

Table of contents

Acknowledgements	III
Abstract.....	V
Resumen	VII
Resum.....	IX
Table of contents	XI
List of figures.....	XVII
List of Tables	XXI
Chapter 1. Introduction.....	23
1.1. Background.....	23
1.2. Aims and contributions	24
1.3. Research methodology	25
1.4. Dissertation structure	27
Chapter 2. State-of the-art.....	29
2.1. Box-girder bridges	29
2.2. Heuristic optimization.....	30

2.3.	Aim of sustainability development.....	33
2.3.1.	Life-cycle perspective	35
2.3.2.	Life-cycle Assessment.....	35
2.3.3.	CO ₂ capture	36
2.3.4.	Emission minimization.....	38
2.4.	Multi-objective and decision-making	39
2.5.	Conclusions	41
Chapter 3. Previous studies		43
3.1.	Aim of the studies.....	43
3.2.	Study 1. Life-cycle greenhouse gas emissions of blended cement concrete including carbonation and durability	45
3.3.	Study 2. Optimization of concrete I-beams using a new hybrid glowworm swarm algorithm.....	49
3.4.	Study 3. Cost and CO ₂ emission optimization of precast–prestressed concrete U-beam road bridges by a hybrid glowworm swarm algorithm	51
3.5.	Study 4. Structural design of precast-prestressed concrete U-beam road bridges based on embodied energy	54
3.6.	Study 5. Hybrid harmony search for sustainable design of post-tensioned concrete box-girder pedestrian bridges	57
3.7.	Study 6. A cognitive approach for the multi-objective optimization of RC structural problems.....	62
3.8.	Conclusions	68
Chapter 4. Optimization problem.....		71
4.1.	Aim of the study	71
4.2.	Problem definition	72
4.3.	Parameters	73
4.3.1.	Geometrical parameters.....	73
4.3.2.	Material parameters.....	75
4.3.3.	Loading related parameters	76
4.3.4.	Transport parameters.....	76
4.3.5.	Code related parameters	76
4.4.	Variables.....	77

4.5.	Heuristic algorithm	81
4.5.1.	Harmony search	82
4.5.2.	Multi-objective harmony search	83
Chapter 5.	Objective functions	87
5.1.	Criteria considered for the sustainable design	87
5.2.	Initial design objectives	90
5.2.1.	Economic cost.....	90
5.2.2.	CO2 emissions.....	93
5.2.3.	Overall safety factor objective.....	95
5.2.4.	Corrosion initiation time.....	96
5.3.	Maintenance objectives.....	97
5.3.1.	Economic impact	97
5.3.2.	Environmental impact.....	99
5.3.3.	Societal impact	99
Chapter 6.	Structural analysis and verification	103
6.1.	Bridge analysis.....	103
6.2.	Limit state evaluation.....	105
6.2.1.	Serviceability limit state of deflection	106
6.2.2.	Serviceability limit state of cracking	106
6.2.3.	Ultimate limit state of torsion.....	107
6.2.4.	Ultimate limit state of flexure.....	107
6.2.5.	Ultimate limit state of shear.....	109
6.2.6.	Ultimate limit state of shear between web and flanges.....	109
6.2.7.	Ultimate limit state of transverse flexion.....	109
6.2.8.	Ultimate limit state of transverse shear.....	110
6.2.9.	Ultimate limit state of punching shear.....	110
6.2.10.	Ultimate limit state of fatigue	110
6.2.11.	Geometrical and constructability constraints.....	110
6.3.	Computer support tool	111
Chapter 7.	Multi-objective optimization of cost, CO2 emissions, and safety.....	115
7.1.	Aim of the study.....	115

7.2.	Definition of the problem	116
7.3.	Results	118
7.3.1.	Multi-objective algorithm	118
7.3.2.	Relationship between cost, CO ₂ emissions and safety	120
7.3.3.	Best designs.....	122
7.4.	Conclusions	129
Chapter 8.	Multi-objective optimization of cost, safety, and corrosion time by ANN	131
8.1.	Aim of the study	131
8.2.	Definition of the problem	132
8.3.	Methodology.....	133
8.3.1.	Step 1. ANN training.....	135
8.3.2.	Step 2. Approximate Pareto set.....	136
8.3.3.	Step 3. Updated Pareto set.....	138
8.3.4.	Step 4. Exact Pareto front.....	139
8.4.	Conclusions	143
Chapter 9.	Maintenance lifetime optimization	145
9.1.	Aim of the study	145
9.2.	Definition of the problem	146
9.3.	Methodology.....	147
9.3.1.	Deterioration process.....	149
9.3.2.	Lifetime performance	150
9.3.3.	Design variables	151
9.3.4.	Optimization algorithm	151
9.4.	Results	152
9.5.	Conclusions	158
Chapter 10.	AHP - VIKOR under uncertainty	161
10.1.	Aim of the study	161
10.2.	Methodology.....	162
10.3.	Results	165
10.4.	Conclusions	170

Chapter 11. Conclusions and future work	173
11.1. Conclusions.....	173
11.1.1. General conclusions.....	174
11.1.2. Specific conclusions	175
11.2. Future work.....	176
References	179
Annex I. Author publications	199