

CONTENT

Content	i
List of Figures	v
List of Table	x
Notations	xi
Acknowledgement	xiii
Abstract	xiv
Chapter 1 Introduction	1
Chapter 2 Literature Review	4
2.1 Introduction	4
2.2 FRP Composites: Development and Characteristics	4
2.3 Mechanisms of Shear Transfer	6
2.3.1 Shear Stress in Uncracked Concrete	7
2.3.2 Interface Shear Transfer	8
2.3.3 Dowel Action	8
2.3.4 Residual Tensile Stress across Cracks	8
2.4 Shear Friction Hypothesis	9
2.5 Behavior of Reinforced Concrete Corbels	10
2.5.1 Experimental Research Work	11
2.5.2 Methods of Shear Strength Analysis	16
2.5.2.1 Method of John, C. <i>et al.</i> [35]	16
2.5.2.2 Mattock Design Procedure [25]	18
2.5.2.3 Walraven Design Procedure [37]	18
2.5.2.4 Hagberg Design Method [41]	20
2.5.2.5 Method of Steinle [43]	23
2.5.2.6 Method of Campione [44]	25
2.5.2.7 Method of Ali, M. A. [45]	28
2.5.2.8 Method of Siao [46]	29
2.5.3 Non Linear Finite Elements Investigations	30

2.6 Building Codes Procedures	32
2.6.1 ECP-203 Procedure [21]	33
2.6.2 ACI-318 Procedure [47]	34
Chapter 3; Experimental Work	37
3.1 General	37
3.2 Material Characteristics	37
3.2.1 Concrete	38
3.2.1.1 Aggregate	38
3.2.1.2 Cement	38
3.2.1.3 Mixing Water	38
3.2.1.4 Admixtures	41
3.2.1.5 Concrete mix proportions	41
3.2.2 Reinforcing Steel	41
3.2.3 Carbon Fiber Reinforced Polymer	43
3.2.4 Epoxy	43
3.3 Test Specimens	43
3.3.1 Shuttering	45
3.3.2 Concrete Mixing	48
3.3.3 Concrete Casting, Compaction and Curing	48
3.3.4 Preparation of Specimen Surface	49
3.3.5 Application of the CFRP	49
3.4 Test Specimens: Strengthening Configurations	50
3.5 Test Procedures and Measurements	50
Chapter 4; Test Results and Discussion	58
4.1 General Behavior of Corbels Specimens	58
4.1.1 Specimen C1	58
4.1.2 Specimen C2	59
4.1.3 Specimen C3	64
4.1.4 Specimen C4	64

4.1.5 Specimen C5	67
4.2 Comparison of Test Results	72
4.2.1 Cracking	72
4.2.2 Mode of Failure	74
4.2.3 Ultimate Capacity	74
4.2.4 Deformations and Strains	76
 Chapter 5; Shear Analysis of Strengthened Corbels	 81
5.1 Non Linear Finite Elements Analysis	81
5.1.1 ANSYS 8.0 Computer Code	81
5.1.1.1 Modeling of Strengthened Corbels	82
5.1.1.2 3-D Reinforced Concrete Solid; Solid65	82
5.1.1.2.1 Concrete behavior	82
5.1.1.2.2 Failure criteria for concrete	84
5.1.1.3 LINK8 3-D Element	87
5.1.1.4 Elastic Shell, SHELL63	88
5.1.2 Non-Linear Analysis of Test Specimens	89
5.1.2.1 Cracking Behavior	89
5.1.2.2 Ultimate Load-Carrying Capacity	92
5.1.2.3 Strains and Deformations	92
5.2 Methods of shear analysis	97
5.3 Parametric study	101
5.3.1 Methods of Corbel Strengthening	101
5.3.1.1 Corbel Strengthened using CFRP Fabrics	102
5.3.1.2 Corbel Strengthened using Steel Sheets	116
5.3.2 Corbel Design Parameters	119
5.3.2.1 Concrete Compressive Strength	119
5.3.2.2 Horizontal Reinforcement	123
5.3.2.3 Flexural Steel Reinforcement	125
5.3.3 Shear Span to Depth Ratio	127

5.3.4 Assessment of ECP-203 Prediction	136
Chapter 6; Conclusion	139
References	143