

Table of Contents

Acknowledgements	ix
Abstract	x
Table of Contents	iii
List of Figures	vii
List of Tables	xiv
List of Symbols	xv
Chapter 1 Introduction	1
 Chapter 2 Literature review	 5
 2.1 Introduction	 5
2.2 High Strength Concrete	6
2.2.1 Development	6
2.2.2 Stress-Strain Behavior	6
2.3 Fibers Reinforced Concrete	7
2.3.1 Types of Fibers	7
2.3.2 Fibers Content and Shape	7
2.3.3 Fibers Reinforced Concrete Properties in the Fresh Case	8
2.3.4 Mechanical Properties of FRHSC	8
2.4 High Strength Concrete Columns under Cyclic Loads	10
2.5 Confinement of Concrete Columns	19
2.5.1 American Concrete Institute (ACI 318-08)	19
2.5.2 American Association of State Highway and Transportation Officials (AASHTO)	20
2.5.3 California Department of Transportation (CALTRANS)	20
2.5.4 ATC-32 Method	21
2.5.5 Paulay and Priestley (1992)	22

2.5.6 New Zealand Code	23
2.5.7 Wehbe <i>et al.</i> (1999)	24
2.5.8 Sheikh and Khoury (1997)	25
2.5.9 Ho and Pam (2003)	26
2.6 Confined HSC Stress Strain Models	26
2.6.1 Mander <i>et al.</i> Model (1984)	27
2.6.2 Young <i>et al.</i> Model (1988)	28
2.6.3 Aziznamini <i>et al.</i> Model (1994)	29
2.6.4 Li <i>et al.</i> Model (1994)	30
2.6.5 Cusson and Paultre Model (1994)	30
2.6.6 Razvi and Saatcioglu Model (1999)	32
2.6.7 Bing <i>et al.</i> Model (2001)	35
2.6.8 El-dash and El-mahdy Model (2006)	36
2.6.9 Akiyama <i>et al.</i> Model (2010)	38
 Chapter 3 Experimental Work	 45
3.1 Introduction	45
3.2 Material Properties	45
3.2.1 Concrete	46
3.2.1.1 Fine Aggregate	46
3.2.1.2 Coarse Aggregate	46
3.2.1.3 Cement	46
3.2.1.4 Cement Replacement Material	47
3.2.1.5 Super-Plasticizer	47
3.2.1.6 Mixing water	48
3.2.1.7 Steel Fibers	48
3.3 Concrete Mix Design	48
3.4 Reinforcing Steel	49
3.5 Specimens Preparation	49
3.5.1 Shuttering	49

3.5.2 Concrete Mixing	49
3.5.3 Concrete Casting	50
3.6 Test Specimens	50
3.7 Test setup	51
3.8 Instrumentation	51
3.9 Test Procedures	52
3.10 Variation in the Column Axial Load	53
 Chapter 4 Test Results and Discussion	 66
4.1 General Behavior	66
4.2 Cracking Behavior	68
4.3 Mode of Failure	69
4.4 Load Displacement Hysteresis Loops	71
4.5 Moment Curvature Hysteretic Response	73
4.6 Strains in Vertical and Transverse Reinforcement	74
4.7 Significance of Test Results	75
4.7.1 Ductility	75
4.7.2 Drift Ratio	77
4.7.3 Strength Decay	78
4.7.4 Stiffness Degradation	79
4.7.5 Energy Dissipation	81
 Chapter 5 Analysis of Test Results	 115
5.1 Steel Fibers Content	115
5.2 Concrete Compressive Strength	117
5.3 Axial Load Level	120
5.4 Yield Strength of Transverse Reinforcement	123
5.5 Confinement Index	124

Chapter 6 Non-Linear Finite Elements Analysis	134
6.1 Non-Linear Finite Elements Model	134
6.1.1 Idealization of Columns	134
6.1.2 Material Model for Concrete	135
6.1.2.1 Compressive Strength of Fibers Concrete	137
6.1.2.2 Proposed Model for Confined FRC	138
6.1.3 Material Model for Steel Reinforcement	143
6.1.4 Material Model for FRC	144
6.1.5 Analytical Procedure	145
6.2 Model Verification	145
6.2.1 Cracking Load	146
6.2.2 Ultimate Capacity	147
6.2.3 Load Displacement Hysteresis Envelopes	147
Chapter 7 Behavior of HSC Columns under Cyclic Loading	164
7.1 Parametric Study	164
7.1.1 Steel Fibers Content	164
7.1.2 Concrete Compressive Strength	166
7.1.3 Axial Load Level	169
7.1.4 Confinement Index	171
7.1.5 Yield Strength of Transverse Reinforcement	174
7.1.6 Longitudinal Steel Reinforcement	175
7.1.7 Slenderness Ratio	176
7.2 Confinement Requirements for Seismic Design of HSC Columns	177
Chapter 8 Conclusions	229
References	234