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Study the Mechanical Properties of Steel tube Reinforced by Composite Materials

A Thesis Submitted to the Council of the College of Engineering, University of Diyala in Partial Fulfillment of the Requirements for the Degree of Masters of Science in Mechanical Engineering

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بسم الله الرحمن الرحيم

﴿رَبِّ هَبْ لِي حُكْمًا وَأَلْحِقْنِي بِالصَّالِحِينَ﴾

صدق الله العظيم

سورة الشعراء: (83)

CERTIFICATION

I certify that the thesis entitled "**Study the Mechanical Properties of Steel tube Reinforced by Composite Materials**" was prepared by "**Ream Husam Ahmed**" under my supervision at the Department of Mechanical Engineering, College of Engineering, Diyala University in a partial fulfillment of the requirements for the Degree of **Master of Science in mechanical engineering.**

Signature:

Supervisor: **Asst. Prof. Dr. Ekhlas Edan**

Date: / /

In view of the available recommendation, I forward this thesis for debate by the examining committee.

Signature:

Name:

Head of the Department of Mechanical Engineering

Date: / /

DEDICATION

THIS WORK IS DEDICATION WITH
ALL MY LOVE AND RESPECT TP MY:

Mr. Sahib Khudair Ajaj

All the love to:
(Mr. Ahmed Habib)

Dear father

Dear mother

Belover husband (Engineer Bassam Sahib)

My children (Tim and Kanz)

My family

Lovely friends

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Ream

ABSTRACT

When exposed to compression and bending stresses, hollow structural members are extremely sensitive structural elements. To safely sustain both service static loads, steel hollow tube members must be strengthened. This study focused on the experimental verification of circular hollow sections of steel of different thicknesses and wrapped with glass fibers and carbon or glass and carbon at different angles 0° and 90° under bending and compression loading. Twelve samples were examined for buckling and 12 of them for bending with thicknesses of 2 mm and 3 mm. The results obtained indicated that the column with the largest thickness of 3 mm and wrapped with two layers of glass and carbon at an angle of carbon 90° bears a greater load than the rest of the samples because (FRP) it is responsible for increasing the axial capacitance of the hollow steel samples and where it can be Using this method to improve the performance of hollow steel sections.

Critical buckling loads showed an increment of 35 % using two layers of Carbon and glass fibers in 2mm steel. The Same behavior was noticed using 3mm Composite tubes. Experimental results of 2mm tube compression test showed a 20% enhancement in Max stress with a 56% reduction in strain when a layer of glass and carbon were. Changing the tube thickness to 3mm showed an increase in applied loads of 70 % while a decrease of 64 % in strain where Ɵ=0.

Analyzing bending test showed a reduction of 77% in strain with an increase in applied load of 62%.

To explore the failure of Composite tubes, failure mode was studied.

2mm steel tube showed an elephant foot buckling at the tube upper region.

Considering 3mm tube elephant foot was noticed at the top with pulled and rupture of glass fiber in the upper region.

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LIST OF ABBREVIATIONS

Abbreviation	Description
Cc	Column constant
CFRP	Carbon fiber-reinforced polymers
CMC	Ceramic matrix composite
F. E.	Finite element method
FRP	Fiber reinforced Polymer
GFRP	Glass fiber-reinforced polymers
MMC	Metals matrix composite
PMC	Polymer matrix composite
SR	Slenderness ratio
S1	Steel tube 2mm thickness
S2	Steel tube 3mm thickness
C1	Carbon fiber ϴ=0
C2	Carbon fiber ϴ=90°
G	Glass fiber
GC1	Glass-Carbon fibers ϴ=0
GC2	Glass-Carbon fibers ϴ=90

LIST OF SYMBOLS

Symbols	Term	Units
P_{cr}	Critical applied load	N
A	Cross- sectional Area	mm^2
c	Half of the specimen width	mm
D_{in}	Inner diameter	mm
D_o	Outer diameter	mm
E	Young's Modulus	GPa
I	Moment of Inertia of Beam	mm^4
K	End-fixity factor	---
L	Actual length	mm
Le	Effective length	mm
M	Internal Bending Moment	N.mm
P	Applied load	N
r_g	radius of gyration	mm
t	Thickness of Sample	mm
v	Poisson Ratio	---
λ	Slenderness Ratio	---
δl	Change in length	mm
σ	Stress	MPa
ϵ	Strain	---
d_I	Inner diameter of deformed section at mid span in lateral direction	mm
dv	Inner diameter of deformed section at mid span in vertical direction	mm

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Chapter One

Introduction

Chapter One

Introduction

1.1 Background

A composite material is defined as one that is composed of two or more materials and that, when used alone, exhibits superior qualities than the separate components. Each substance keeps its own chemical, physical, and mechanical characteristics, unlike metallic alloys.

Based on the form of matrix material, composite structures can be divided into three types [1]:

1. Polymer matrix composite (PMC) is a term that is used to describe a material that is made up of many different polymers.
2. Composite made of metals as matrix (MMA)
3. Ceramic matrix composite (CMC)

The benefits of composite materials include their superior weight-to-strength ratio, corrosion resistance, electromagnetic inertness, high ratio of stiffness to weight, and fatigue resistance [2].

Fiber and matrix are the two basic components of laminated composite. The reinforcing agent that contributes most to the strength and stiffness of composites is characterized as fibers. The matrix, on the other hand, can be thought of as the binder that binds the fibers together, disperses the load, and safeguards the fibers from chemical and environmental assaults. A laminated composite material is made up of a stack of laminas stacked in various directions, with each lamina being characterized as a thin, flat or curved layer of unidirectional fibers or woven fabric in a matrix that functions as an orthotropic material. In general, the laminated composite material will exhibit anisotropic behavior as a result of the differences in the material's characteristics in each direction.

The usage of laminated composite materials has increased over the last several decades in a variety of industrial applications, including aerospace engineering, marine engineering, automotive engineering, and civil engineering. As a result, there is a growing need to comprehend the mechanical behavior of laminated composite. Some of the concerns that required investigation were stability (i.e. buckling) problems before collapse. Anisotropic laminated composite member buckling has received scant attention in the literature. However, sufficient study has been done to forecast how cylinders, shells, plates, and beams would behave in terms of stability [2].

Failures because of the instability phenomena can occur suddenly and may cause the whole structure to breakdown. It’s therefore in the engineer’s interest to have good knowledge about this phenomenon. Column buckling is one of the most common examples of instability phenomena [3].

The buckling phenomenon is characterized by structural elements bending under an axial compressive force. The thin elements known as columns support the axial compressive load. A column might collapse if the compressive load is too great owing to buckling, a structural instability. Consequently, the issue of the columns' buckling is a crucial one. Underestimating this impact might have devastating consequences or unnecessary safety considerations [4].

Any system that has a chance of slightly deviating from the equilibrium configuration is considered stable. This possibility may be provided by a degree of mechanical freedom that is more or less constrained, in which case the issue is one of static stability and is essentially unaffected by the propensity that any actual body exhibits to deform when applied forces; or it may be caused, more or less entirely, by this propensity [5].

In the latter situation, the issue is one of elastic stability, and other approaches must be taken. However, there is no fundamental difference between the two types, with most mechanical systems' stability only depending on the relative sizes of its constituent parts [5].

However, researcher [6] pointed out that under compressive stress, instability of buckling is likely to happen and limits the success of the service performance or forming process. Thus, it is crucial and extremely important to have a thorough grasp of the buckling process and behavior. Instability is the phenomena on a physical level where a structure shifts a transition from one equilibrium to another, or an unstable condition. This secondary equilibrium path, also known as the bifurcation path, is what Liu et al. [7] the situation where the structure deviates from the basic equilibrium course ((beginning with no force).

Steel tubes blanks may exhibit instability axisymmetric, diamond instability, Euler instability, instability of barrel, and mixed axisymmetric and so on, under axial compression. When the tube blank's thickness in comparison (the diameter to plate thickness ratio) exceeds 0.02 and it has good homogeneity, axisymmetric instabilities will become evident. Jones and Karagiozova [8] specifically drew attention to the fact that the tube's blank end was in touch with the die to uniformly swell and shrink, folding into a corrugated tube shape. According to Abbas et al. [9], after buckling takes place, as the load decreases, the matching maximum force may be used as the crucial value P_{cr} to determine maybe buckling has taken place or not. Therefore, it is crucial to understand how to anticipate the critical buckling force properly [10]. The ability to understand and manipulate materials has been fundamental to our technical development over time.

Today scientists and engineers recognize the importance of in nova-tive materials use for economic and environmental reasons. Functionally graded materials (FGMs) are advanced engineering materials designed for a specific performance or function in which a spatial gradation in structure and/or composition lend itself to tailored properties. This occurs by providing in-depth graded com-positions, microstructures and properties. FGMs are not new to Nature. Similar to many other man-made materials, function-ally graded natural materials such as bamboo have been used for thousands of years in decorating and construction [11].

1.2 Buckling

A structural component buckles when it undergoes an abrupt change in form under pressure, such as when a column bows under compression or a plate wrinkle under shear. A portion may abruptly change shape when a structure is subjected to a load that is gradually increasing; this is called as buckling [12].

Even if the strength that occur in the structure are smaller than those necessary to cause failure in the metal wherein the building is formed, may buckling occur. Additional stress might cause significant, unexpected deformations that could eventually prevent the part from bearing load. Whether the distortion that press buckling do not cause the structure to totally breakdown, the structure can still sustain the load that led it to buckle. Some airplanes are made so that thin skin panels can sustain load even when they are buckled [13].

1.3 Bending

In fundamental mechanics, bending (also called as flexure) describes how a thin structural element responds to a load that is applied perpendicular to the element's longitudinal axis.

Several steel buildings have bended, including in 1907 in Canada the Quebec Bridge, in 1978 in the United States the Hartford Gymnasium, and in 2008 in south China the steel power transmission towers accident. One of the key failure types that commonly occurred, causing both significant financial losses and substantial deaths, was this one. In China, the development of steel constructions, especially those that are lightweight, is extremely rapid. There are several unsafe constructions margins in terms of potential for stability, some of which may result in unstable failure accidents, as a result of people's inexperience or excessive pursuit of economy; meanwhile, many structures lack sufficient bearing capacity because of the increasing imposed load, construction inaccuracy, damage of corrosion, and other factors. Steel structure strengthening is important as the steel building industry develops [14].

Due to a number of factors, composites are particularly well suited for this objective [15]:

i. Extremely high ratios of stiffness to weight and strength to weight
ii. Exceptional toughness in hostile circumstances.

A structural part's performance, specifically, its rigidity, capacity for weight, toughness, and fatigue behavior under cyclical loadings has been demonstrated to be greatly improved by the inclusion of externally bonded FRP composites, both theoretically and empirically [16].

Compared to the conventional ways of bolting or welding steel plates, there are various benefits of using FRP material for steel component repair and rehabilitation. Since carbon FRPs (CFRPs) tend to have better stiffness than other FRP materials, they have been chosen over other FRP materials for reinforcing steel structures. The development of high-modulus CFRP plates having a higher elastic modulus than steel has allowed researchers to transmit a large amount of load into steel beams before the steel yields [16].

1.4 Aims and objectives

The aims of this study are: Study of the properties of steel reinforced with carbon fibers and glass by 50% carbon and 66% glass in order to strengthen the steel's bearing of the imposed load and its bearing of vertical and horizontal compressive loads (Compression and Bending) loads, while the objectives are:

1. Studying instability and buckling resistance of steel reinforced by composite material laminated composite columns.
2. Study the use of Glass and Carbon fibers reinforcing materials in reinforcing and sequence of layer on the composite stability considering buckling.
3. Examine bending strength of Glass and Carbon fibers composite reinforced steel.
4. Study the possibility of using the composite material for a specific application and evaluate its effectiveness and performance considering applied load, type of loading and cost.
5. Applying different composite reinforcement to hollow structural steel to determine the behavior of circular hollow section column under the compression loading.
6. Studying structure configuration on its stability considering thickness.
7. Understanding the CFRP reinforced steel failure modes to find solutions for preventing or retarding the failures.

1.6 Research layout

The research is divided in to six chapters:

1. Chapter One includes an introduction to Glass and Carbon fibers composite materials, purpose, problem statement, drawbacks, and methodology.

2. Chapter Two include a study of literature, including magazines, papers and thesis-related publications.
3. Chapter Three includes the theoretical aspect take into account composites.
4. Chapter Four includes the experimental of work including composite production process and mechanical tests.
5. Chapter Five includes the find tests results and the discussion of Glass and Carbon fibers composite experimental work.
6. Chapter Six includes conclusion and recommendations for further work.