Table of Contents

Item	Title	Page
	List of Tables	V
	List of Figures	VII
Chapter 1	INTRODUCTION	1
1.1	General	2
1.2	Thesis Overview	3
Chapter 2	LITERATURE REVIEW	5
2.1	General	6
2.2	Manufacturing of laminated section	6
2.2.1	Hand lay-up technique	6
2.2.2	Calendar technique	7
2.2.3	Prepreg technique	8
2.2.4	Pultrusion technique	9
2.3	Overall FRP properties	11
2.4	Mechanical behavior of thin-walled laminated composite	
	beams and columns	11
2.5	Local buckling	14
2.6	Interaction between local and global buckling	17
2.7	Euler - Overall – buckling	18
Chapter 3	COMPOSITE MATERIAL	23
3.1	General	24
3.2	Lamina properties	24
3.2.1	Assumptions	24
3.2.2	Physical properties of material	25
3.2.3	Strength and failure	29
3.2.3.1	Axial tensile strength	29
3.2.3.2	Axial compressive strength	30
3.2.3.3	Matrix mode strength	31
3.2.3.4	Strength under combined stress	32
3.3	Laminates analysis	34
3.3.1	Stress-strain relations of lamina	34
3.3.2	Theory of lamination	40
3.3.3	Properties of laminate	46
3.3.3.1	Membrane stresses	46
3.3.3.2	Bending	49
3.3.4	Stress analysis of laminate	50
3.3.4.1	Stress – Strain relationship	50

Item	Title	Page
3.3.4.2	Netting analysis	51
3.3.5	Strength and failure modes of laminate	53
3.3.5.1	Sequential ply failure approach	53
3.3.5.1.1	Initial ply	53
3.3.5.1.2	Subsequent failures	56
3.3.6	Laminate failure approach	56
Chapter 4	BUCKLING - STABILITY	58
4.1	General	59
4.2	Plate buckling and crippling	59
4.2.1	Stacking sequence effects in buckling	59
4.3	Columns buckling load	59
4.3.1	Introduction	59
4.3.2	Buckling equations	60
4.3.3	Empirical FRP column buckling load equation under	
	axially Compression loading	65
4.3.3.1	Assumptions	64
4.3.3.2	Out-of-Straightness	65
4.3.3.3	Material properties	65
4.3.3.4	Buckling load equation	66
4.3.3.5	Design guidelines for FRP composite axially loaded	
	members in which global buckling limit state controls	67
4.3.4	Imperfection sensitivity equation	68
4.3.4.1	Failure start	69
4.3.4.2	Continuum damage model	71
4.3.4.3	Explicit formula	72
Chapter 5	ANALYSIS & MODEL VERIFICATION	77
5.1	Introduction	78
5.2	Plate physical properties	78
5.3	Buckling failure mode	82
5.4	Theoretical working plan	83
5.5	Assumptions	85
5.6	Finite elements analysis program	85
5.7	Element assumptions and restrictions	86
5.8	Model verification	87
5.9	Column models description	89
5.10	Column buckling analysis	89
5.10.1	"H" shape column – preliminary study	90
5.10.1.1	Model characteristics	90
5.10.1.2	Model analysis	91
5.10.1.2.1	Model 1: Investigation of different layers layout	91

combinations 5.10.1.2.2 Check for the initial imperfection different values and	
5.10.1.2.2 Check for the initial imperfection different values and	
·	
direction	99
5.10.1.2.2.1 Model 2: Stated values of initial imperfection toward the	
minor axes effect	99
5.10.1.2.2.2 Model 3: Initial imperfection directions (toward minor	
and major axes) effect	99
Chapter 6 ANALYSIS	101
1	102
	102
\mathcal{E}	102
	102
	102
,	104
ϵ	104
\mathcal{E}	113
6.2.1.2.3 Model 3: Buckling behavior of fixed-hinged end	111
	114
6.2.1.2.4 Model 4: Buckling behavior of fixed-fixed end	117
	117
6.2.1.2.5 Model 5: Buckling behavior of fixed-free end conditions	440
	118
1	121
	121
3	122
6.2.2.2.1 Model 1: Investigation of minor global column's axes	
	122
6.2.2.2.2 Model 2: Buckling behavior around the major axes	
6.2.2.2.3 Model 3: Buckling behavior of fixed-hinged end	
conditions column	
6.2.2.2.4 Model 4: Buckling behavior of fixed-fixed end	
conditions column	
6.2.2.2.5 Model 5: Buckling behavior of fixed-free end conditions	
column	
6.2.3 Square tube shaped column	127
	127
	128
6.2.3.2.1 Model 1: Investigation of minor global column's axes	-
	128
6.2.3.2.2 Model 2: Buckling behavior of fixed-hinged end	0
	136

Item	Title	
6.2.3.2.3	Model 3: Buckling behavior of fixed-fixed end	
	conditions column	136
6.2.3.2.4	Model 4: Buckling behavior of fixed-free end conditions	
	column	137
6.2.4	Rectangular tube shaped column	
6.2.4.1	Model characteristics	
6.2.4.2	Model analysis	
6.2.4.2.1	Model 1: Investigation of minor global column's axes	
	buckling for different (0/90)° layers layout combinations	139
6.2.4.2.2	Model 2: Buckling behavior around the major axes	
6.2.4.2.3	Model 3: Buckling behavior of fixed-hinged end	
	conditions column	
6.2.4.2.4	Model 4: Buckling behavior of fixed-fixed end	
	conditions column	
6.2.4.2.5	Model 5: Buckling behavior of fixed-free end conditions	
	column	
6.2.5	Rectangular tube with internal web shaped column	149
6.2.5.1	Model characteristics	149
6.2.5.2	Model analysis	150
6.2.5.2.1	Model 1: Investigation of minor global column's axes	4 = 0
	buckling for different (0/90)° layers layout combinations	150
6.2.5.2.2	Model 2: Buckling behavior around the major axes	
6.2.5.2.3	Model 3: Buckling behavior of fixed-hinged end	
60504	conditions column	
6.2.5.2.4	Model 4: Buckling behavior of fixed-fixed end	
() [) [conditions column	
6.2.5.2.5	Model 5: Buckling behavior of fixed-free end conditions	
	column	
Chanton 7	EMPIRICAL EQUATION	159
Chapter 7 7.1	Introduction	160
7.1	Empirical load failure equation	160
7.3	"H" shape study Load failure empirical equation	161
7.4	Buckling empirical equation for square tube section	101
/. T	columns	167
7.5	Buckling empirical equation for rectangle tube section	107
1.5	columns	169
7.6	Buckling empirical equation for box with stiffeners	10)
7.0	section columns	171
	Section Columns	1/1
Chapter 8	CONCLUSIONS AND RECOMMENDATIONS	173
8.1	Summary	174

Item	Title	Page
8.1.1	Summary of literature review	174
8.1.2	Summary of this study	175
8.2	Conclusions	176
8.2.1	Plates	176
8.2.2	Columns	177
8.3	Recommendations	178
	References	180