Numerically and Experimentally Studying of Some Mechanical Properties of the Polyester Matrix Composite Material Reinforced by Jute Fibers

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ABSTRACT

This research focuses on the preparation of polymer matrix composite material by (hand lay – up) method, where the material (rectangular beam) was prepared from unsaturated polyester resin as a matrix reinforced by natural jute fiber with different volume fraction (3%, 4%, 5%, 6%).

Numerical studies by using finite element method (Ansys 11 package) to study the effect of selected volume fractions of jute fibers on the bending properties.

Results of this experimental research indicate that increasing the volume fraction of jute fibers lead to increase bending modulus of elasticity.

The values of flexural strength and shear stress increase with the increase of jute fibers volume fraction while the values of deflection and maximum strain decreases for both experimental and numerical studies.

Keywords: Composite materials, jute fibers, polyester, bending modulus of elasticity, flexural strength, shear stress.

دراسة تحليلية وعملية لبعض الخصائص الميكانيكية لمادة متراكبة ذات أساس من البولي استر مقواة بألياف الجوت

الخلاصة

في هذا البحث تم تحضير مادة متراكبة ذات أساس بوليمري بطريقة الصب اليدوي من البولي استر غير المشبع كمادة أساس مقواة بألياف الجوت الطبيعية وبكسور حجميه مختلفة هي (3%, 4%, 5% و 6%) .

تضمن البحث دراسة عملية وتحليلية باستخدام طريقة العناصر المحددة لدراسة تأثير الكسور الحجمية المختارة لألياف الجوت على خصائص الانحناء.

أظهرت النتائج العملية للبحث بأن زيادة الكسر ألحجمي لألياف الجوت أدت إلى زيادة قيم معامل مرونة الانحناء.
مع زيادة الكسر الحجمي لألياف الجوت, فان قيم متانة الانحناء واقصى إجهاد القص تزداد بينما انخفضت قيم الاستطالة والانفعال الأعظم ولكلا الدراستين العملية والتحليلية.

INTRODUCTION

The industrial technological developments gave up rise to an ever increasing demand of some industrial materials with selected mechanical and chemical properties. Thus, new materials with special properties are in continuous need and as result in new field of composite materials started to develop.

The Jute composites may be used in every day application such as lamp shades, suit cases, paper weights, shower bath units and also used for covers of electrical appliances, pipes, post boxes, grain storage silos, bio-gas containers, construction of low cost, mobile prefabricated building which can be used in times of natural calamities such as floods, earth quakes, …etc. [1].

The composite materials have many important mechanical properties which make them suitable for many industrial uses. This is approach the scientist to studying the effected of different type of reinforced phase on the mechanical properties for the composite material, such as (bending, flexural strength, shear stress, etc.).

Rashed, Islam and Rizvi prepared jute fiber reinforced polypropylene composites under various processing parameters using hot compression molding technique. The fiber sizes was (1, 2 and 4 mm) and percentages (5%, 10% and 15% by weight). The goal of this work is to understand the changes of tensile strength under various process parameters. The results show that tensile strength increases with increase in the fiber size and fiber percentage [2].

Tai-Kuang Lee, proposes reliable and computationally efficient beam–column finite element model for the analysis of the composite under uniaxial bending and axial force and make comparison between the modal and empirical data [3].

Smulski S. J studies the flexural behavior of glass fiber reinforced wood fiber composite and found that the static flexural modulus of elasticity increasing effective by increase reinforced volume fraction [4].

H. Ali, studying mechanical and thermal behaviors for unsaturated polyester reinforced by synthetic and natural fibers results of the work shows that the positive effected of the fibers orientation process in the hybrid composite which content orientation fibers and corporation with the hybrid composite which content random fibers and shows decrease the values of the (hardness, compression stress, and impact strength) with increase impeded period in the solution [5].

J.H. Hussein, studying some properties of the epoxy reinforced by plum fibers concludes that the values of the thermal conductivity coefficient, weight, and cost of the composite materials decrease with the increase of plum fibers volume fraction [6].

A study by A. Lames, of some mechanical and physical properties for unsaturated polyester composites reinforced by nylon and glass fibers results of the work shows that the values of (tensile stress at fracture, tensile modules of elasticity, bending modules of elasticity, fracture toughness, and impact strength) increased with the increase of nylon fibers volume fraction but the values of compression strength, and hardness decrease with the increase of nylon fibers volume fraction [7].

A. Satapthy and A. Kumar, studying some properties of jute - epoxy composite reinforced with SiC derived from Rice Husk results of the work shows effect of filler in modifying the physical and mechanical properties of jute - epoxy composite, it is found that the incorporation of Rice Husk derived SiC modifier the tensile, flexural strength shear stress of the jute – epoxy composite and the values of microhardness, density influenced by the content of these fillers [8].

The aim of this work is to study the effect of the volume fraction of jute fibers on the bending properties of the polyester matrix composite material reinforced by jute fibers with different volume fraction (3%, 4%, 5%, 6%) that this ratio can give sensible change in mechanical properties in the same time the interference between jute fibers and polyester stay in compatible.

Experimental and theoretical methods

1.Mechanical testing

Bending strength can be defined ability of sample to bending under external load applied on it without happen any fracture in the sample [9] and can be affected by moisture, Temperature, strain rate [10]. Can be calculated by the three point test method which is the most widely used and more simple and easy.

The bending modulus of elasticity (E_b) can be calculated by the following formula [11].

$$E_b = \frac{P.L^3}{48.I.d} \quad \text{(MPa)} \qquad \ldots(1)$$

where;

P: Applied load at the midpoint of the sample (N)
L: Length of the sample (m)
δ: Deflection (m)
I: Moment of inertia = $bd^3/12$ (m^4)
b: width of sample (m).
d: thickness of sample (m).

Flexural strength can be calculated from the bending test which represent the resistance of material to the outer bending stress when subjected to the different centre load to obtain the fracture. And can be calculated by the following formula [11].

$$F.S = \frac{3.F.L}{2.b.d} \quad \text{(MPa)} \qquad \ldots(2)$$

where (F) applied load at mid-point of the sample at fracture.

Also can be calculated the shear stress τ_{max} by the following formula [12, 13].

$$t_{\max} = \frac{3.F}{4.b.d} \quad \text{(MPa)} \qquad \ldots (3)$$

And can be calculated the maximum strain(r) in the mid-span by the following formula [14].

$$r = \frac{6 \cdot d \cdot d}{L^2} \qquad \ldots(4)$$

where:

r: Maximum strain (mm/mm).

δ: Maximum deflection at mid-span (mm).

Experimental work

The samples which are made from the composite material consist of this material

1- Matrix material

The resin system in the present study is the unsaturated polyester provided by (SIR) company. This is representing one type of thermosetting polymers.

The polyester have modulus of elasticity about (2.06-3.41) GPA and tensile strength about (41.4-89.7) MPa and absorption of water about (0.2-0.3) % and density about (1.2) gm/cm^3 and fracture toughness about (0.6) MPa.

Bulk resin sheets were prepared by mixing resin with 2% of hardening that formation from (Methy1 Ethy1 Keton peroxide) to increasing velocity of solidification we used catalyst as acceleration material which consist of Naphthalet Cobalt that is added with 0.5% to the resin [15].

2- Reinforcing Materials

The Jute fibers represent the reinforcing phase in the present studies. Jute fiber is long, soft, shiny, vegetable fiber that can be spun into coarse strong threads.

Jute fiber is one of the cheapest Natural fibers and is second to Cotton in amount produced and variety of uses. Jute fiber have density about (1.3) gm/cm^3, tensile strength about (442) MPa, Modulus of elasticity about (55.5) GPa, Specific strength about (340) MPa, specific modulus of elasticity about (42.7) GPa [9].

Hand Lay- molding method is used to prepare composite material in this research because it is simple in using and can be obtain samples with different shape and size. A mounts of reinforced fiber were calculated according to the following equation [16].

$$\phi = \frac{1}{1 + \frac{1-\psi}{\psi} \times \frac{\rho_f}{\rho_m}} \qquad \ldots(5)$$

Where:

ψ: Weight fraction of fibers.

ϕ: Volume fraction of fibers.

ρ_f: Fibers density (g/cm^3).

ρ_m: Matrix density (g/cm^3).

The bending device figure (1) and Flexural strength device figure (2), used the samples dimensions (L=100, b=10, d=5.5), samples are prepared according to ASTM (D 790 – 86).

Finite element analysis:

1- Modeling

For the finite element method analysis of the bending of the composite beam problem, the ANSYS11 package program was adopted. This program has very efficient capabilities to perform finite element analysis of most engineering problem. The displacement approach to the solution of finite element problem is lustrated by uniaxial loading spring [17].

$$[K]^e.[\delta]^e = [F]^e \quad \ldots(6)$$

Where:

$[K]^e$ = element stiffness matrix.

$[\delta]^e$ = is the displacement vector.

$[F]^e$ =is the element applied load vector.

The following steps represent the procedure of modeling the problem:-

1. Build the model: in this step made definition to the element types, element real constants, material properties, and the model geometry.
2. . Applied loads (displacement and force), specify load step options, meshing of the problem and begin the finite element solution.
3. Review the results: it consists of bending deflection and stress, strain and shear stress distributions.

Element Selected

Figure (3) shows the solid element model solid (8 Node 45) was adopted from the ANSYS 11 element library to perform this type of analysis. This element is used to model the column. The 8-node, 3-D solid element, SOLID 45, with three degrees of freedom per node (UX, UY, UZ). It is designed to model thick layered shells or layered solids, the element with bending, tension, and compression capabilities. The mesh generation of the beam represented in figure (4).The composite beam is simply supported beam and the load is applied concentrated on the middle span.

Results and Discussion

The results obtained from the experimental work and the finite element analysis of the bending analysis of the composite beam made from polyester reinforced by natural jute fibers with different volume fractions are discussed here.

Figure (5) shows the experimental load – deflection curves with different fiber volume fraction (V_f) (3 %, 4 %, 5 % and 6 %) produced by bending test. The deflection increase with increase load and the maximum deflection (1.09 mm) at (V_f =3%) that due to role of the reinforcing materials. Also, the load will increase with increase fiber volume fraction at constant deflection.

Figure (6) shows the finite element load – deflection curves with different fiber volume fraction, is the same as for experimental curves and the maximum deflection (1.25 mm) at (V_f =3%).

Figure (7) relationship between the experimental and finite element load – deflection curves with (V_f = 3% and V_f = 6%) fiber volume fraction. In general the finite element deflection results are slightly greater than the experimental results. This difference in results is due to conditions of experiment work.

Figure (8) shows the deflection curves with different fiber volume fraction for the experimental and finite element. The deflection will decrease with increase fiber volume fraction at constant load, also the deflection difference increases when load increase. The minimum deflection was in experimental method (0.18 mm) at (F= 5N and V_f = 6%) in this figure.

Figure (9) relationship between the experimental bending modulus with different fiber volume fraction. The experimental bending modulus of elasticity obtained from bending test increased with increase fiber volume fraction the maximum value is (E_c =3.5 GPa at V_f =6 %).

Figure (10) relationship between flexural strength and fiber volume fraction for the experimental and finite element results increase with increase fiber volume fraction. And the results of experimental work were high coinciding with finite element results.

Figure (11) relationship between shear stress and fiber volume fraction for the experimental and finite element results increase with increase fiber volume fraction.

Figure (12) relationship between maximum strain and fiber volume fraction for the experimental and finite element the strain decrease with increase fiber volume fraction, the maximum experimental strain (0.0786).

Figure (13) shows the flexural strength with different fiber volume fraction for composite beams of the bending analysis 3D model by Ansys11. The stresses distribution on the beam is clearly showed and the maximum flexural strength (223 Gpa at V_f =6 %) at middle span.

Figure (14) the shear stress with different fiber volume fraction for composite beams by Ansys11. it shows the 3D beam shear stress distribution and the maximum shear stress (12.1 MPa at V_f =6 %).

CONCLUSION

The study involved the bending analysis of the rectangular beam made from composite material of polyester matrix and reinforced by natural jute fiber at the different fiber volume fraction, by using finite elements techniques compared with experimental method.

The main conclusion of result is:

1- The maximum deflection (1.09 mm) at (V_f = 3%) in experimental result and from Ansys11 is (1.25 mm) at (V_f =3%). The deflection will decrease with increasing fiber volume fraction.

2- The experimental bending modulus of elasticity increased with increasing fiber volume fraction the maximum value is (E =3.5 GPa at V_f =6 %).

3- The experimental and finite element flexural strength and shear stress values increasing with increase fiber volume fraction.

4- The experimental and finite element results obtained for the bending analysis is approximately agreement.

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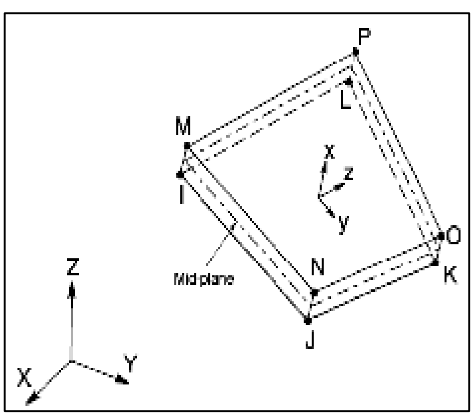
Figure (1) Bending device

Figure (2) :Flexural strength device



Figure(3): The solid element 8-node

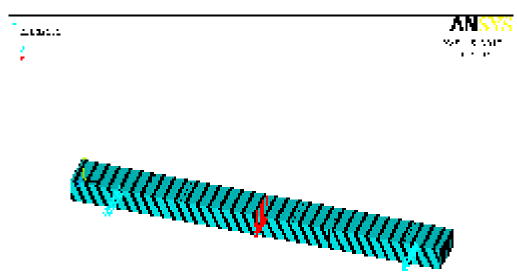


Figure (4):The mesh of the 3D beam

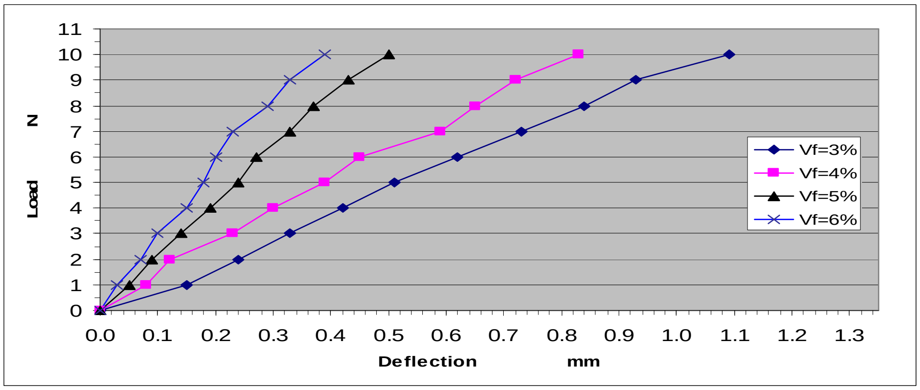


Figure (5): Shows the experimental load – deflection curves with different fiber volume fraction.

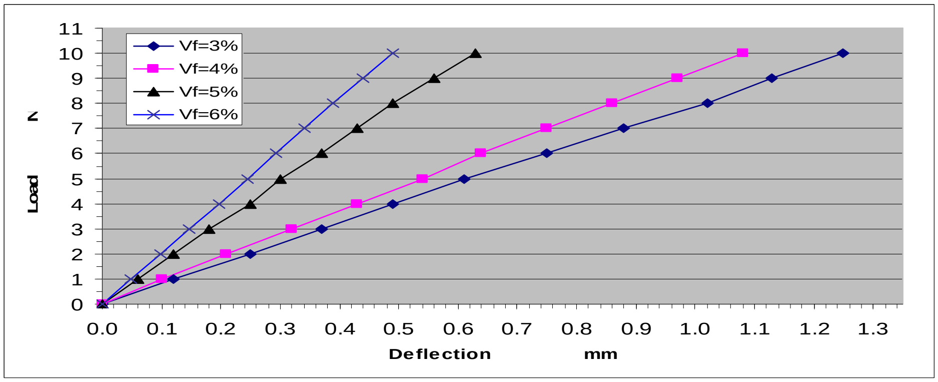


Figure (6): shows the F.E.M. load – deflection curves with different fiber volume fraction.

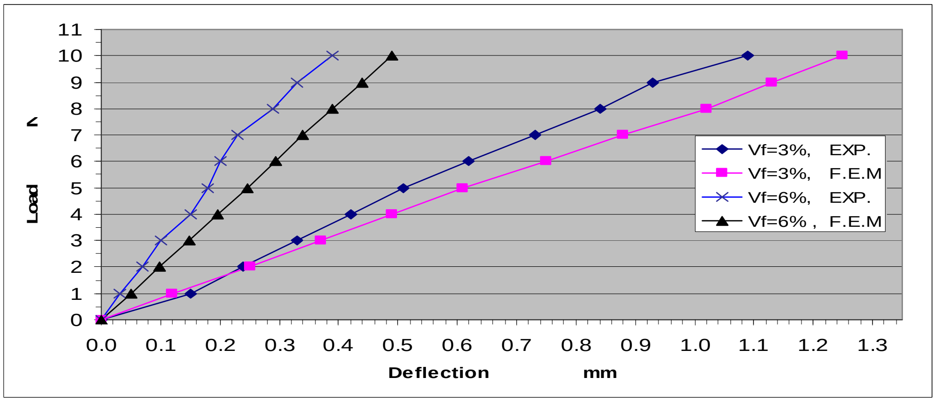


Figure (7): Relationship between the experimental and F.E.M. load – deflection curves with different fiber volume fraction.

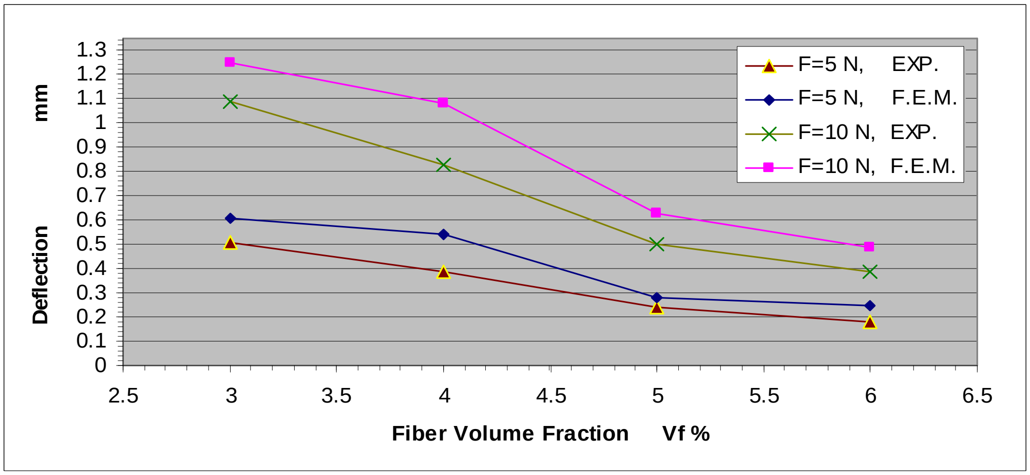


Figure (8): Shows the deflection curves with different fiber volume fraction for the experimental and F.E.M

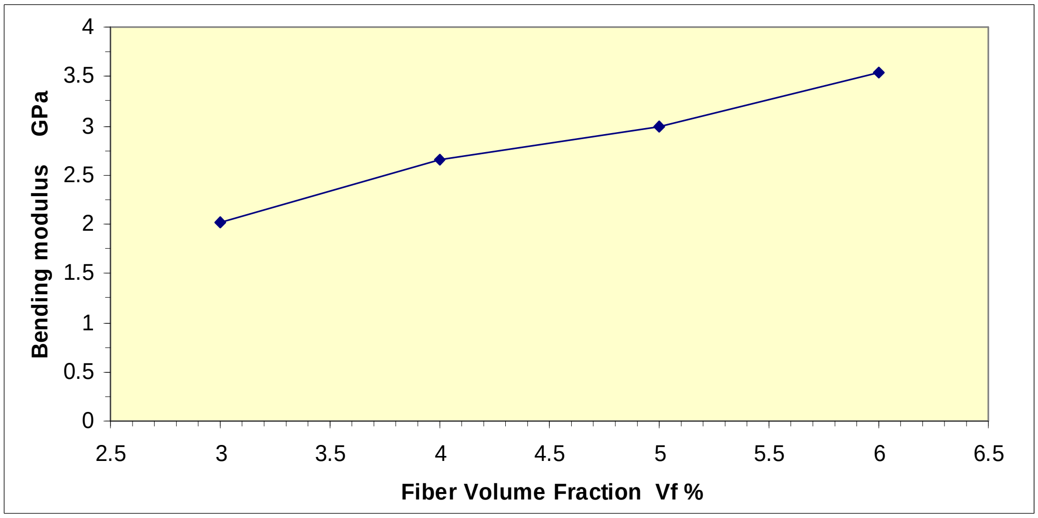


Figure (9): Relationship between the experimental bending modulus of elasticity with different fiber volume fraction.

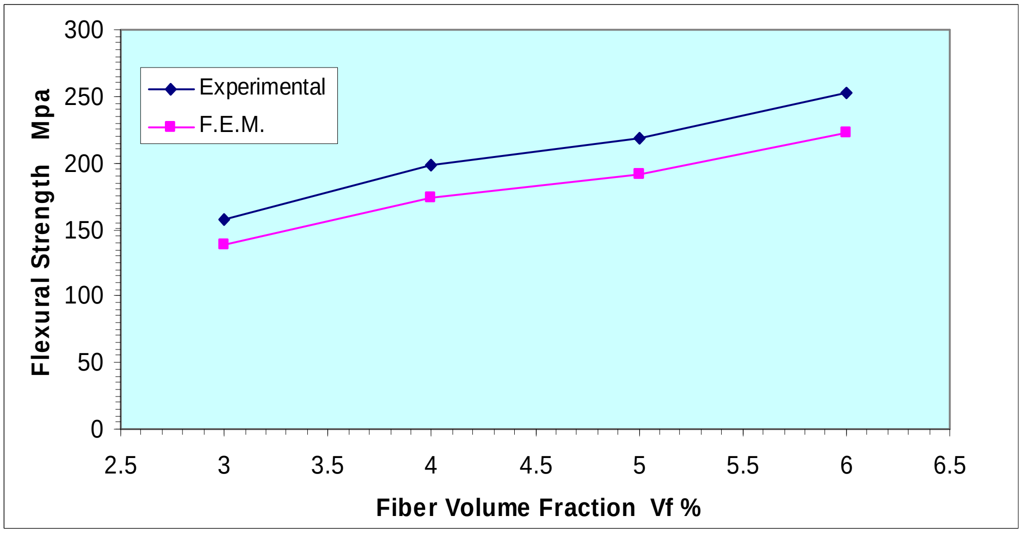


Figure (10): Relationship between Flexural strength and fiber volume fraction.

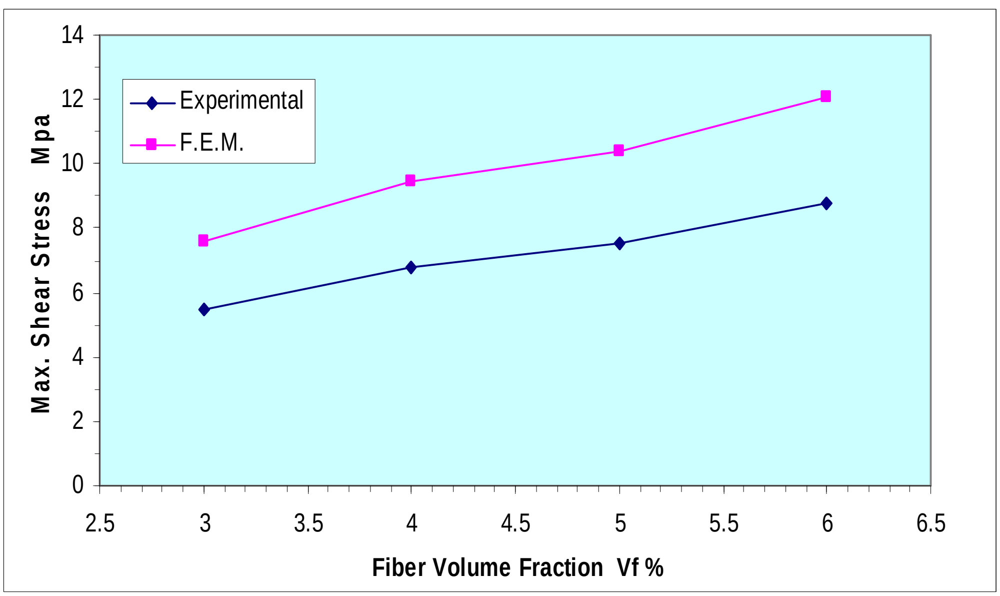


Figure (11): Relationship between maximum shear stress and fiber volume fraction.

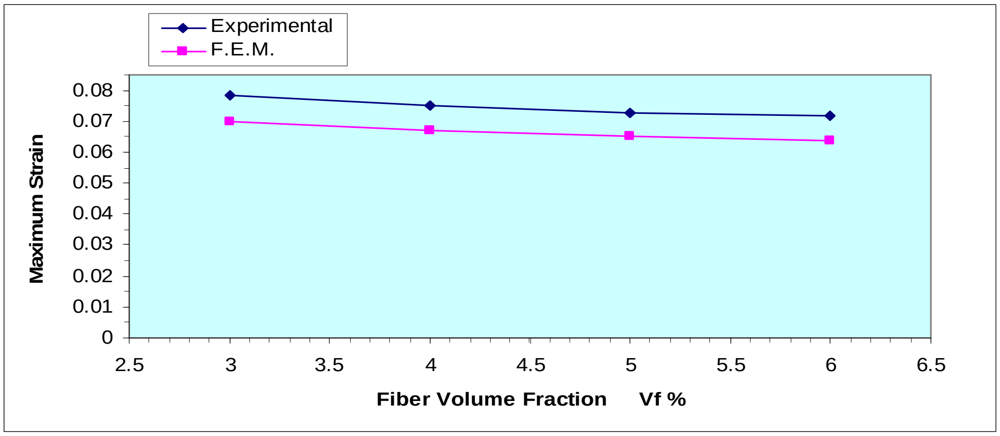
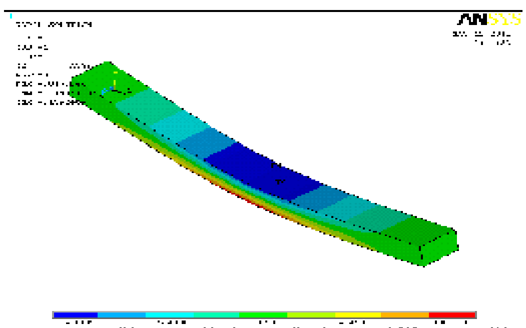
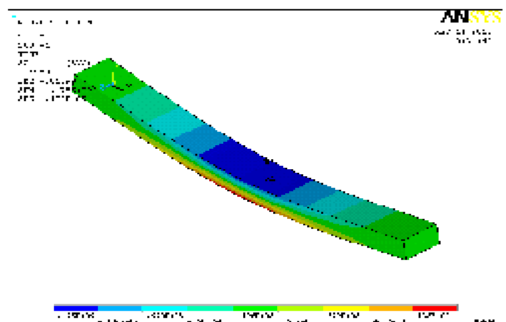


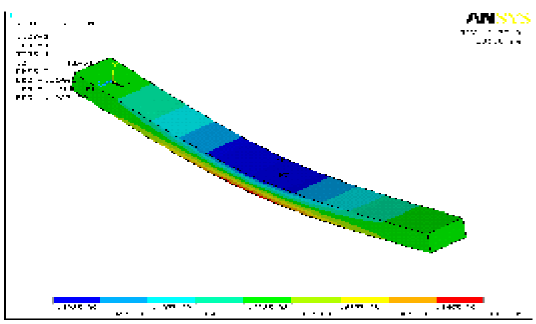
Figure (12): Relationship between maximum strain and fiber volume fraction.



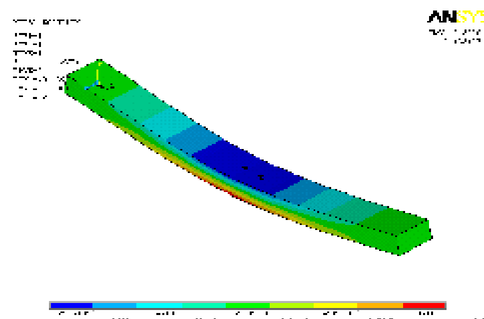
Vf = 3 %.



Vf = 4 %.

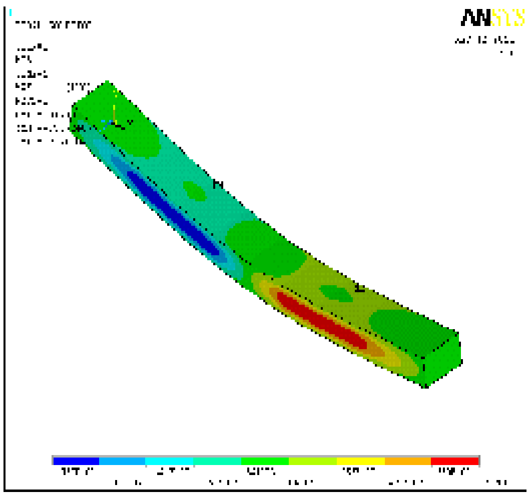


Vf = 5 %.

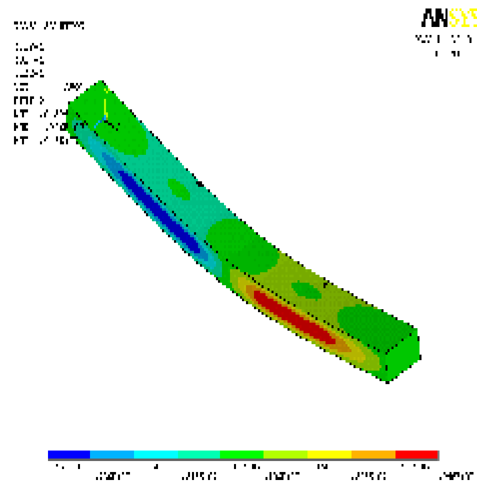


Vf = 6 %.

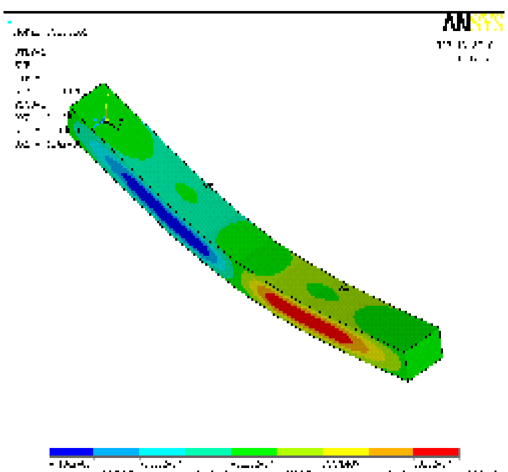
Figure (13): The Flexural strength with different fiber volume fraction for composite beams by Ansys.



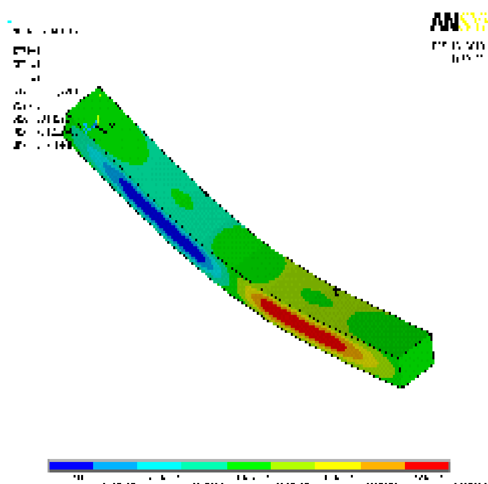
Vf = 3 %.



Vf = 4 %.



Vf = 5 %.



Vf = 6 %.

Figure (14): The maximum shear stress with different fiber volume fraction for composite beams by Ansys.