

Contents

1	Introduction of Design Philosophy	1
1.1	The Essentials of Engineering Design	1
1.2	The Concept of Comparative Design	2
1.2.1	Design Space Theory	2
1.2.2	The Fuzzy Expression of P_d	4
1.3	From Empirical to Intelligent Design	5
1.4	Functional Aspect of Design	8
1.5	On Sustainable Development	9
1.6	On Aesthetics in Design	10
1.6.1	Principles in Consideration of Aesthetics	10
1.6.2	National Characteristics in Aesthetics	11
1.7	Conclusions	12
2	Introduction to Structural Design	13
2.1	The Features of Modern Structures	13
2.2	The Processes of Structural Design	16
2.3	The Process of Architectural Design	17
2.3.1	The Elements of Architectural Design	17
2.3.2	The Relation Between Structure and Architecture	18
2.3.3	The Process of Architectural Design	21
2.3.4	The Application of Structural Concepts in Architectural Design	22
2.4	The Structural Behavior and Design Principles	23
2.4.1	The Structural Behavior and Energy Principle	23
2.4.2	Overall Stability of Structure and Stability in Its Geometric Composition	25
2.4.3	The Upper- and Lower-Bound Theorem in Limit Analysis of Structure	27
2.4.4	Instability and Structural Dynamics	29
2.4.5	Fundamental Principles of Structural Design	31

2.5	The Loadings Analyses	33
2.5.1	Vertical Load	34
2.5.2	Wind Load	37
2.5.3	Seismic Load	40
2.5.4	Other Loads and Effects	45
2.6	The Acting Loads and the Structural Deformation Response	47
3	Global Design of Structures	49
3.1	The Classification of Structural Systems	49
3.2	Methods of Global Analysis of Structures	63
3.3	Facade Allocation Analysis Through “Force Flow” Method	64
3.4	Planar Layout Analysis Through “Footprint” Method	67
3.5	External Configuration and Balancing Design of Structures	75
3.6	Decomposition of Asymmetric Complex Structures	82
3.7	Overall Structural Performance	93
3.8	Conclusion	113
4	Systematic Analyses of Substructures	115
4.1	Analyses of Structural Components	115
4.1.1	Analysis of Horizontal Components	115
4.1.2	Analysis of Vertical Components	127
4.2	Analysis of Prestressed Structural Elements	137
4.3	Structural Joints and Connections	147
4.4	Decomposition of Structural Systems	149
4.5	Integrated Structures and Substructures	152
4.6	Characteristics and Simplified Analysis of Horizontal Substructure Systems	157
4.6.1	Characteristics of Horizontal Substructure Systems	157
4.6.2	Simplified Analysis of Horizontal Substructure Systems	161
4.7	Characteristics and Simplified Analysis of Vertical Substructure Systems	171
4.7.1	Characteristics of Vertical Substructure Systems	171
4.7.2	Classification and Simplified Calculation of Vertical Substructure Systems	172
4.8	Conclusions	198
5	Comparative Design and Analyses of High-Rise Buildings	201
5.1	Characteristics of High-Rise Structures	201
5.1.1	General Characteristics	201
5.1.2	Overall Analysis of Vertical Structures	208
5.2	Design of Shear Wall Structures	210
5.3	Design of Frame Structures	212
5.4	Design of Tube Structures	214

5.5	Design of Mixed Vertical Structures	220
5.5.1	Skip-Floor Truss Structural System	221
5.5.2	Giant Frame Structures	222
5.5.3	Connecting-Tower Structural System	224
5.5.4	Framed Tube Structural System	225
5.5.5	Suspended Core-Tube Structural System	225
5.5.6	Inclined Column Truss Structural System	227
5.6	Comparative Analyses of Milestone High-Rise Buildings	231
5.6.1	Outer Trussed Tube-in-Tube System in Shanghai World Financial Center	231
5.6.2	The World Trade Center in New York, USA	238
5.6.3	Beijing CCTV Tower	244
6	Comparative Design and Analyses of Large-Span Structures	253
6.1	Characteristics of Large-Span Structures	253
6.2	Design for Arch Structural System	256
6.3	Design for Suspension Cable Structural System	266
6.4	Design for Cable-Stayed Structural System	270
6.5	Comparative Analyses of Well-Known Large-Span Structures	272
6.5.1	Shanghai Lupu Bridge	272
6.5.2	Guangxi Nanning Bridge	276
6.5.3	Jiangyin Yangtze River Bridge	286
6.5.4	Gibraltar Strait Bridge	290
6.6	Conclusions	296
7	Comparative Design and Analyses of Spatial Structures	299
7.1	Characteristics of Spatial Structures	299
7.2	Design for Spatial Truss and Grid Structural System	301
7.3	Design for Latticed Shell Structural System	305
7.4	Design for Membrane Structural System	308
7.5	Design for Spatial Deployable Structural System	311
7.6	Comparative Analyses of Sophisticated Spatial Structures	313
7.6.1	Shanghai New International Expo Center	313
7.6.2	Beijing National Center for the Performing Arts	316
7.6.3	The Georgia Dome	320
7.6.4	Kunming Peacock Art Square of World Garden Expo	323
8	Intelligent Design Based on Knowledge Engineering	329
8.1	Introduction of Intelligent Design	329
8.2	Fuzzy-AI Model Applied to Comparative Design	331
8.2.1	The Fuzzy Expression of P_d	331
8.2.2	Fuzzy Reasoning of the Intelligent Design	332
8.2.3	How Fuzzy-AI Model Works in Intelligent Design?	332
8.3	Mathematical Modeling of Design Space	332

8.4	Fuzzy Mathematical Distance in Design Space	334
8.4.1	Fuzzy Mathematical Distance by Membership Difference	334
8.4.2	Fuzzy Mathematical Distance by Nearness Degree	336
8.5	Fuzzy Reasoning and AI-Machine Learning Model	339
8.5.1	AI-Machine Learning Model	339
8.5.2	Machine Learning Modeling	340
8.6	Neural Network Reasoning for Structural Design Parameters	348
8.6.1	Neural Network (NN)	348
8.6.2	Fuzzy Neural Network (Fuzzy-NN).	352
8.6.3	Fuzzy-NN Architecture for Machine Learning	353
8.6.4	Conclusive Remarks	356
8.7	Fuzzy Neural Network Model for Structural Design.	356
8.7.1	Introduction	356
8.7.2	Neural Network Back-Error Propagation Learning.	357
8.7.3	NN Machine Learning for Sample Classification.	357
8.7.4	The Implementation of Fuzzy Machine Learning	358
8.7.5	Fuzzy-NN Machine Learning for Structural Design.	361
	Conclusion	369
	Appendix A	371
	Appendix B	385
	References	401