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**EFFECT OF BENDING AND SHEAR ON THE
TORSIONAL FRP STRENGTHENING EFFICIENCY OF
REINFORCED CONCRETE BEAMS**

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ABSTRACT

This research presents an experimental-analytical investigation in the structural behavior of RC fixed-fixed beams strengthened to resist torsion stresses by different schemes of strengthening using CFRP sheets as phase one, as well as investigation of the effect of the change in the longitudinal steel ratio and vertical steel ratio on the resistance of torsion of Beams strengthened with CFRP as phase two. The experimental program consisted of statically testing five medium scale specimens for phase one as well as ten specimens with the same dimensions for phase two. The beams had 150x300 mm rectangular cross-sectional dimensions with overall length of 2000mm over a clear span of 1500 mm. The tested specimens were divided into two phases; phase one consists of one group of beams the first beam (B1) was a control beam while the other four beams (B2,B3,B4,B5) were strengthened in different schemes with CFRP to resist torsion. Phase two consists of three groups of beams each of them discuss the effect of a parameter on the torsional efficiency of RC strengthened beams. The comparison will always take place with beam B1 as a control beam and Beam B3 as the best scheme as concluded from phase one. The latter studies are suggested to aim at developing design oriented guidelines concerning the behavior of RC beams strengthened in torsion by FRP sheets.

LIST OF CONTENTS

CHAPTER 1

1.1 BACKGROUND	1
1.1.1 COMPOSITION OF ADVANCED COMPOSITE MATERIALS (FRPs)	2
1.1.2 MECHANICAL PROPERTIES OF FRPs	2
1.1.3 ADVANTAGES OF FRPs	3
1.1.4 DISADVANTAGES OF FRPs	4
1.1.5 TYPES OF FRPs PRODUCTS	4
1.2 TORSIONAL STRENGTHENING OF BEAMS	5
1.3 OBJECTIVES	7
1.4 SCOPE OF WORK	7

CHAPTER 2

2.1 REVIEW OF LITERATURE	1
2.2 LITERATURE REVIEW ON TORSIONAL STRENGTHENING OF RC BEAMS	3
2.3 OBSERVATION FROM THE LITERATURE	12
2.4 OBJECTIVE AND SCOPE OF THE PRESENT WORK	12

CHAPTER 3

3.1 EXPERIMENTAL STUDY	1
3.1.1 PHASE ONE	1
3.1.2 PHASE TWO	2
3.2 MATERIALS	3
3.2.3 FIBER REINFORCED POLYMER (FRP)	7
3.3 DESIGN MIX	9
3.4 CASTING OF BEAMS	10
3.5 STRENGTHENING OF BEAMS	12

3.6 EXPERIMENTAL SETUP	13
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CHAPTER 4

4.1 INTRODUCTION	1
4.2 TEST OBSERVATIONS AND BEAM BEHAVIOR	2
4.2.1 PHASE ONE	2
4.2.1.1 CONTROL BEAM (B1)	3
4.2.1.2 BEAM (B2)	4
4.2.1.3 BEAM (B3)	5
4.2.1.4 BEAM (B4)	6
4.2.1.5 BEAM (B5)	7
4.2.1.6 COMPARISONS AND DISCUSSIONS OF THE EXPERIMENTAL RESULTS IN PHASE ONE	8
4.2.2 PHASE TWO	12
4.2.2.1 GROUP ONE	12
4.2.2.2 GROUP TWO	14
4.2.2.3 GROUP THREE	17
4.2.2.4 COMPARISONS AND DISCUSSIONS OF THE EXPERIMENTAL RESULTS IN PHASE TWO	19
4.3 EFFECT OF PERCENTAGE OF LONGTUDINAL STEEL AND STIRRUPS ON THE STRENGTHENING EFFICIENCY	23

CHAPTER 5

5.1 INTRODUCTION	1
5.2 FINITE ELEMENT FORMULATION	3
5.2.1 FINITE ELEMENT METHOD	4
5.2.2 SOLUTION STRATEGY	9
5.2.3 SOLUTION OF NONLINEAR EQUATIONS IN ABAQUS	11

5.2.3.1	NONLINEAR SOLUTION METHOD	11
5.2.3.2	INCREMENTS, AND ITERATIONS	12
5.2.3.3	CONVERGENCE OF THE LINEAR SYSTEM OF EQUATIONS	13
5.2.1	THE RIKS METHOD	17
5.2.4.1	OVERVIEW	17
5.2.4.2	UNSTABLE RESPONSE	18
5.2.4.3	ENDING A RIKS ANALYSIS STEP	19
5.2.4.4	MODIFIED RIKS ALGORITHM	20
5.3	FE MODELS	23
5.4	MODELING PARAMETERS	23
5.4.1	ELEMENTS USED	24
5.4.1.1	GENERAL	24
5.4.1.2	SOLID ELEMENTS	25
5.4.2	MATERIAL MODELS	29
5.4.2.1	GENERAL	29
5.4.2.2	CONCRETE MATERIALS	30
5.4.2.2.1	COMPRESSIVE BEHAVIOR	30
5.4.2.2.2	IDEALIZED UNI-AXIAL COMPRESSIVE STRESS-STRAIN CURVE	32
5.4.2.2.3	TENSILE BEHAVIOR	33
5.4.2.2.4	FAILURE RATIOS	34

5.4.2.2.5 CONCRETE SMEARED CRACKING MODEL	35
5.4.2.2.6 TENSION STIFFENING AND POST CRACKING BEHAVIOR	36
5.4.2.3 STEEL REINFORCEMENT	39
5.4.3 MESH CONFIGURATION	40
5.4.3.1 CONCRETE MESH	40
5.4.3.2 REINFORCEMENT MESH	42
5.4.4 BOND BETWEEN CONCRETE AND STEEL REINFORCEMENT	42
5.4.5 LOADING AND BOUNDARY CONDITIONS	45
5.4.5.1 LOADING CONDITIONS	45
5.4.5.2 BOUNDARY CONDITIONS	45
5.5 COMPARISON BETWEEN EXPERIMENTAL AND ANALYTICAL RESULTS	46
5.6 MODEL VALIDITY	50
5.7 PARAMETRIC STUDY	51

CHAPTER 6

6.1 INTRODUCTION	1
6.2 CONCLUSIONS	1
6.3 RECOMMENDATIONS FOR FUTURE RESEARCH WORK	5

STATEMENT

This thesis is submitted as partial fulfillment of the requirements for the degree of Doctor of Philosophy in Civil Engineering (Structures), Faculty of Engineering, Ain Shams University.

The author carried out the work included in this thesis, and no part of it has been submitted for a degree or a qualification at any other scientific entity.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

For years, civil engineers have been in search for alternatives to steel and alloys to combat the high costs of strengthening and maintenance of structures. Since the 1940, composite materials, formed by the combination of two or more different materials in a microscopic scale, have gained increasing popularity in the engineering field. Fiber Reinforced Polymer (FRP) is a relatively new class of composite material manufactured from fibers and resins and has proven efficiency for strengthening of new and deteriorating structures, respectively. The mechanical properties of FRP make them ideal for widespread strengthening applications in construction as demonstrated in figure 1.1. However these materials are characterized by some disadvantages that might affect their efficiency and behavior in the construction industry. Among these disadvantages, such as weak fire resistance, two main defects are the most critical in structural applications. Those are typically the low modulus of elasticity as well as the linear-

elastic tensile stress-strain relationship up to failure. In this respect, while the former property results in large deflections, the latter one would raise many causes of brittle failure and lack of ductility in concrete members.

1.1.1 COMPOSITION OF ADVANCED COMPOSITE MATERIALS (FRPs)

Fiber Reinforced Polymer (FRPs) is a relatively new class of composite material manufactured from fibers and resins. Fiber Reinforced Polymer (FRP) composites is defined as a polymer (plastic) matrix, either thermoset or thermoplastic, that is reinforced (combined) with fibers with sufficient aspect ratio (length to thickness) to provide a discernible reinforcing function in one or more directions. The resin is the glue that holds the composite together and influences the physical properties of the end product.

1.1.2 MECHANICAL PROPERTIES OF FRPs

All fibers have generally higher tensile strength than ordinary steel and are linear elastic until failure. The most important properties that differ between the fiber types are the Young's modulus and tensile strain. The tensile characteristics