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UV radiation effect on static and dynamic behavior of fiber reinforced Composite plates

Dr.Safaa H. Abdulrahman (Assit.Prof)
University Of Technology, Electromechanical Department

Abstract

The exposure to sever environment has undesired impact on the behavior of mechanical and physical properties of composite materials. This research studies the effect of ultraviolet radiation on composite material of symmetrical and anti-symmetrical cross ply [0/90] 8-layer glass-fiber reinforced composite laminates. The samples were placed inside a special designed container and exposed to the radiation which simulates the natural sun light for 2000 hrs .The flexural properties (strength and stiffness) were determined experimentally before and after exposure to the radiation. Samples were examined using the three point bending test method to determine the properties of the composite laminate. Analytical solution based on the classical laminates theory been used, where shear effect taken into consideration because of and due to merging this theory with three point bending equations to compare the convergence between experimental and theoretical results of samples without environmental effect. The finite element analysis method were used to verify the experimental results ,and analyze the vibration characteristics to obtain the natural frequencies , response and stress distribution when exposed to radiation for different time range and harmonic load .It was shown that the exposure to ultraviolet radiation reduces the bending strength, were the symmetrical laminates lose 64% of its bending strength after 2000 hrs of exposure ,while the anti-symmetrical laminates lose 34% for the same time. Also it was shown that the natural frequencies of the cantilever and simply supported plates which is similar to the three point bending specimen reduces with the increased exposure time .The result of displacement and effective stresses at point of the applied load for symmetrical cantilever plates were directly proportional with increase of load and exposure time of radiation , while for the anti-symmetrical plates reduces with the increase of load and exposure time

Keywords: UV – radiation, physical properties, vibration characteristics, effective stresses

(تأثير الاشعه فوق البنفسجيه على التصرفات الاستاتيكيه والديناميكيه للصفائح المركبه) المقوات بألياف

المستخلص

أن التعرض لطبيعة بيئية قاسية له صدمه غير مرغوب فيها على الخواص والتصرفات الاستاتيكية والديناميكية للمواد المركبة .ففي هذا البحث تم دراسة تأثير الأشعة البنفسجية على مواد مركبة مكونة من ثمانية طبقات متقاطعة [90/0] مرتبة بشكل متماثل وغير متماثل.وضعت النماذج داخل حاوية وعرضت للأشعة لحد ما تشابهه أشعة الشمس الطبيعية ولمدة 2000 ساعة .تم تحديد خواص الانحناء (القوة والصلابة)عمليا قبل وبعد التعرض للأشعة وقد استخدمت طريقة انحناء النقاط الثلاثية لتحديد خواص الطبقات المركبة .لقد استند التحليل النظري على نظرية الطبقات الكلاسيكية (CLT) حيث اخذ تأثير القص بنظر الاعتبار بسبب ونتيجتا إلى دمج هذه النظرية بقوانين الانحناء الثلاثية وذلك لمقارنة مدى التقارب بين النتائج العملية والنظرية للنماذج بدون تأثير بيئي.استخدمت طريقة تحليل العناصر المحددة (FEM) للتحقق من النتائج العملية ولتحليل الخواص الاهتزازية للحصول على الترددات الطبيعية والاستجابة وتوزيع الاجهادات لتعرضها للأشعة لمختلف الأزمان والأحمال التوافقية.تبين أن الأشعة فوق البنفسجية تقلل من صلابة الانحناء حيث الرقاق المتماثلة تفقد 64% من صلابة الانحناء بعد زمن تعرض 2000 ساعة كذلك الرقاق الغير متماثلة تفقد 34% من صلابة الانحناء لنفس زمن التعرض كما وتبين أن الترددات الطبيعية للصفحة المدعومة الكابولية والمسند ببساطة المتماثلة إلى عينة الاختيار الانحناء الثلاثي تقل بزيادة زمن التعرض لأشعة .لقد أظهرت نتائج الإزاحة القصوى والإجهاد الفعال نتيجة تطبيق حمل توافقي عند نقطة تأثير الحمل لصفحة كابولية متماثلة تتناسب طرديا مع زيادة الحمل وتزداد بزيادة زمن التعرض للأشعة بينما في العينة الغير متماثلة تقل بزيادة زمن التعرض والحمل .

Introduction:

Fiber-reinforced composite materials continue to replace the conventional metals in primary and secondary mechanical, aerospace , aircraft and marines structural elements owing to their superior mechanical properties. The requirement for lightweight and stronger materials spurred the development of high strength and low ductility materials such as fiber reinforced matrix composites. Fibre reinforced composite materials consist of fibers of high strength and modulus embedded in or bonded to a matrix material with distinct interfaces between them . In this form , both the fibers and the matrix retain their physical chemical identities , yet they produce a combination of properties that can not be achieved with either of the constituents acting alone [1] .A complete set of linear equations of the second-order theory of laminated composite plates are obtained by a generalized Levy type solution in conjunction with the state space concept is used to analyze the free vibration behavior of cross-ply and anti-symmetric angle-ply laminated plates. Exact fundamental frequencies of cross-ply plate strips are obtained for arbitrary boundary conditions. The exact analytical solutions are obtained for thick and moderately thick plates as well as for thin plates and plate strips. It is shown that the results of the second-order theory are very close to the results of the first-order and third-order theories, and different from those of the classical Kirchhoff's theory for thick laminates [2] **.A** new Reddy type elements based on formulations of Reddy’s higher-order theory to determine the natural frequencies of isotropic, orthotropic, and layered anisotropic composite and sandwich plates were used . The material properties typical of glass fibre polyester resins for the skin and HEREX C70 PVC (polyvinyl chloride) foam materials for the core are used to show the parametric effects of plate aspect ratio, length-to-thickness ratio, degree of orthotropy, number of layers and lamination scheme on the natural frequencies. A consistent mass matrix is adopted in the present formulation. The results presented in this investigation could be useful for a better understanding of the behaviour of sandwich laminates under free vibration conditions and potentially beneficial for designers of sandwich structures [3] **.** The classical laminated plate theory was developed , and a variation approach for the study of the statical and dynamical behaviour of arbitrary quadrilateral anisotropic plates with various boundary conditions was applied. The analytical formulation using the Ritz method in conjunction with natural coordinates to express the geometry of general plates in a simple form. The deflection of the plate is approximated by a set of beam characteristic orthogonal polynomials generated using the Gram–Schmidt procedure. The algorithm developed is quite general and can be used to study fibre reinforced composite laminates with symmetric lay-ups, which may have general anisotropy and any combinations of clamped, simply supported and free edge support conditions. Various numerical applications are presented and some results are compared with existing values to demonstrate the accuracy and flexibility of the present method. New results were also determined for plates with different geometrical shapes, combinations of boundary conditions, several stacking sequences and various angles of fiber orientation [4] **.**An investigation was carried to see if E-glass fibres-reinforced UV-cured vinyl ester composites can effectively repair damaged RC beams. The repaired beams were again subjected to four-point bending test, this time until failure. The effectiveness of UV curing FRP on fast repairing damaged RC beams was evaluated based on the test results [5] . **A** study to evaluate the flexural strength and the Weibull modulus of a micro hybrid and a nano-fill composite by means of 3- and 4-point bending tests was presented. Thirty specimens were prepared and submitted to 3- and 4-point bending tests using a universal testing machine with a crosshead speed of 1mm/min after 24hr in distilled water at 37 ◦C. In conclusion a higher flexural strength was produced by the 3-point bending test than by the 4-point bending test, independent of the composite evaluated. The flexural strength and the fracture behaviour of both composites were similar, despite the difference in the average filler size of the composites tested, probably due to the micro-structural arrangement of the nano-fillers in clusters that approximate the average size of the filler of the micro-hybrid composite and due to the similar filler volume in both composite [6] .The flexural stiffness of GFRP pultruded profiles were evaluated experimentally, numerically and analytically. A procedure that simultaneously yields the flexural and the shear modulus of GFRP pultruded profiles directly from 3-point bending tests is applied. Direct tension and 3-point bending tests on coupons extracted from these profiles were also conducted. The Timoshenko Beam Theory (TBT) and the FEM were applied to analyze the profiles under bending, using material properties estimated by Classical Laminate Theory (CLT). Comparisons of numerical, analytical and experimental results are presented and discussed [7] **.**Glass fabrics and unsaturated polyester resin were selected to fabricate 2, 3 and 5-layer laminates. Laminates were subjected to tensile strength testing, after ultraviolet (UV) radiation for 20–200 hr. For the 2-layer laminates, after 170-h UV lamp radiation, the tensile strength reduction of the materials became significant. Distinctive degradation was noticed after 200-h UV irradiation for the 3-layer specimens. No evident strength reduction was discovered for the 5-layer samples after 200-h treatment. It is concluded from the research that short period of UV radiation has no significant influence on the material as far as tensile strength is concerned. Examinations of the fracture surface of the specimen under SEM revealed the deteriorated matrix after extended UV radiation [8] **.**As the laminated beam, plates or shells become more and more important in all industries and in modern engineering application, so wide attention has been paid on the experimental, theoretical and numerical analysis for static and dynamic problem of such structure in recent year. And as a result, it has been important objective reason for studying and investigating the effect of UV radiation exposure time on the composite material which consists of E-glass and polyester with 8-layers cross ply [0/90]8 with different stacking sequence (symmetric and anti-symmetric) model for the next parameters, the flexural stiffness and strength of the fiber glass polyester composite at different exposure time, determining load-deflection curve by merging the classical laminate theory with three point bending equations, evaluating the natural frequencies and response , then determining the effective stress distribution on the composite plate due to the vibration parameters .

Analytical analysis:

Consider a symmetric ($[B]=0$) cross-ply specimen of size L X h X b subject to three-point bending as shown in Figure (1). Let the neutral axis of the specimen coincide with the x-axis. The bending moment resultants at the mid-span of the specimen determined from the equilibrium conditions of the test are [9]

$$M_x = \frac{PL}{4b} \qquad M_y = 0 \qquad M_z = 0 \quad \text{........ (1)}$$

where M_x, M_y and M_z are moment resultants; *P* is the applied line load acting across the width at the mid-span of the specimen; b is width; L is length. Based on the classical laminate theory, the stress-strain relations for especially orthotropic lamina (ɵ = 0 or 90) [10] .

$$\begin{bmatrix} \sigma_x \\ \sigma_y \\ \tau_{xy} \end{bmatrix} = \begin{bmatrix} Q_{11} & Q_{12} & 0 \\ Q_{21}=Q_{12} & Q_{22} & 0 \\ 0 & 0 & Q_{66} \end{bmatrix} \begin{bmatrix} \varepsilon_x \\ \varepsilon_y \\ \gamma_{xy} \end{bmatrix} = [Q] \begin{bmatrix} \varepsilon_x \\ \varepsilon_y \\ \gamma_{xy} \end{bmatrix} \text{...... (2)}$$

Where [Q] represent the stiffness matrix and the various element in [Q] matrix are given by :

$$Q_{11} = \frac{E_{11}}{1-\nu_{12}\nu_{21}}$$

$$Q_{22} = \frac{E_{22}}{1-\nu_{12}\nu_{21}}$$

$$Q_{12} = Q_{21} = \frac{\nu_{12}E_{22}}{1-\nu_{12}\nu_{21}} = \frac{\nu_{21}E_{11}}{1-\nu_{12}\nu_{21}}$$

$$Q_{66} = G_{12}$$

Where E11,E22 are young's moduli in fiber and transverse direction ; vij is Poisson's ratio for transverse strain in the j-direction when stressed in i-direction ; G12 is shear modulus in the 1-2 direction .The stiffness matrices of the laminate are defined as [10] :

$$A_{ij} = \sum_{K=1}^{K} \left(Q_{ij}\right)_K \left(Z_k - Z_{k-1}\right)$$

$$B_{ij} = \frac{1}{2}\sum_{K=1}^{K} \left(Q_{ij}\right)_K \left(Z^2{}_k - Z^2{}_{k-1}\right) \qquad \text{.......... (3)}$$

$$D_{ij} = \frac{1}{3}\sum_{K=1}^{K}\left(Q_{ij}\right)_K \left(Z^3{}_k - Z^3{}_{k-1}\right)$$

Where [A] is the extensional matrix for the laminate (N/m) , [B] is the coupling stiffness matrix for the laminate (N), [D] is the bending stiffness matrix for the laminate (N/m), K is the total number of piles in the laminate, Zk and Zk-1 are the distance from the reference plane to the two surface of the Kth ply and (Qij)k is elements of the stiffness matrix of the Kth ply .The relation between the moment and curvatures for composite orthotropic specimen can be expressed as [9] **:**

$$\begin{Bmatrix} M_x \\ 0 \\ 0 \end{Bmatrix} = \begin{bmatrix} D_{11} & D_{12} & 0 \\ D_{12} & D_{22} & 0 \\ 0 & 0 & D_{66} \end{bmatrix} \begin{Bmatrix} k_x \\ k_y \\ k_{xy} \end{Bmatrix} \qquad \ldots\ldots\ldots\ldots\ldots (4)$$

$$M_x = D_{11} k_x \qquad \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

The inversion of equation (4) gives

kx = d11Mx . …………. (6)

Where d11 is the first element in the inverse of [D]

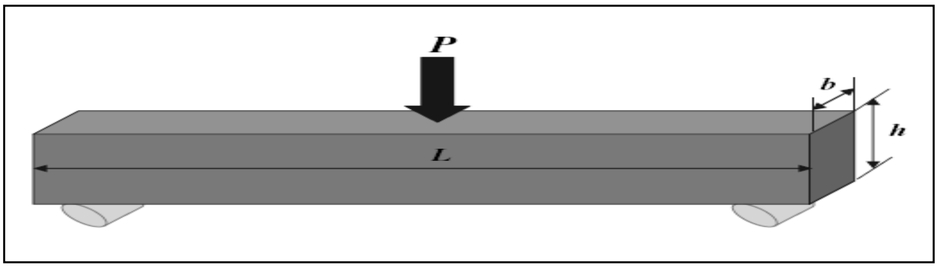


Figure (1): Schematic drawing of three point bending test

The bending stiffness matrix $[D]$ calculated from equation. 3 according to the untransformed reduced stiffness is expressed as:

$$Q = \begin{bmatrix} Q_{11} & Q_{12} & 0 \\ Q_{12} & Q_{22} & 0 \\ 0 & 0 & Q_{66} \end{bmatrix} \qquad \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

For symmetric cross-ply laminate composite specimen 8 layers [0/90]s as shown in

Figure (2)

$$(Q_{11})_0 = (Q_{22})_{90} \quad , \quad (Q_{22})_0 = (Q_{11})_{90}$$

$$(Q_{12})_0 = (Q_{12})_{90} \quad , \quad (Q_{66})_0 = (Q_{66})_{90}$$

$$(Q_{61})_0 = (Q_{16})_{90} = 0$$

$$(Q_{26})_0 = (Q_{26})_{90} = 0$$

0
90
0
90
90
0
90
0

Figure (2): Symmetric cross-plies

The Calculation of the Deflection of Composite Specimen under Flexural Load:

The assumptions of Kirchhoff's theory remain and the shear stresses throughout the beam are ignored. For a pure flexure situation, this assumption is valid. However, as mentioned previously, shear is of importance when considering FRP, which therefore warrants the use of methods that include shear deformations. Such a method is Timoshenko's beam theory . Timoshenko's beam theory allows for the rotation of the plane section. Added to Timoshenko's beam theory is a shear adjustment factor to allow for the non-uniform shear stress distribution at a section while retaining the one-dimensional approach. A simply-supported beam of length L is subject to three-point bending, with a load of P The bending tests were performed according to ASTM standard D790-02 [11] , using a universal tensile testing machine MTS (20/MH). Equations (8) and (9) give the calculated deflection at mid-point, via the Euler-Bernoulli and Timoshenko methods, respectively [12].The following limitations of three-point flexural tests should be recognized [9].

1- In the three-point bending mode, both normal stress and shear stress are present throughout the beam span. If contributions from both stresses are taken into account, the total deflection at the mid span of beam by equation (9) is

$$\delta = \frac{pL^3}{48\,EI} \qquad \text{…..……… (8)}$$

$$\delta = \underbrace{\frac{pl^3}{48\,E_{eff}\,I}}_{\text{Normal}} + \underbrace{\frac{3\,PL}{10\,GA}}_{\text{Shear}} \qquad \text{…..……….. (9)}$$

*E*eff = the effective bending modulus of beam is defined as

$$E_{eff} = \frac{12}{h^3 d_{11}} \qquad \text{………… (10)}$$

The maximum deflection can be calculated by replacing the isotropic modulus E with effective bending modulus *Eeff*. The effective bending stiffness for laminate beam can be written as

$$E_{eff} I = \frac{b}{d_{11}} \qquad \text{……… (11)}$$

Then

$$\delta = \frac{pL^3}{48 \frac{b}{d_{11}}} + \frac{3PL}{10\,GA} \qquad \text{……………. (12)}$$

For a symmetric beam containing isotropic layers or specially orthotropic layers (such as all 0°, all 90°, or combinations of 0 and 90° layers), the effective bending stiffness becomes

$$\left(E_{eff} I\right) = \sum \left(E_{11}\right)_j I_j \qquad \text{…………….(13)}$$

Where

$\left(E_{11}\right)_j$ = longitudinal modulus of the jth layer.

I_j = moment of inertia of the jth layer with respect to the midplane.

The maximum fiber stress at failure on tension side of a flexural specimen is considered the flexural strength of the material. Thus, using a homogeneous beam theory, the flexural strength in three-point flexural test is given by

$$\sigma_{UF} = \frac{3P_{max} L}{2bh^2} \qquad \text{…………… (14)}$$

Pmax = maximum load at failure.
b= specimen width
h= specimen thickness.
L = specimen length between the two support points.

2- The maximum fiber stress may not occur at the outermost layer in a composite laminate. Thus, equation. (14) gives only an apparent strength value. For more accurate values, lamination theory should be employed.

3- Owing to large deflection at high L/h ratios, significant end forces are developed at the supports. This in turn affects the flexural stress in a beam. Unless a lower L/h ratio, say 16:1 is used, equation.(14) must be corrected for these end forces in the following way:

$$\sigma_{max} = \frac{3P_{max}L}{2bh^2}\left[1+6\left(\frac{\delta}{L}\right)^2-4\left(\frac{h}{L}\right)\left(\frac{\delta}{L}\right)\right] \qquad \text{...........(15)}$$

4- Although the flexural strength value is based on the maximum tensile stress in the outer fiber, it does not reflect the true tensile strength of the material. The discrepancy arises owing to the difference in stress distribution in flexural and tensile loadings. Flexural load creates a nonuniform stress distribution along the length, but a tensile load creates a uniform stress distribution. Two parameter Weibull distribution for both tensile and flexural strength to the median tensile strength can be written as

$$\frac{\sigma_{UF}}{\sigma_{UT}} = \left[2(1+\alpha)^2\frac{V_T}{V_F}\right]^{1/\alpha} \qquad \text{............ (16)}$$

α = shape parameter in Weibull distribution function (assumed to be equal in both test).

VT= volume of material stressed in tension test.

VF= volume of material stressed in three-point flexural test.

Assume *VT*=*VF* and utilize typical value of α =15 to 25 for E-glass-epoxy and carbon-epoxy 0° laminates, respectively, equation.(16) shows that.

$\sigma_{UF} = 1.52\,\sigma_{UT}$ for 0°E-glass-epoxy laminates.

$\sigma_{UF} = 1.33\,\sigma_{UT}$ for 0°carbon-epoxy laminates

Thus, the three-point flexural strength of composite laminate can be significantly higher than tensile strength.

Sample preparation:

It is well known that the laminated composites consist of layers of at least two different materials that are bonded together. Lamination is used to combine the best aspects of the constituent layers in order to achieve a more useful material. This definition quite fits with the class of laminated fibrous composites (composed of fibres in a matrix) in which the final composite product results from the layer stacking. In this study, E-glass fibres and polyester resin matrix were used for the preparation of the laminated plates. Table.1 shows the mechanical properties of E-glass and polyester material [13].

Table (1): Mechanical properties of E glass/ polyester

Material	Density (g/cm^{3})	Young's modulus	Tensile strength	Failure strain (%)
Polyester	1.2-1.5	2.0-4.5	40-47	2.2
E-glass	2.56	76	2000	2.6

Ultraviolet Chamber:

To study UV effect, Special wood chamber designed and built with dimensions (70 X 70 X 70) cm. A 300 Watt R40 *OSRAM SUN LAMP* - E27 BASE - 230 Volts - HIGH UV LIGHT BULB, 1000 hr virtual age. UV lamp was used as the UV radiation and specimens (symmetric and anti-symmetric) put inside the chamber to simulate the ultraviolet environment. The distance between UV lamp and the samples surface was about 60 cm [14], UV lamp and chamber shown in Figure 3 a & b.

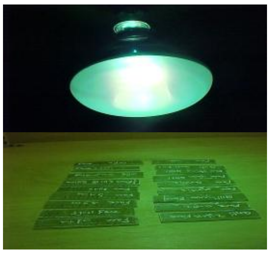


Figure (3)

a- UV lump and specimens b- UV Chamber

Determination of fiber volume fraction, Vf :

The relative quantity of the various constituents in a composite is known as the volume fraction and is normally expressed as the ratio of volume of reinforcement and the total volume of the composite [15].Experimentally, it is easier to determine the fibre weight fraction Wf from which the fibre volume fraction can be calculated using the following equation.17:

$$V_f = \frac{1}{\left[1 + \frac{\rho f}{\rho m}\left(\frac{1}{Wf} - 1\right)\right]} \qquad \text{.......................} (17)$$

where Vf is the fibre volume fraction, Wf is the fibre weight fraction, ρm is the matrix density (g/cm3) and ρf is the fibre density (g/cm3). The fibre weight fraction can be experimentally determined by ignition loss method, it is used for
the polymeric matrix composites containing fibres that do not lose weight at high temperature, such as E-glass fibres. In this method, cured resin is burned off a small test sample at 565 °C in a muffle furnace. Based on the above method [10]. Table 2 shows the values of elastic and shear modules and the ratios for the symmetric and anti-symmetric samples.

Table (2): Theoretical expression and result of mechanical properties

Mechanical properties	Expression	Results	
		Symmetric Vf=41.59,Vm=58.41	Anti symmetric Vf=43.46,Vm=56.54
E_1(Gpa)	$E_1=E_f V_f + E_m V_m$	32.77	34.16
E_2(Gpa)	$E_2 = \frac{E_f E_m}{V_m E_f + V_f E_m}$	3.36	3.467
V_{12}	$v_{12}= v_f V_f + v_m V_m$	0.272	0.27
V_{21}	$v_{21} = v_{12} \, E2/E1$	0.0278	0.0273
G12(Gpa)	$G_f V_f + G_m V_m$	1.283	1.32

Experimental Results:

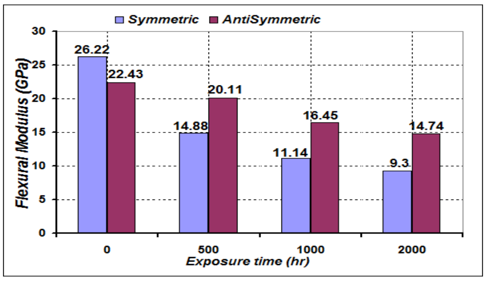
Impact of Ultraviolet Radiations on the Laminates Specimens:

A - Flexural Modulus:

When the laminate is exposed to ultraviolet radiation Figure (4) the UV radiation reduces the flexural modulus of the laminate specimens, symmetric laminate loses 43.25% of their flexure modulus during the first 500 hrs of exposure time, and from 1000 up to 2000 hrs of exposure time symmetric laminate loss about 64% of flexure modulus. Similarly the anti-symmetric laminates lose about 10 % of their flexure stiffness during the first 500 hrs of exposure time, and lose 34% from 1000 up to 2000 hrs of exposure time .

B- Flexural Strength:

Figure (6) shows the impact of UV radiation on the flexural strength of the symmetric and anti-symmetric laminates. Increasing the exposure time from 1000 to 2000 hrs of exposure time, symmetric laminates was observed to lose about 3.785% to 9% of their flexural strength of which 2% was lost during the first 500 hrs of exposure time. On the other hand the anti-symmetric samples lost (4 - 4.8) % of the flexural strength of which 0.78% was lost after 500 hrs of exposure time .From above results, it can be deduced that when laminates are exposed to ultraviolet radiation, polymeric matrix composites degraded. The reasons for this degradation of the fiber reinforced plastic (FRP) may be attributable to the UV radiation, which lead to deterioration of the resin matrix and fiber/matrix interfacial bonding . The current study has showed that ultraviolet radiation has a negative impact on the durability of GFRP laminates. They both make the laminates lose most of the flexure modulus during the first 500 hrs of exposure time which increases after the next period while the strength loses most values during (1000-2000) hrs .Degradation is a process where the deterioration in the properties of the polymer takes place due to different factors like, light, thermal, mechanical factors. As a consequence of degradation, the resulting smaller fragments do not contribute effectively to the mechanical properties, the article becomes brittle and the life of the material becomes limited. Thus, any polymer or its composite, which is to be used in outdoor applications, must be highly resistant to all environmental condition.



Figure(4):variation in the flexure modulus Of composite symmetric and ant-Symmetric specimens due to UV radiation Exposure impact.

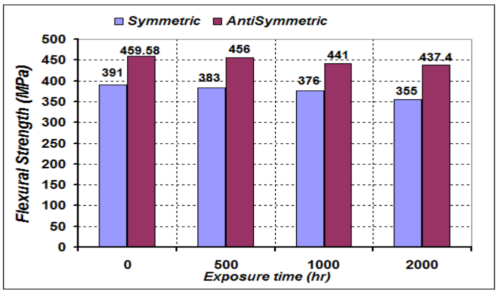


Figure (5): Variation in the flexure strength of composite symmetric and anti- symmetric laminate due to UV radiation exposure impact.

Dynamic studies:

The finite element method is one of the most effective method for numerical solution of field problem formulated in partial differential equations [16] . ANSYS (version 8) software is used for the FE analysis. The element employed in this research is shell 99 which an extension to shell 91 may be used for layered applications of structure shell model . In this part of analysis, the obtained results of material properties will be used to investigate the vibration characteristic due to the UV radiation exposure on cantilever and simply supported laminated symmetric and anti-symmetric plates natural frequencies , mode shapes and stress distributions.

Cantilever Laminated Plate (Clamped-free-free-free)

Figure (6) shows the dimensions of cantilever laminated plate,

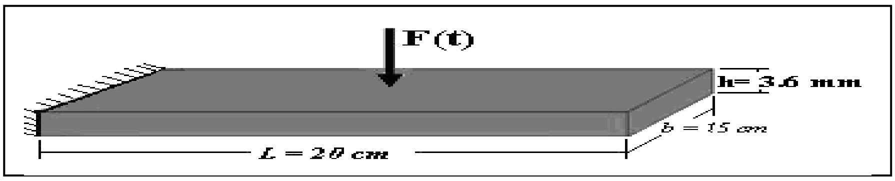


Figure (6): Cantilever laminate plate

Part I: Fundamental Natural Frequencies Variation

Table (3) shows the variation in the natural frequencies of specimens for free vibration of laminated plate symmetric and anti-symmetric for zero hour exposure for different modes shapes, while Table (4) shows the effect of ultraviolet radiations on the fundamental natural frequencies for different orientations (cross-ply) of eight layers Symmetric (0/90/0/90/90/0/90/0) and anti-symmetric (0/90/0/90/0/90/0/90). Figure (9) shows the relation between the natural frequencies with exposure time to ultraviolet radiation; within the first time at 500 hrs the symmetric laminate loses 25% up to 40% after 2000 hrs, anti-symmetric laminate lose 5% up to 19% after 2000 hrs. it can be observed that the natural frequencies of cantilever laminate plates decrease with increased exposure time . This is because that mass of the structure increases in magnitude and the reduction in the structure stiffness magnitude. Also the fiber orientation has a great effect on the magnitudes of frequencies as exposed to UV radiation but the frequencies in the anti-symmetric are a little bit higher than symmetric case this is because the stiffness magnitude will be definitely larger so that high frequencies will happen. Figure (10) shows the modes of the free vibration of symmetric and anti-symmetric plate for the first mode shapes. It can be observed that 1^{st},3^{rd},5^{th} modes are very much pure bending while the 2^{nd},4^{th} have combined action of bending and torsion as exposed to UV radiation

Table (3): Variation in the natural frequencies at exposure time zero hour for cantilever laminate plate using FEM (ANSYS) .

Natural frequencies (Hz) at time = 0					
Mode No. / Sequence	First freq.	Second freq.	Third freq.	Fourth freq.	Fifth freq.
Symmetric	57.335	176.477	354.552	601.925	719.088
Anti-Sym.	52.653	162.064	325.597	552.767	660.361

Table (4): Variation in the natural frequencies for UV radiation exposure for cantilever laminate plate for five mode shapes of vibration, using FEM (ANSYS)

Conditions		Natural frequencies (Hz) at exposure time (hr)					
		500		1000		2000	
	Mode No.	Sym.	Anti-Sym.	Sym.	Anti-Sym.	Sym.	Anti-Sym.
Ultraviolet	Mod1	43.192	49.855	37.372	45.091	34.146	42.683
	Mod2	132.945	153.454	115.031	138.789	105.102	131.378
	Mod3	267.095	308.298	231.103	278.836	211.157	263.945
	Mod4	453.448	523.4	392.346	473.381	358.482	448.102
	Mod5	541.71	625.278	468.714	565.523	428.26	535.323

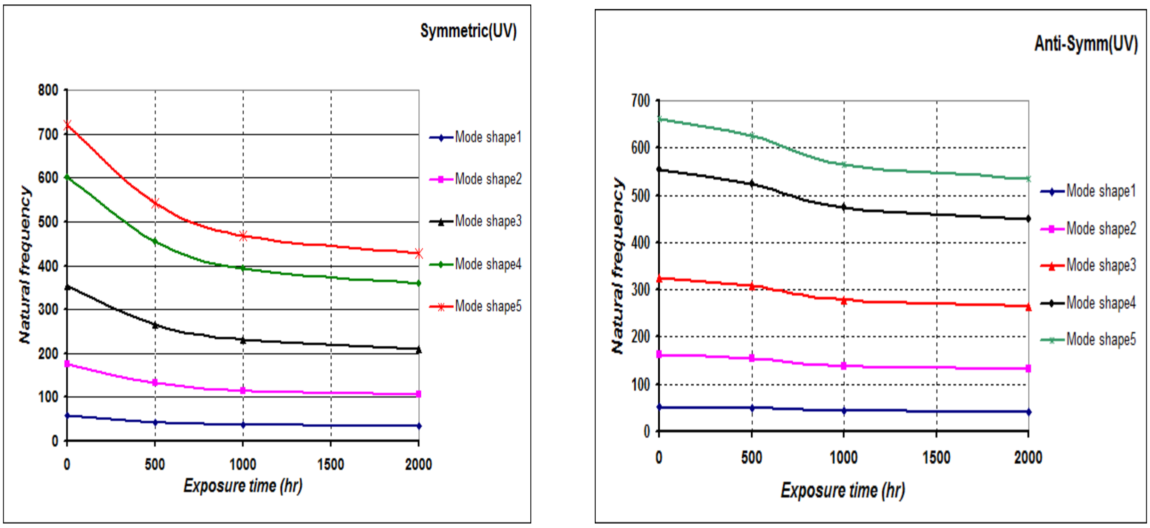


Figure (7) Variation in the natural frequencies with exposure time to UV radiations (a) symmetric (b) anti-symmetric (cantilever plate) .

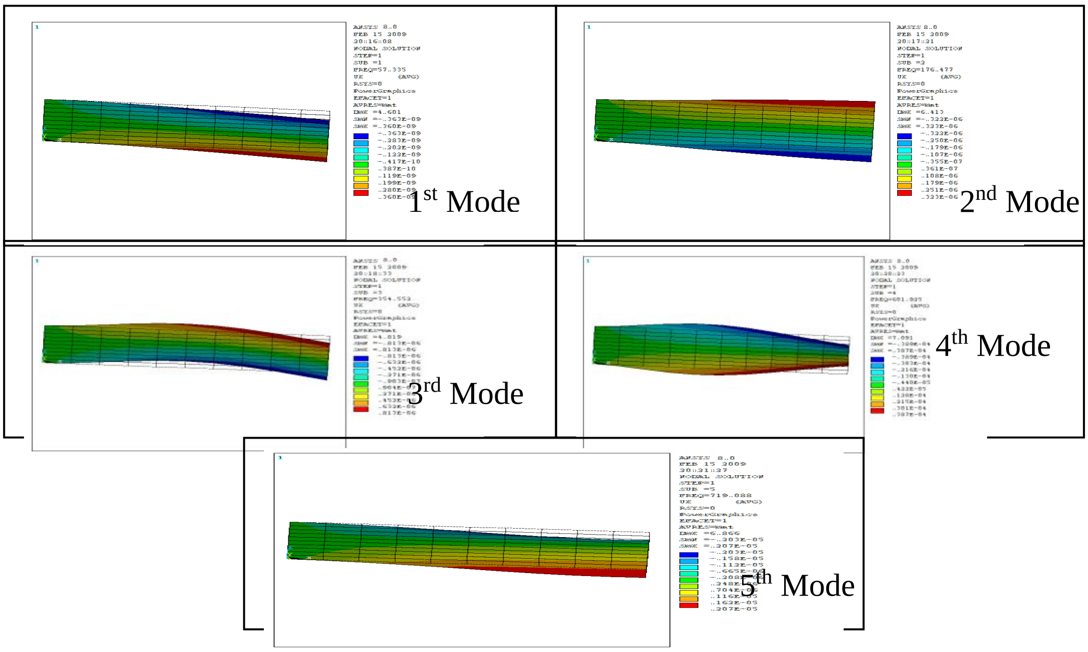


Figure (8): 1st, 2nd, 3rd, 4th, 5th mode shapes of symmetric cantilever plate

Part 2: Laminated Plate with Simply Supported Boundary Condition

The simply supported model is done as the three point bending mode as shown in Figure (9) in order to study the variation in natural frequencies.

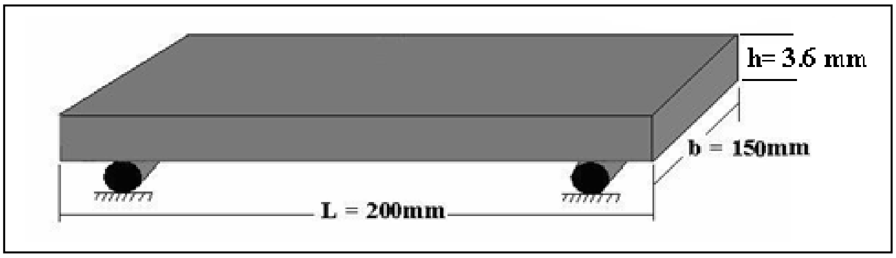


Figure (9): Simply supported laminate plate.

Table (5) shows the variation in the natural frequencies of specimens for free vibration of special case of simply supported laminate plate symmetric and anti-symmetric for zero hour exposure for different mode shapes, while Table (6) shows the effect of ultraviolet radiations on the fundamental natural frequencies for different orientations (cross-ply) of eight layers Symmetric and anti-symmetric plates. Figure (10) shows the effect of ultraviolet radiation exposure on the natural frequencies of the symmetric and anti-symmetric laminates for different exposure time (500,1000,2000 hrs) . The natural frequencies of symmetric plate lose 24% during the first 500 hrs of exposure time while they lose 40% after 2000 hrs of exposure time; anti-symmetric samples lose 5% of the natural frequencies after 500 hrs of exposure time and about 16% of the natural frequencies after 2000 hrs. From these figures it can be concluded that the natural frequencies of simply supported laminate plates decrease with

increased exposure time of UV radiation. This is because the mass of the structure increases in magnitude . Also the fiber orientation has a great effect on the magnitudes of frequencies as exposed to UV radiation, where the frequencies in the anti-symmetric plates are a little bit higher than that of symmetric case, this is because the stiffness magnitude will definitely have some effect to make this happen .When comparing the variation in natural frequencies due to effect of the boundary conditions (cantilever and simply supported) of laminate plate ,due to UV radiation, can be observe that the values of the natural frequencies for simply supported are higher than those for cantilever laminate plate, because this case has quite special boundary conditions in order to be similar to the three point bending specimen test.
Figure (11) shows the first five mode shapes of the special simply supported plate , in which it can be observed a mix of bending and torsion modes .

Table (5): Variation in the natural frequencies at exposure time zero hour for simply supported laminate plate using FEM (ANSYS).

Natural frequencies (Hz) at time = 0					
Mode No. / Sequence	First freq.	Second freq.	Third freq.	Fourth freq.	Fifth freq.
Symmetric	359.967	796.718	930.068	1011	1182
Anti-Sym.	330.569	731.652	854.111	928.843	1085

Table (6): Variation in the natural frequencies for UV radiation exposure for simply supported laminate plate for five mode shapes of vibration, using FEM (ANSYS)

Conditions		Natural frequencies (Hz) at exposure time (hr)					
		500		1000		2000	
	Mode No.	Sym.	Anti-Sym.	Sym.	Anti-Sym.	Sym.	Anti-Sym.
Ultraviolet	Mod1	271.174	313.006	234.633	283.094	214.382	276.976
	Mod2	600.191	692.781	519.315	626.574	474.493	593.114
	Mod3	700.648	808.734	606.235	731.446	553.911	692.386
	Mod4	761.952	879.495	659.278	795.446	602.376	752.968
	Mod5	890.221	1028	770.263	929.352	703.781	925.106

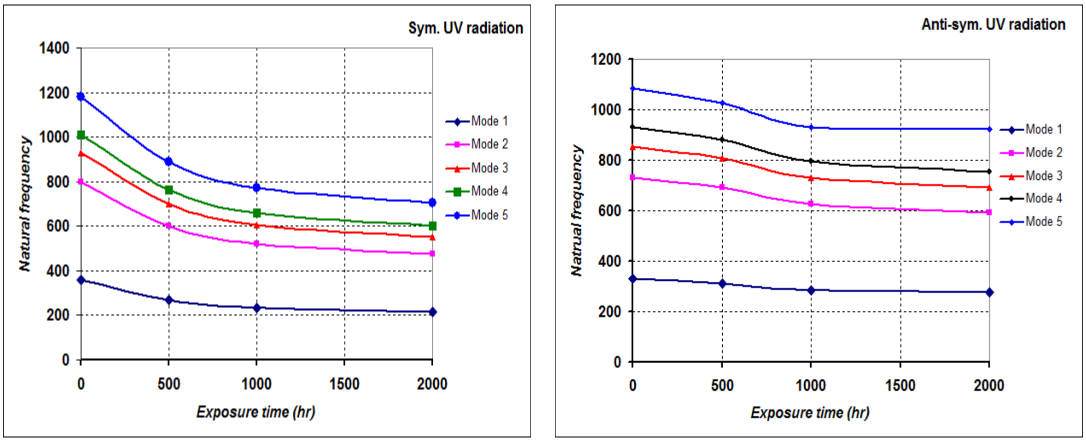
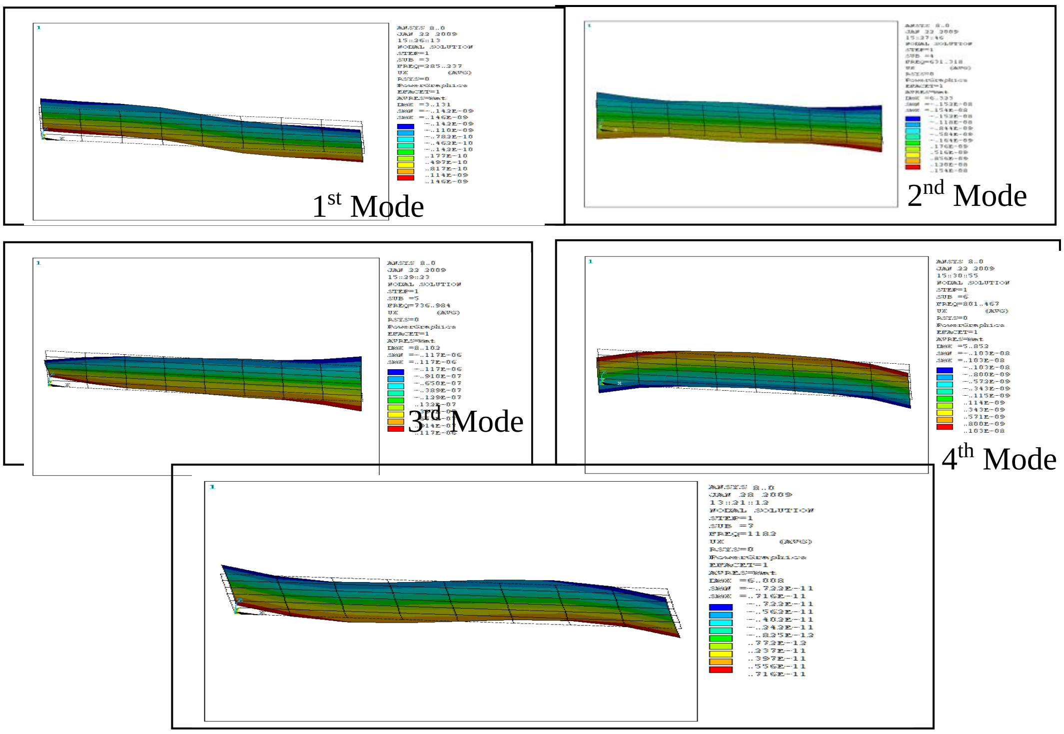


Figure (10) Variation in the natural frequencies with exposure time to UV radiation (a) Symmetric (b) Anti-symmetric (simply supported)



5th Mode

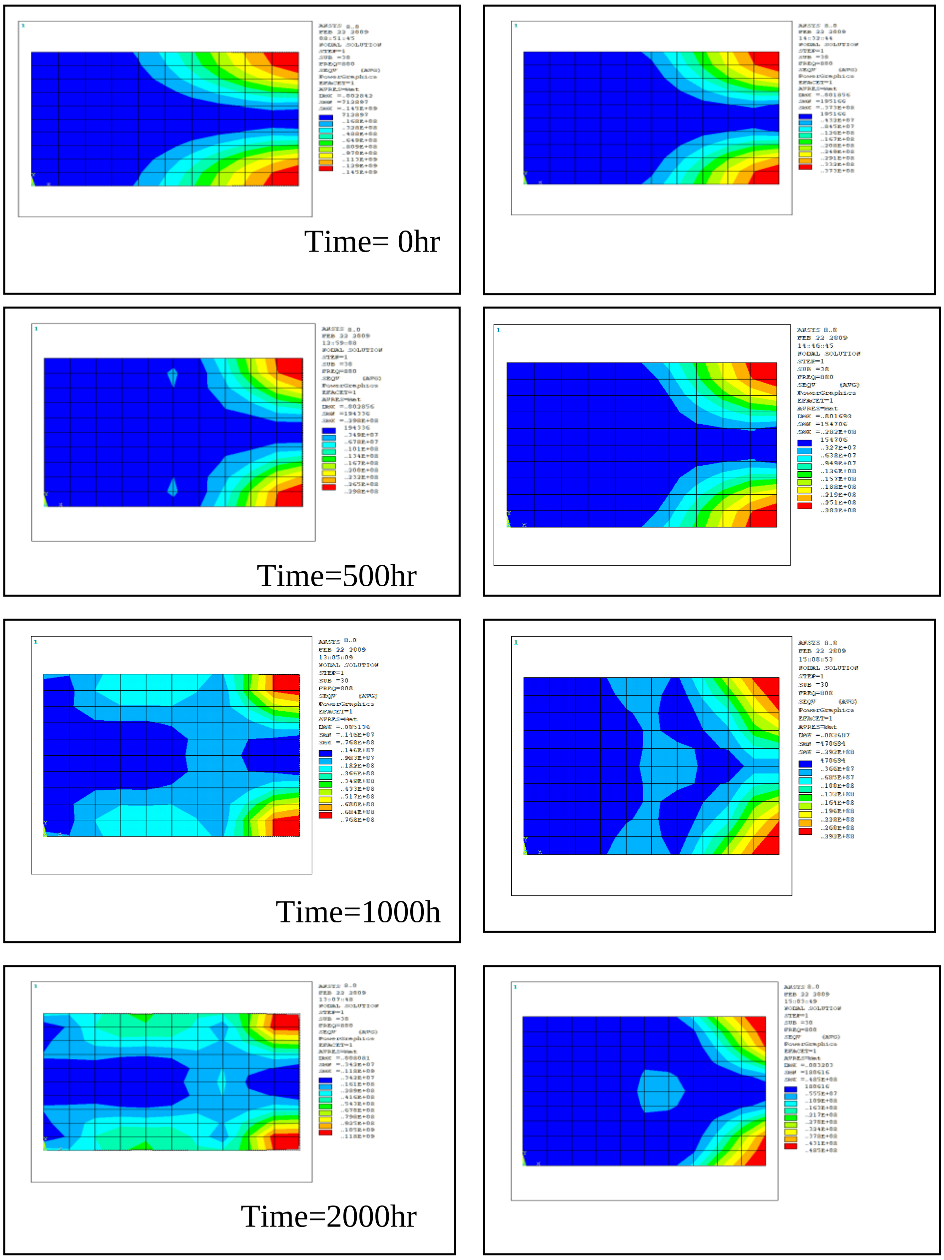
Figure (11) represents the modes of free vibration of symmetric and anti-symmetric simply supported plate for the (1st), (2nd), (3rd), (4th) and (5th) mode shapes of vibration.

Part 3: Results of Effective Stresses:

In this study, the stress distribution is analyzed to investigate the effective maximum stress (Equivalent Von Mises). The study of effective stresses is done when different harmonic loads of magnitudes (500) N and (1000) N and at range of exciting frequency (0-800) Hz are applied to the center of cantilever symmetric and anti-symmetric composite plate, with the effect of UV radiation. Table (7) shows the values of equivalent stresses at point of harmonic load application. It can be shown that for the exposure time of zero hour the effective stresses are directly proportional with increasing the load for symmetric and anti-symmetric laminate cantilever plates. It can be seen from the results that the stress increases with increasing the exposure time and the load because the mass of composite increases and the stiffness of composite decreases due to exposure to UV radiation . Also it can be observed that the fiber orientation has effect, for anti-symmetric cantilever laminate plate the maximum stresses increases with increasing the exposure time and load less than symmetric even mass of composite increases but this decrease is very clear because the fiber orientation depends on the manufacturing of composite materials. Figure (12) shows the stress distribution contours .

Table (7): Values of maximum effective stresses for UV radiation condition at point of harmonic load application

Specimens	Load (N)	Exposure time (hr)	Effective stress (Pa)	
			Symmetric	Anti-symmetric
Original	500	zero	0.145E9	0.373E8
	1000	zero	0.813E9	0.157E9
UV radiation	500	500	0.298E8	0.282E8
		1000	0.768E8	0.292E8
		2000	0.118E9	0.485E8
	1000	500	0.517E9	0.107E9
		1000	0.343E9	0.823E8
		2000	0.271E9	0.817E8



a- Symmetric *b- Anti-symmetric* ***Figure (12): Effective stresses for exposure to UV radiation for cantilever laminate plate (500N)***

Conclusions

The main conclusion obtained from the present work can be summarized as follows:

1. It was found that the three point bending test is very suitable to determine the properties of composite materials.
2. It was noticed that UV radiation reduces the flexural stiffness of the laminate specimens ; because a symmetric laminates lose 64% of their flexure stiffness after
3. The anti-symmetric composite laminate material loses less flexural properties than symmetric composite laminate material .
4. The main failure mechanism of the laminates in bending tests is the breakage of fibers under tensile stress , on the surface opposite to the effect area .
5. The natural frequencies of cantilever and simply supported laminate plates decrease with increased exposure time for the different environmental conditions because of the increase in mass and also because of some reduction in the stiffness .
6. The effective stress due to applied harmonic load for symmetric and antisymmetric specimens increases with increasing the time to UV radiation and load

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