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Studying of Buckling Behavior on Composite Material

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Abstract- *In this paper the buckling behavior of composite specimen manufactured from polyester reinforced with fiberglass, jute fiber and eggshell powder were studied. Several samples with rectangular cross section area of (1.5*19) mm are prepared with length of (400, 500, and600) mm and with addition weight ratio of (5%) of different material for reinforcement, used for tensile and buckling test. Different types of natural and synthetic materials (matrix and random glass fibers)are used first without any addition then with adding (5% SiC or 5% Eggshell powder or 5%AL_2O_3) to the matrix, and Jute fibers. The critical load for its best results was to the random016 fiberglass without addition but its worst results were with jute addition. The results of other additions (SiC, Egg shell powder, AL_2O_3) and matrix without addition was in between. The experimental with theoretical results has been calculate and then compared*

Keywords- *buckling of columns, buckling of composite material.*

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1. Introduction

Composite materials are extensively used in naval industry airframe structures, storage tanks, petroleum pipes, cars, and high- tech designs, because of their high strength to weight ratios. So it is very useful to predict their degradation service loads and environment [1].As well as it used in many fields of engineering like buildings, bridges, boat hulls, swimming pool panels, race car bodies, shower stalls, bathtubs and storage tanks. In addition to that, industries where weight reduction is of prime concern (aviation etc.). Composites are capable enough to take different types of loading both tensile and compressive based on the requirement [8].In many engineering structures such as columns, beams, or plates, their failure develops not only from excessive stresses but also from buckling. The magnitude of the compressive load at which the plate becomes unstable is called the "critical buckling load." the mechanical properties can be varied as required by suitably orienting the fibers. Development of new applications and new composites is accelerating due to the requirement of materials with unusual combination of properties that cannot be met by conventional monolithic materials. Actually, composite materials are capable of covering this requirement in all means because of their heterogeneous nature. Properties of composite arise as a function of its constituent materials, their distribution and the interaction among them and as a result, an unusual combination of material properties can be obtained [4].

2. Literature Review

Lee et al. studied the buckling behavior of orthotropic square plate, either with or without a central circular hole. Results showed that the existence of central circular holes might cause a higher buckling strength than the plates without holes. [2]. Oleiwi et al studied the buckling analysis of composite specimen reinforced with two types of glass fibers (fine and coarse woven fibers). In addition, make mathematical models by using statistical analysis, which shows the critical load of the composite specimen as a function of volume fraction, fiber angle and aspect ratio [3]. Al Qblan studied the effect of various parameters on the buckling load of square cross-ply fiber-glass laminated plates with circular cutouts. (Size, cutout location, fiber orientation angle and type of loading) Three types of loading were considered; uniaxial, biaxial compression and shear loading. The results of buckling load are compared to theoretical and numerical values [4]

Kumar studied the influence of cut-out shape, length/thickness ratio, and ply orientation and aspect ratio on the buckling of woven glass epoxy laminated composite plate is examined experimentally. Clamped–free -Clamped-free boundary condition is considered for all case. Experiments have been carried out on laminated composites with circular, square and rectangular cut-outs. The thickness of the plate was changed by increasing the number of layers. After the buckling experiments, micro electroscopic scanning was performed for the failed specimens.

Comparisons are made between the test results, by using two different approaches. The results shows effect of various cut-out shapes, orientation of fiber, aspect ratio and length to thickness ratio on the buckling load (All specimen were loaded slowly until buckling) [5].
Ganesan et al. studied the presence of holes redistributes the membrane (E-glass woven roving with polyester resin.) stresses in the plates and may reduce their stability significantly. The buckling of such perforated plates deal with the buckling analysis of symmetrically and laminated composite plates under two sides simply supported and two sides free boundary condition. The effects on buckling load by various cut out shapes (circular, squared elliptical) and sizes are investigated. It was observed that the plate with the circular cutout yielded the greatest critical buckling load when compared with the square and elliptical cutouts [6].
Oleiwi estimated the critical load of unidirectional polymer matrix composite plate by using experimental and finite element techniques at different fiber angles and fiber volume fraction from glass fiber reinforced unsaturated polyester). The composite specimens were prepared by hand lay-up technique with different fiber volume fraction Vf, aspect ratio and angle of The results illustrated the critical load decreases in nonlinear relationship with the increases of the fiber angle and that it increases with the increases of the fiber volume fraction [7].
Parth Bhavsar buckling behavior of glass fiber reinforced polymer subjected to linearly varying loading has been studied by finite element method effects of varios parameters on the buckling load of rectangular plates with aspect ratios1 have been investigated [8].
The aim of this research was to study the influence of addition (5%) from (SiC, 〖AL〗_(2O_3) egg shell) and increase of the length on critical load to synthetic and natural composite column made from of unsaturated polyester reinforced by(matrix and random glass-fibers)and jute fiber as natural fiber .

Theory

Column fails by buckling when the axial compressive load exceeds some critical load. The critical load of the composite column can be calculated from the Euler equation as follows [7]

$$P_{Cr=}\ C\frac{\pi^2\ \times E\times I}{L^2} \qquad (1)$$

Where-:
C: is the end condition number ,
L; is the length of the column (m)
I: is the moment of inertia (m^4)
E: Modulus of elasticity (Gpa)

3. Materials and Experimental Procedure

The critical load of composite material was measured for the following cases:-
1-Different types of reinforcement fiberglass (Random, mat), jute, and Eggshell (SIC,AL_{2O_3}) as powder with polyester as the matrix were used the volume fraction is 30% for all types.
2-Three type of fixation were used, such as (Fixed-fixed end, Pin -fixed end, Pin-pin end)
3-Three type of length (400,500,600 mm) were used The Materials Used:
The hardener used is (Methyl Ethyl Keton Peroxide “MEKP”)

Table 1: The properties for epoxy (Sikadur-300)

Properties	Unit	Q
Density	10^3Kg\\m^3	1.3
Tensile strength	MPa	30
E-modulus	GPa	3800

Table (2) the properties for E-glass [Hull 1981]

Properties	Unit	E-Glass
Density	10^3Kg\\m^3	2.5
Tensile strength	GPa	1.4-2.5(typical)
E-modulus	GPa	76

I. Specimen’s preparation

The specimens used, are prepared in the workshop laboratory, University of Al-Mustansiriya by hand-Lay-up moulding, using an open glass mould with dimensions (65cm*50cm). before pouring begins ,mould sides and surface treated chemically with paraffin for the purpose of closing the spaces and take out the sample easily ,putting plastic sheet, fixed fiber glass ,(epoxy and hardener) deposited on the mould by brush ,any air which may be entrapped was removed using serrated steel roller, again plastic sheet cover mold upper part by applying poly vinyle alcohol inside the sheet as releasing agent. Then heavy flat metal rigid platform was kept top of plate for compressing purpose. Left for (48hr) before being transported to cut to exact shape for testing.
In this study, three different plate lengths were used: 400mm, 500mm and600mm. The width (19mm) and thickness of the plates are (1.5mm).

II. Experimental apparatus

The buckling testing apparatus used in this work (in University of Al-Mstansiriya, Mechanical department) is shown in Figure 1.

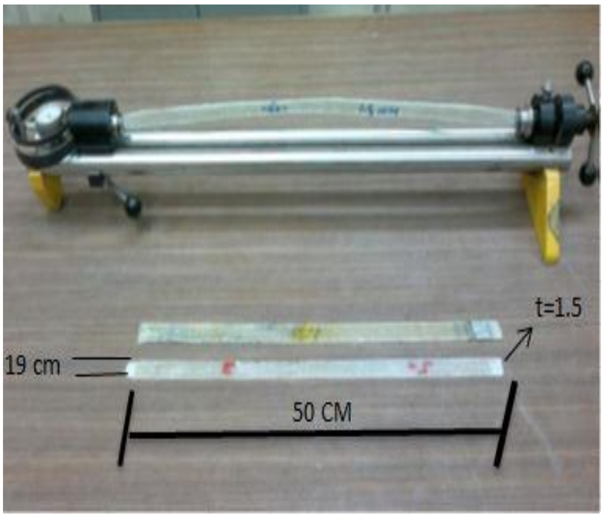

Figure 1: the test apparatus

III. Tensile test

The specimens were loaded in axial tension using an Instron tensile testing machine of 100 KN capacities. The specimen was clamped at two ends. Applied load until they were failed

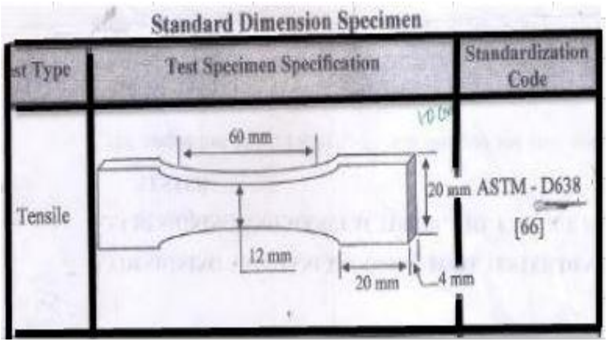

Figure 2: Standard Dimension Specimen

Figure 3: samples of tensile test at ASTM-D638 [Experimental work P39]

4. Results and Discussion

Young modulus

The values of young's modulus show the highest value for random glass-fiber compration with other used material this is due to random orientation for fiber which form zero angle as well as the transverse fiber plays secondary role in resistance and it is function to reduce deflection in the matrix material in the other hand the specimens with addition come in the second place then matrix glass-fiber. The Young's Modulus is calculated experimentally and the result is shown in Table 3.

Table 3: Young's modulus

Specimen	Young Modulus MPa	Moment of inertia mm^4
Mat (glass fiber+polyester)	2616.6	5.34375
Random(glass fiber+polyester)	7880	5.34375
Jute fiber+polyester	1918.27	5.34375
5%Eggshell(glassfiber+polyester)	2948	5.34375
5%SiC(Mat glassfiber+polyester)	2812.5	5.34375
5%AL_2O_3(Matglassfiber+polyester)	4116.6	5.34375

Critical load: - Sample of calculation (critical load):-

1-for pin ended:-

Pcr=$\frac{\pi^2 \times E \times I}{L^2}$

Pcr=$\frac{\pi^2 \times 2616.6 \times 5.34375}{400^2}$=0.86N

2-for fixed ended:-

Pcr=$\frac{4\pi^2 \times E \times I}{L^2}$

Pcr=$\frac{4\pi^2 \times 2616.6 \times 5.34375}{500^2}$=2.2N

3-for pin fixed ended

Pcr=$\frac{2\pi^2 \times E \times I}{L^2}$

Pcr=$\frac{2\pi^2 \times 2616.6 \times 5.34375}{600^2}$=0.76N

Buckling (critical load) of composite material is investigated when discuss the effect of the type of fixture it can be seen that the maximum critical load occurs with Fixed-fixed ended for all cases. From figures.4, 5, 6 it can be clearly seen that the egg shell composite sustain higher load while the jute fiber composite sustains lower load this means that the egg shell powder which contains $(CaCO_{3)}$is stiffer than jute-fiber

According to the effect of the length, there is increase in critical load with addition at a ratio of(6.5% for SiC,11% for Egg-shell and 13%for AL_2O_3)at a length of (400mm) and fixed end method, while reinforce with jute gives decrease (26%)when it compared with sample (matrix glass-fiber and without addition).At length(500mm)without addition was the best while At length of (600mm) the samples with addition except (with jute) give better results and this is can be seen clearly at fig(4-6).

All theoretical charts figs (7-9) the highest value was to the random fiber-glass (with or without addition) and this is because of the randomly distributed fibers that cause distribution in stress so increases the resistance of material to withstand the external force. , while with addition the best material is (AL_2O_3) due to it is good properties when compared with others [9]

Experimental figures differ when compared with theoretical one while using the same (length and fixation method) this is due to method of preparing the sample (hand lay-up) and homogenous in properties over all the samples.

Charts

Expermental chart

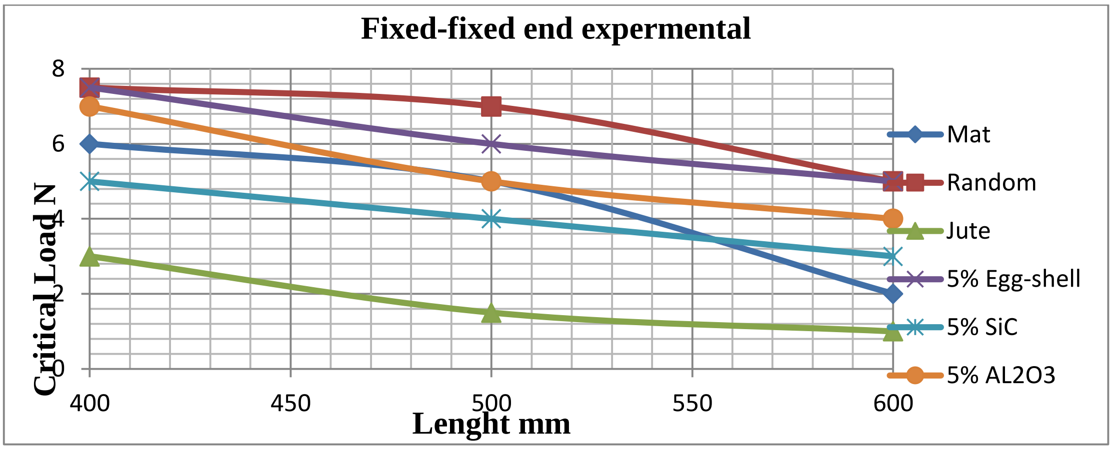

Figure 4: relation between the critical load and the length (Fixed ended)

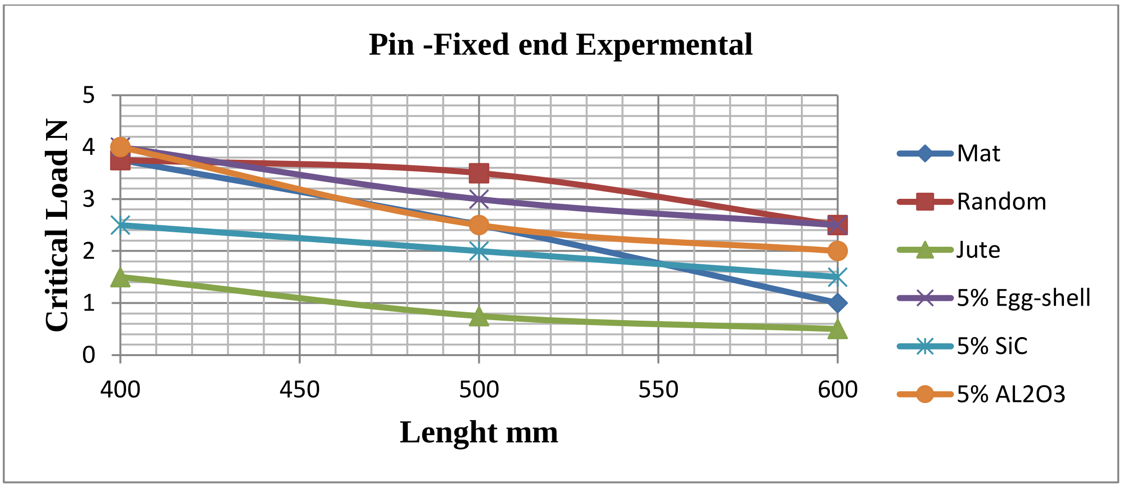

Figure 5: relation between the critical load and the length (Pin fixed)

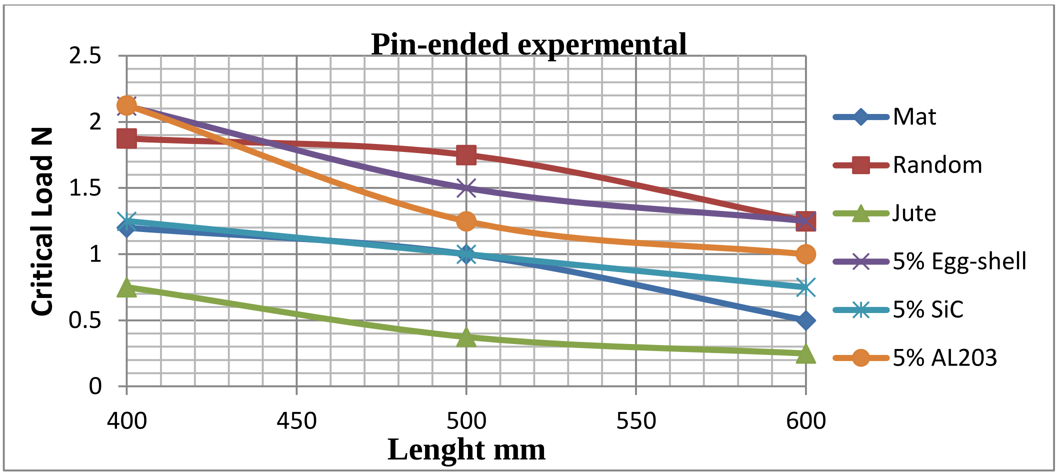

Figure 6: relation between the critical load and the length (Pin ended)

Theoretical chart

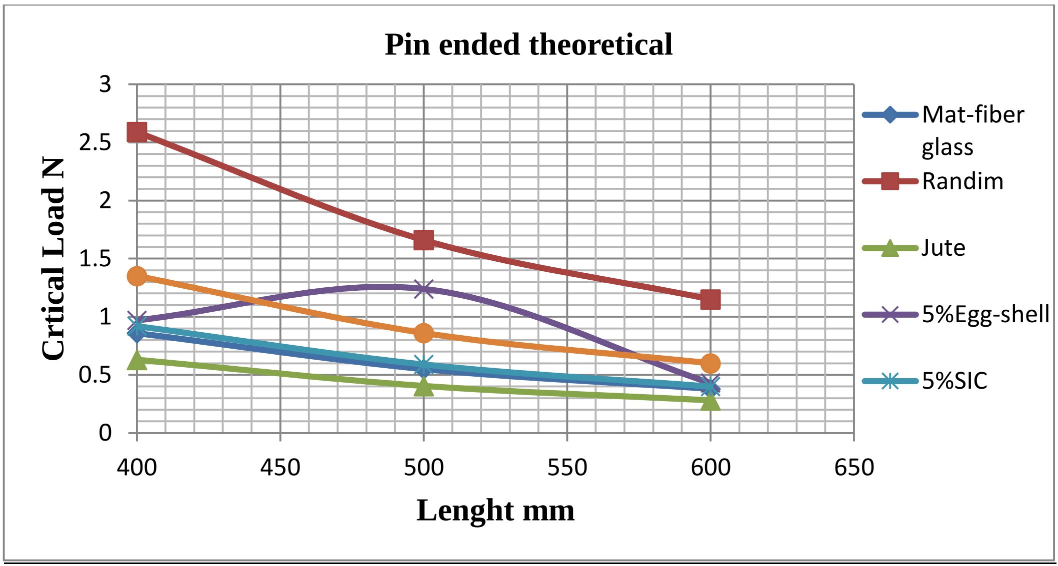

Figure 7: relation between the critical load and the length (Pin ended)

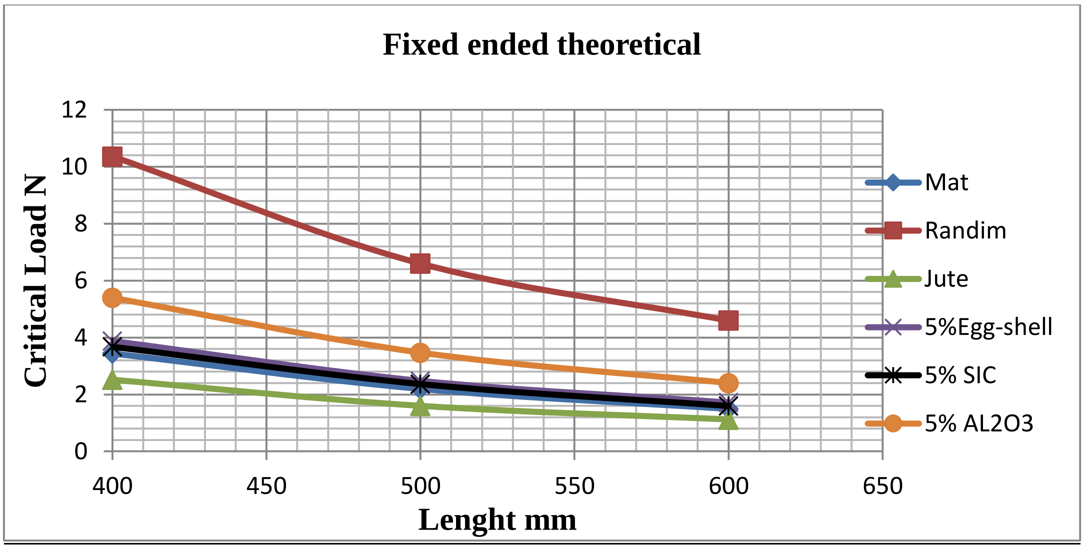

Figure 8: relation between the critical load and the length (Fixed ended)

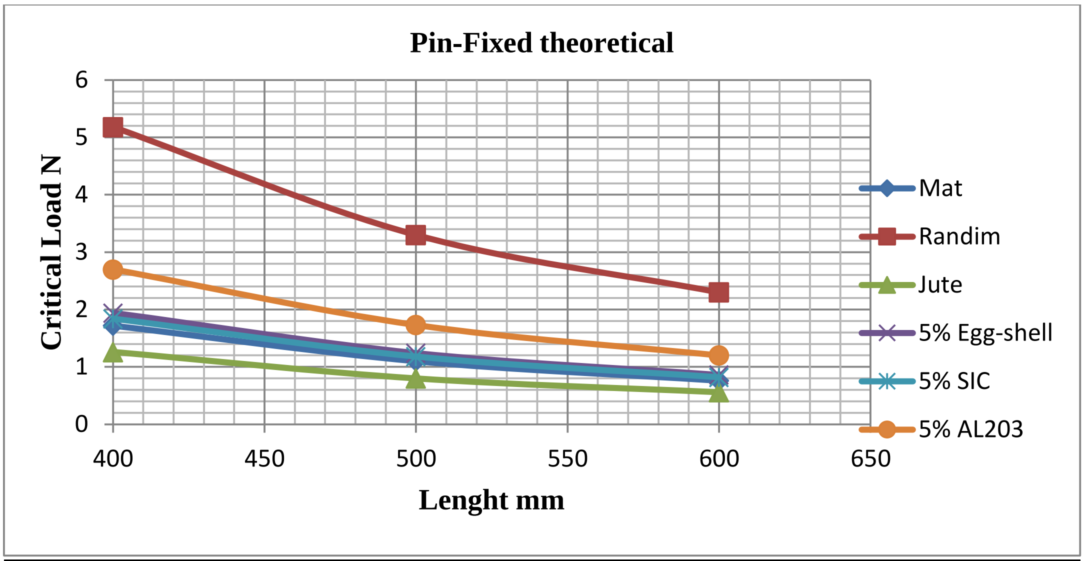

Figure 9: relation between the critical load and the length (Pin fixed)

5. Conclusion

1. Failure modes of composite column depend on the type of loading, constituent material, properties and geometrical dimensions.
2. It was noted that different length affected at critical buckling load. Buckling load decreases as the length increases. The rate of decrease of buckling load is not uniform with the rate of increase length [8].
3- There is a difference between experimental and theoretical results, and this is due to: method of preparing the samples and homogenous in properties over all the samples.
4- It can be noticed that addition of (AL_2O_3, SiC, egg-shell) to the samples lead to uniform slop whereas without addition suffering sharp tangent slop.
5- The critical load values decreased for all prepared samples with addition while it's higher without any addition due to the alteration in metal stiffness, which is an indicator of Young's modulus that can vary somewhat due to differences in sample composition and test method

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