Experimental Investigation of Modulus Elasticity for Reinforced Composite Material

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Abstract. The aim of this research is to study young modulus of composite specimen manufactured from polyester reinforced with fiberglass (matrix, random) as synthetic material and jute fiber as natural from the buckling behavior and mechanical property (tensile). Several samples with rectangular cross section area of (4*19) mm are prepared with a length of 500mm with an addition weight ratio of (5%) of different materials (eggshell powder, pomegranate seed, Sic and \( \text{Al}_2\text{O}_3 \)) for reinforcement, used for buckling test. While the sample of tensile test prepared according to (ASTM-D638) to compute young modulus and compare with others that obtain from buckling, all the sample with addition fiber reinforcement mixed with (5%) powder show improvement in buckling resistance and maximum tensile properties when compared with a sample without addition. The highest value with \( \text{Al}_2\text{O}_3 \) addition then Sic and this is related to increase interface bonding between matrix and fiber.

Keywords: composite material, buckling of columns, young modulus, reinforced material, and mechanical properties.

1. Introduction
The first paragraph after a heading is not indented Composite structures are widely used in industry because of their good properties like good strength with respect to weight ratio, corrosion resistance and can be get product with different shape easily, so that they used in wide range from aerospace to sports equipment. (1) Now, composite usage is clearly occurring for example helicopters are manufactured using composite materials also automobile, marine, mechanical, and civil engineering. But some problems like (Delamination, High Cost, Damage inspection composite to metal joining, moisture absorption and no recycling) related to its use appear so it needs in-depth studies to investigate. One of this studies add (fiber or particle) such as alumina nanoparticles to epoxy composites reinforced with S2 fiberglass reinforcement to improve the interface bonding characteristics among the fiber and matrix constituents of the composite laminate then studied their static and dynamic behavior. Pre-processing of alumina involves particulate functionalization. Dispersion schemes by grafting alumina particles in epoxy resin and on fabric reinforcement are employed (2). to select any material primary properties must be calculate is modulus of elasticity three models of finite element had been evaluated by comparing the result with experimental that obtain from tensile test to specimen manufactured from polypropylene as matrix reinforced with glass-fiber at different volume fraction (3) also FEM based software package ANSYS 13.0 was used to compare the result with an experimental investigation on vibration and buckling for driven woven fiber Glass-Carbon/epoxy hybrid composite panels are cast.
using hand lay-up technique. INSTRON 1195 to get the critical buckling load then compared with the numerical predictions. A very good agreement was observed between the experimental and ANSYS results (4), while another research using ANSYS14 package to study the critical load of composite columns depended on tensile properties result of specimens made of unsaturated polyester reinforced with different volume fraction, aspect ratio and angle of coarse and fine woven fibers prepared by hand lay-up technique. The results were also shown a good agreement with theoretically (5). others take the effect of the temperature in buckling behavior applied at samples used perlon or mixed with carbon fiber as reinforcement with acrylic resin as bonding matrix with several lay-up and analyses experimentally and numerically the result show improve in buckling resistance with combine fiber is the best and temperature has clear effect (6) mixing between natural and synthetic fiber were used as reinforcements in the epoxy resin matrix has been done in some research combinations of Jute-Sisal-Glass and Jute Banana-Glass fibers were prepared by hand layup method, subjected to mechanical tests to compute their tensile, impact and flexural strength. The results of the mechanical tests of composites were compared and presented as a detailed report (7). other factors have been discussed like the effect of different fiber volume fractions and different beam length on the critical buckling load for epoxy reinforced by composite, theoretical and experimental(8). (DULA/2018) put a review study of Fiber reinforced polymer materials used in aerospace applications such as Carbone, glass and Aramid Fiber reinforced polymer, their preparation methods and different test such as tensile test, hardness test, compression test, 3 points bending test, impact test, test for flexural strength, moisture abortion test. All this has been done to find out proper materials for proper applications(9). adding circular and elliptical opening shape in the sheet that made of both continuous and discrete fiber orientations then compare with others without hole were studied shows the effects of stress concentration on buckling. The results of finite element (FE) computations prove that the optimal laminate configurations occur at the boundaries of the feasible regions. (10) lastly there was a study about the effect of adding powder with different volume fraction or short fiber as reinforcement on mechanical properties and buckling behavior to composite material then compare the experimental result with numerical by applied (FEM) that show difference between two method equal(10.5%)(11).

2. Methodology

Lateral deflection (buckling) will not occur in the beams when the load is lower than critical load equation (1) show in:-

\[ P_{Cr} = \frac{\pi^2 \times I \times E}{L^2} \]

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

The relationship between critical load and lateral deflection (buckling) is growth progressively so as the load increase, lateral deflections increase too load beyond the critical load causes the column to fail by buckling, until it may fail in other modes such as yielding of the material.

2.1. Specimen’s preparation

All samples are prepared by the hand-Lay-up method in the workshop laboratory/ Mustansiriyah University of using wooden mold with dimensions (54cm*8cm). begins with lubricate mold sides and surface treated chemically with paraffin to close the spaces and make the removal of the sample easily, putting plastic sheet, fixed fiber glass, (epoxy and hardener) deposited on the mold, separated with steel roller also used to remove any air which may be entrapped, employ poly-vinyle alcohol as releasing agent then cover upper part of the mold with plastic sheet agent. The lastly rigid flat metal was put at the top of the plate for compressing purpose. Left for (48hr) before being transported to give the desired
shape with dimension: 500mm in length, in width (19mm) and thickness (4mm) ‘Figure 1’ show the mold that used and ‘Figure 2’ shows the samples after cut and take the final dimension

![Mould Image](image1)

**Figure 1.** The mould

![Samples Image](image2)

**Figure 2.** The samples

**Table 1.** Fiber and powder that used in preparation sample.

| symbols | E-glass Random | E-glass Mat | Jute | Egg shell Seed | Pomegranate | Sic | \( AL_2O_3 \) |
|---------|----------------|-------------|------|---------------|-------------|-----|-------------|
| \( A_3 \) | +              | 0           | 0    | 0             | 0           | 0   | 0           |
| \( A_2 \) | +              | 0           | 0    | +             | 0           | 0   | 0           |
| \( A_1 \) | +              | 0           | 0    | 0             | +           | 0   | 0           |
| \( B_3 \) | 0              | +           | 0    | 0             | 0           | 0   | 0           |
| \( B_2 \) | 0              | +           | 0    | +             | 0           | 0   | 0           |
| \( B_1 \) | 0              | +           | 0    | 0             | +           | 0   | 0           |
| \( B_0 \) | 0              | +           | 0    | 0             | 0           | +   | 0           |
| \( B_{00} \) | 0              | +           | 0    | 0             | 0           | 0   | +           |
| \( C_3 \) | 0              | 0           | +    | 0             | 0           | 0   | 0           |
2.2. Experimental apparatus
The buckling testing apparatus used in this work in (Mustansiriyah University /Mechanical department) is shown in ‘Figure 3’

2.3. Tensile test
This test has been done in the Ministry of Science and Technology (Instron) device applied load at the specimens that jointed between two ends clamped until they were failed as shown in ‘Figure 4’

2.4. Volume fraction

\[ V_f = \frac{1}{1 + (\frac{1 - \varphi}{\rho_f})}\frac{\rho_f}{\rho_m} \]  

(2)[Kileenholz and Molinier, 1986]
\[ \varphi = \frac{W_f}{W_c} \]  

(3)

\( \varphi \): Weight fraction

Wf, Wc: Fibers and composite material weights respectively

\( \rho_f \rho_m \): Fibers and matrix material density respectively

Samples of calculation volume fraction for Jute + pomegranate seed (C1)

\[ \varphi = \frac{30.6}{53.7} \]

\[ \varphi = 0.569 \]

\[ Vf = \frac{1}{1+\left(1-0.569\right)^{2.56}} = 40\% \]

2.5. Buckling

Samples of calculation (pin-ended) for (A3)

\[ b = 19 \text{ mm} \quad h = 4 \text{ mm} \quad k = \frac{10}{0.06 \text{ mm}} \]

Where K=Load cell spring stiffness it mean that every 10 N Load deflected (0.06mm)

\[ P_{cr} = c \frac{\pi^2 \times I \times E}{L^2} \]

The value of effective length depend on the end fixed condition

Pin ended column \( L_{eff} = L_{total} = 500\text{mm}(in\ this\ test) \)

\[ E = \frac{P_{cr} \times L^2}{\pi^2 \times I} \]

\[ I = \frac{bh^3}{12} = 101.333 \text{ mm}^4 \]

\[ P_{cr} = K \times \delta \]

\[ P_{cr} = \frac{10}{0.06} \times 7.2 \times 10^{-2} = 12 \text{ N} \]

\[ E = \frac{12 (N) \times 500^2(\text{mm}^2)}{3.14^2 \times 101.333(\text{mm}^4)} = 3002.693 \frac{N}{\text{mm}^2} \]

3. Results and Discussion

Table 2. The young’s modulus for all the composite material samples

| Material                        | \( \delta(\text{mm}) \) | Pcr(N) | E(GPa) |
|--------------------------------|-------------------------|--------|--------|
| Random without add (A3)        | 7.2                     | 12     | 3      |
| Random + egg shell (A2)        | 8                       | 13.33  | 3.35   |
| Random + pomegranate seed (A1) | 10.3                    | 17.16  | 4.29   |
| Material                                      | σ yield (Mpa) | σ max (Mpa) | E (MPa) | E (GPa) |
|-----------------------------------------------|---------------|-------------|---------|---------|
| Random without add (A3)                       | 6.47          | 38.84       | 6.269   |         |
| Random + egg shell (A2)                       | 7.8           | 40.5        | 2.95    |         |
| Random + pomegranate seed (A1)                | 58            | 58          | 6.4     |         |
| Mat without add (B3)                          | 41            | 52          | 7.15    |         |
| Mat + egg shell (B2)                          | 71.3          | 71.3        | 6.7     |         |
| Mat + pomegranate seed (B1)                   | 25.61         | 46.2        | 3.65    |         |
| Mat + Sic (B0)                                | 11            | 80          | 2.810   |         |
| Mat + Al2O3 (B00)                             | 15            | 106         | 4.110   |         |
| Jute without add (C3)                         | 2.262         | 16.65       | 5.89    |         |
| Jute + egg shell (C2)                         | 2.032         | 21.82       | 5.8     |         |
| Jute + pomegranate seed (C1)                  | 2.402         | 14.89       | 5.36    |         |

The Young's Modulus of a material is a fundamental property of every material that cannot be changed. It is dependent upon temperature and pressure. But many factors play an important role in change young’s modulus value like volume fraction, fibre orientation and casting method so by controlling at this factors can be get good mechanical properties, random glass-fiber show the highest value of young’s modulus comparion with other used material this is due to fiber
orientation which forms range of angle, as well as the transverse fiber, which plays secondary role in resistance and it is function to reduce deflection in the matrix material in the other hand the second place was matrix glass-fiber. While the jute show the lowest values and this can be clearly shown in table 2 and table 3.

The particle addition leads to improve mechanical properties and this depended on its grain size diameter as it decrease the matrix hardening increase also its regular distribution lead to improve buckling to resist load applied.as well as($P_{cr}$) increased as fiber volume fraction increased because of the glass fiber have stiffness and this lead to increase the stiffness of composite specimen and improved buckling resistance .All prepared samples with addition show improvement in resistance to buckling when compare without addition due to the alteration in metal stiffness, also amount of maximum stress increased with addition when compare with the sample without addition. while elastic modulus and tensile are measured relative to fiber direction that is lead to importance of geometric shape so material has fibrous form has tensile strength several time greater than in bulk and that explain the difference between the result of young modulus that obtain from buckling behavior and tensile test as well as some error happen during preparation of samples(hand-lay-up) out of controlling

4. Conclusion

All fiber reinforcement give higher result in buckling resistance and maximum stresses when compare with composite material without adding but synthetic fiber come in first while jute in last this can be effect of his natural properties that depend on kind of plant, age and environment effect.

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