

Table of contents

ABOUT THE AUTHORS	XI
LIST OF SYMBOLS	XIII
INTRODUCTION	1
ACKNOWLEDGEMENT	5
1 MATHEMATICAL OPTIMIZATION METHODS	
1.1 Introduction	7
1.2 The genetic algorithm	8
1.2.1 Principle of the genetic algorithm	8
1.2.2 Operators of the genetic algorithm	8
1.3 The Differential evolution technique	11
1.4 The particle swarm algorithm	14
1.4.1 Description of the particle swarm algorithm	15
1.4.2 The three methods	17
1.5 The Leap-frog method	18
1.5.1 The basic dynamic model	19
1.5.2 LFOP: Basic algorithm for unconstrained problems	19
1.5.3 LFOPC: Modification for constrained problems	20
2 COST CALCULATIONS	
2.1 Introduction	21
2.2 Cost elements	22
2.2.1 Material cost	22
2.2.2 Fabrication cost	22
2.2.2.1 Fabrication times for welding	22
2.2.2.2 Fabrication times of post-welding treatments	30
2.2.2.3 Time for flattening plates	31
2.2.2.4 Surface preparation time	31
2.2.2.5 Painting time	31
2.2.2.6 Plate cutting and edge grinding times	31
2.2.2.7 Times of hand cutting and machine grinding of strut ends	33
2.2.2.8 Total cost function	33
2.3 Numerical examples	34
2.3.1 Welded box beam	34
2.3.2 Welded stiffened plate	38
2.3.3 Conclusions	42

3	WELDED BOX AND I-BEAMS	
3.1	Introduction	45
3.2	Minimum weight design of welded box beams with longitudinal stiffeners	47
3.3	Minimum cost design of longitudinally stiffened box beams	49
3.3.1	The cost function	49
3.3.2	Design constraints	51
3.3.3	Optimization and results	51
3.3.4	Conclusions	52
3.4	Optimum design of compressed columns of welded I-section and comparison with rolled profiles	53
3.4.1	Design of compressed I-beam for overall buckling	53
3.4.2	Design of beams for bending	56
3.4.3	Design of beams for combined bending and compression	58
3.4.4	Numerical examples	62
3.4.4.1	Optimum design of compressed columns for overall buckling	62
3.4.4.2	Optimum design of beams under bending for lateral-torsional buckling	64
3.4.4.3	Optimum design of beams compressed and bent simultaneously for overall and lateral-torsional buckling	67
3.4.4.4	Comparison of welded and rolled I-sections	69
3.5	Optimum design and comparison of hollow flange beams	71
3.5.1	Sectional characteristics of a general hollow flange beam	72
3.5.2	General optimum design	74
3.5.3	Triangular flange beam (TFB)	75
3.5.4	Circular hollow flange beam (CFB)	79
3.5.5	Square hollow flange beam (SFB)	81
3.5.6	Welded I-section	82
3.5.7	Lateral-torsional buckling strength	84
3.5.7.1	The EC3 method	84
3.5.7.2	The method of Pi & Trahair (1997)	85
3.5.7.3	Comparison of lateral-torsional buckling factors using the EC3 formulae	86
3.5.8	Conclusions	88
3.6	Optimum fatigue design of welded I-beams with post-welding treatments	88
3.6.1	Improvement of fatigue strength using various PWTs	89
3.6.2	Minimum cost design of a welded I-beam considering the improved fatigue stress range and the additional PWT cost	90
3.6.2.1	The cost function	91
3.6.2.2	Design constraints	92
3.6.2.3	Numerical example	93
4	TUBULAR STRUCTURES	
4.1	Introduction	95
4.2	Circular and square hollow section compression struts made of stainless steels	96
4.2.1	Introduction	96
4.2.2	Problem formulation	97
4.2.3	Limiting slendernesses for local buckling constraints	98
4.2.4	Characteristic data for different types of stainless steels	99
4.2.5	Optimization results for two stainless steels	100
4.2.6	Numerical example	100
4.2.7	Conclusions	101
4.3	Mass and cost savings by changing the height of a parallel chords plane tubular truss	101

4.3.1	Member forces in function of H/a	102
4.3.2	Check of profiles for $w=0.85333$ and 1.3	103
4.3.3	Check of joints for eccentricity	103
4.3.4	Check for chord plastification	104
4.3.5	Comparison of masses and costs	105
4.4	Optimum fatigue design of a uniplanar CHS truss	107
4.4.1	Introduction	107
4.4.2	Problem formulation	108
4.4.3	Design constraints	108
4.4.4	The cost function	112
4.4.5	Mathematical optimization and results	113
4.4.6	Conclusions	114
4.5	Height optimization of a triangular CHS truss	115
4.5.1	Introduction	115
4.5.2	Problem formulation	118
4.5.3	Calculation of member forces	119
4.5.4	Determination of member groups	119
4.5.5	Design constraints	119
4.5.6	The cost function	122
4.5.7	Mathematical minimization and results	124
4.5.8	Conclusions	125
5	SANDWICH STRUCTURES	
5.1	Introduction	127
5.2	Welded cellular plates for ship deck panels	128
5.2.1	Introduction	128
5.2.2	The cost function	129
5.2.3	The design constraints	132
5.2.4	The optimization procedure	135
5.2.5	Conclusions	136
5.3	Five-layer sandwich beams	137
5.3.1	Introduction	137
5.3.2	Bending theory of sandwich beams with thick faces	139
5.3.3	The loss factor of three-layer sandwich beams	141
5.3.4	Objective function and constraints	143
5.3.5	Numerical data and results	146
5.3.6	Conclusions	148
6	FRAMES	
6.1	Introduction	149
6.2	A frame constructed from welded I-bars	150
6.2.1	Introduction	150
6.2.2	Stress constraint for a column	151
6.2.3	Local buckling constraint for the column web	152
6.2.4	Stress constraint for the beam	153
6.2.5	Local buckling constraint for the beam web	153
6.2.6	Local buckling constraint for flanges	153
6.2.7	Computational result	155
6.2.8	Conclusions	156
6.3	A welded tubular frame	157
6.3.1	Problem formulation	157
6.3.2	The cost function	158

6.3.3	Design constraints	159
6.3.4	Numerical data	163
6.3.5	Optimization and results	164
6.3.6	Conclusions	165
6.4	Cost comparison of bolted and welded frame joints	166
6.4.1	Introduction	166
6.4.2	The structural model	162
6.4.3	Design of the beam with welded beam-to-column connections	169
6.4.4	Calculation of rotational stiffness k_i	169
6.4.5	Calculation of stiffness coefficients	169
6.4.6	Cost calculation using suggestions of The Steel Construction Institute (UK)	172
6.4.7	Cost calculation using South African data	174
6.4.8	Conclusions	176
7	WELDED STIFFENED PLATES	
7.1	Introduction	177
7.2	Uniaxially compressed plates with flat, L- or trapezoidal stiffeners	178
7.2.1	Design constraints	179
7.2.2	Formulae for different stiffener chapes	183
7.2.3	Numerical example	186
7.2.4	Conclusions	188
7.3	Square plates subject to uniform normal load	188
7.3.1	Residual welding stresses and distortions	188
7.3.2	Numerical example	190
7.4	Square plates stiffened by edge-parallel or diagonal grid of flat ribs	194
7.4.1	Edge-parallel grid of ribs	194
7.4.2	Diagonal grid of ribs	198
7.4.3	Conclusions	199
7.5	Stiffened plates loaded by hydrostatic normal pressure	200
7.5.1	Introduction	200
7.5.2	Optimum position of horizontal stiffeners	201
7.5.3	Design of stiffeners	203
7.5.4	Numerical example	204
7.5.5	Comparison with vertical stiffeners	206
7.5.6	Conclusions	208
7.6	Longitudinally stiffened plates subject to uniaxial compression and normal load	208
7.6.1	Geometric characteristics of the stiffened plate	209
7.6.2	Calculation of the deflection due to compression and lateral pressure	210
7.6.3	Deflection due to shrinkage of longitudinal welds	211
7.6.4	The stress constraint	212
7.6.5	Numerical data	213
7.6.6	The optimization procedure and results	213
7.6.7	Conclusions	214
8	WELDED STIFFENED CYLINDRICAL SHELLS	
8.1	Introduction	215
8.2	Thickness design of axially compressed unstiffened shells with circumferential welds	215
8.2.1	Introduction	215
8.2.2	Basic formulae for thermal impulse during welding	216
8.2.3	Differential equation of local shell deformation	217
8.2.4	Solution of the differential equation	218
8.2.5	Buckling strength and minimum required thickness according to ECCS	220

8.2.6	Numerical examples	222
8.2.7	Conclusions	223
8.3	Minimum cost design of a ring-stiffened axially compressed cylindrical shell	224
8.3.1	Buckling strength of ring-stiffened axially compressed shells	224
8.3.2	Numerical example	225
8.3.3	Cost calculation	226
8.3.4	Conclusions	229
8.4	Minimum cost design of ring-stiffened shells subject to external pressure	229
8.4.1	Introduction	229
8.4.2	Geometrical characteristics	230
8.4.3	Design constraints	231
8.4.4	Cost function	232
8.4.5	Optimization and results	234
9	STEEL BRIDGE DECKS	
9.1	Introduction	237
9.2	The Pelikan-Esslinger method	238
9.2.1	Deck plates with open ribs	239
9.2.2	Deck plates with closed ribs	240
9.2.3	Effective width of stiffened deck plate	241
9.3	Economic design of bridge deck with open ribs	243
9.3.1	Flexible floor beams	245
9.3.2	Bending moment modification at midspan of ribs	247
9.3.3	Bending moment modification at floor-beam	249
9.3.4	Loading	250
9.3.5	Constraints	250
9.3.5.1	Stress constraints	250
9.3.5.2	Stability constraints	251
9.3.5.3	Fatigue constraints	253
9.3.5.4	Deflection constraint	254
9.3.6	Fabrication cost calculations	255
9.3.7	Numerical example	255
9.4	Economic design of steel bridge decks with closed ribs	257
9.4.1	The live load considered for highway bridges	257
9.4.2	The bending and torsional stiffness of stiffeners	257
9.4.3	The moment of inertia of crossbeams	259
9.4.4	The bending moment in stiffeners at midspan	260
9.4.5	The bending moment in a crossbeam at midspan	261
9.4.6	Fatigue constraint for stiffeners	262
9.4.7	Fatigue constraint for crossbeams	262
9.4.8	Deflection constraints	263
9.4.9	Local buckling constraint for stiffeners	263
9.4.10	Shear buckling constraint for crossbeam web	263
9.4.11	Frequency constraints	264
9.4.12	Size limitations	264
9.4.13	Fabrication times for welding	264
9.4.14	Size limitations	269
9.4.15	Results and conclusions	270
10	A TRUCK FLOOR WELDED FROM ALUMINIUM ALLOY PROFILES	
10.1	Introduction	273
10.2	Load cases	273

10.2.1	Loads in the horizontal floor position	273
10.2.2	Loads on the distorted floor	275
10.3	Geometric characteristics of cross members	276
10.4	Design constraints	277
10.4.1	Constraints on fatigue stress range for horizontal floor position	277
10.4.2	Constraint on fatigue stress range for distorted floor position	277
10.4.3	Constraints on local buckling of profiles	278
10.4.4	Fabrication constraints: size limitations	278
10.5	Optimization characteristics and results	279
10.6	Mass savings	279
10.7	Cost savings	280
10.8	Conclusions	281
11	A WELDED PUNCH PRESS FOR LIGHT INDUSTRY	
11.1	Introduction	283
11.2	Constraints on stiffness and fatigue stress range	283
11.3	Verification of the original table beam	285
11.3.1	Local deflection of the upper flange plate	285
11.3.2	Deflection of the whole box beam	285
11.3.3	Fatigue of welded joints	286
11.3.4	Local deformation of inner stiffeners in the upper flange	286
11.3.5	Outer stiffeners of the upper flange	289
11.3.6	Cost calculation	289
11.4	Optimum design of a new structural version	290
11.4.1	Thickness of the upper flange plate t_{f1}	290
11.4.2	Design of thicknesses t_{w1} and t_{f2}	291
11.4.3	Thicknesses of inner stiffeners t_1 and t_2	291
11.4.4	Thicknesses of outer stiffeners t_{w2} and t_3	292
11.4.5	Cost calculation	293
11.5	Conclusions	293
12	BUNKERS CONSTRUCTED FROM WELDED STIFFENED PLATES	
12.1	Introduction	295
12.2	Optimum positions and number of horizontal stiffeners of bin walls	297
12.3	Optimum number of horizontal stiffeners of hopper walls	301
12.4	Optimum design of transition beams	303
12.5	Vertical edge beams of the bin	305
12.6	Design of columns	305
12.7	Calculations of the total cost of the bunker of $H/a = 1$	306
12.8	The optimum H/a -ratio	307
12.9	Conclusions	309
	APPENDIX TO CHAPTER 1	311
	REFERENCES	313
	NAME INDEX	333
	SUBJECT INDEX	337