364
5.5	Possible Causes of the Damage	368
5.5.1	Seismic Excitability of the Monument: Effects of Soil-Structure Interactions	368
5.5.2	Seismic Strength of the Monument.....	373
5.5.3	The Dismantling Hypothesis.....	376
5.5.4	Conclusions.....	378
	References	379
6	Masonry Stairways.....	381
6.1	Geometrical Features of Masonry Stairs: Cantilevered Stairs	381
6.2	Brick Layout	383
6.3	Other Types of Stairs	385
6.4	Paradoxical Static Behavior of Cantilevered Masonry Stairs	385
6.5	Numerical Investigations on the Statics of a Single Cantilevered Masonry Flight.....	387
6.6	Resistant Model of a Horizontal Flight of Stairs with Side Landings	390