RESEARCH PAPER | Engineering | Volume : 5 | Issue : 5 | May 2015 | ISSN - 2249-555X

Review on: Analysis for Laminated Composite Plate

KEYWORDS: composite beam, bending analysis, Higher order shear deformation theory, Lamina, classical plate theory etc.

Sandhya K. Swami

Department of Civil Engineering, Dr. D.Y. Patil School of Engineering & Technology, Lohgaon, Pune

ABSTRACT *In the present paper, basic terminology of laminated composite plates are discussed. Laminated composite plate structures find numerous applications in aerospace, military and automotive industries. The role of transverse shear is very important in composites, as the material is weak in shear due to its low shear modulus compared to extensional rigidity. Hence, an accurate understanding of their structural behavior is required, such as deflections and stresses. From the present Literature Review the effect of bending, buckling, thermal & hygrothermal on composite plates discussed and different theories like Classical Plate Theory, First Order Shear Deformation Theory, Higher order Shear Deformation Theory etc. for analysis of composite plate are mentioned.*

1. Introduction

Laminated composite materials are increasingly being used in a large variety of structures including aerospace, marine and civil infrastructure owing to the many advantages they offer: high strength/stiffness for lower weight, superior fatigue response characteristics, facility to vary fiber orientation, material and stacking pattern, resistance to electrochemical corrosion, and other superior material properties of composites.

1.1 General:

Composite materials are those formed by combining two or more materials on a macroscopic scale such that they have better engineering properties than the conventional materials, for example, metals. Some of the properties that can be improved by forming a composite material are stiffness, strength, weight reduction, corrosion resistance, thermal properties, fatigue life, and wear resistance. Most manmade composite materials are made from two materials: a reinforcement material called fiber and a base material, called matrix material. The matrix material keeps the fibers together, acts as a load-transfer medium between fibers, and protects fibers from being exposed to the environment. Matrix materials have their usual bulk-form properties whereas fibers have directionally dependent properties.

Composite materials are commonly formed in three different types: (1) fibrous composites, which consist of fibers of one material in a matrix material of another; (2) particulate composites, which are composed of macro size particles of one material in a matrix of another; and **(3)** laminated composites, which are made of layers of different materials, including composites of the first two types. The particles and matrix in particulate composites can be either metallic or nonmetallic. Thus, there exist four possible combinations: metallic in nonmetallic, nonmetallic in metallic, nonmetallic in nonmetallic, and metallic in metallic. A lamina or ply is a typical sheet of composite material. A laminate is a collection of laminae stacked to achieve the desired stiffness and thickness. The sequence of various orientations of a fiber-reinforced composite layer in a laminate is termed the lamination scheme or stacking sequence. The layers are usually bonded together with the same matrix material as that in a lamina. If a laminate has layers with fibers oriented at 30 or 45, it can take shear loads. The larnination scheme and material properties of individual lamina provide an added flexibility to designers to tailor the stiffness and strength of the laminate to match the structural stiffness and strength requirements. Fiber reinforced composite materials consists of fibers of significant strength and stiffness embedded in a matrix with distinct boundaries between them. Both fibers and matrix maintain their physical and chemical identities, yet their combination performs a function which cannot be done by each constituent acting singly. fibers of fiber reinforced plastics (FRP) may be short or continuous. It appears obvious that FRP having continuous fibers is indeed more efficient. Classification of FRP composite materials into four broad categories has been done accordingly to the matrix used. They are polymer matrix composites, metal matrix composites, ceramic matrix composites and carbon/carbon composites. Polymer matrix composites are made of thermoplastic or thermo set resins reinforced with fibers such as glass, carbon or boron. A metal matrix composite consists of a matrix of metals or alloys reinforced with metal fibers such as boron or carbon. Ceramic matrix composites consist of ceramic matrices reinforced with ceramic fibers such as silicon carbide, alumina or silicon nitride. They are mainly effective for high temperature applications. This project is deal with fiber reinforced polymer matrix composite materials.

2. Review of Literature

A detailed study of the available literature was conducted to know the present state of knowledge available in the open literature, which can assist in achieving the present goals effectively.

Borkar *et.al* [1]carried out bending analysis of simply supported composite beam by using refined beam theories. The theory accounts for the parabolic variation of shear strain through the depth of beam, hence avoid need of shear correction factor. The governing differential equations and boundary conditions are obtained by using the principle of virtual work. Sayyad [2] is used unified shear deformation theory to analyze simply supported thick isotropic beams for the transverse displacement, axial bending stress, transverse shear stress and natural frequencies. This theory enables the selection of different in-plane dis-

Volume : 5 | Issue : 5 | May 2015 | ISSN - 2249-555X

placement components to represent shear deformation effect. Kant *et.al* [3] present The theoretical model to incorporates laminate deformations which account for the effects of transverse shear deformation, transverse normal strain/stress and a nonlinear variation of in-plane displacements with respect to the thickness coordinate. Dharma Raju *et.al* [4] work an analytical procedure is developed, to investigate the Transient characteristics of different laminated composite plates based on higher order shear displacement model with zig-zag function. This function improves slope discontinuities at the interfaces of laminated composite plates. Dharma Raju *et.al* [5] present an analytical procedure is developed to investigate the bending characteristics of laminated composite plates based on higher order shear displacement model with zig-zag function. This zig-zag function improves slope discontinuities at the interfaces of laminated composite plates. The equation of motion is obtained using the dynamic version of Hamilton's principle. The solutions are obtained using Navier's and numerical methods for anti-symmetric cross-ply and angle-ply laminates with a specific type of simply supported boundary conditions. Sayyad *et.al* [6] present Trigonometric shear deformation theory is applied for bending and free vibration analysis of thick plate. In this theory in plane displacement field uses sinusoidal function in terms of thickness coordinate. It accounts for realistic variation of the transverse shear stress through the thickness and satisfies the shear stress free surface conditions at the top and bottom surfaces of the plate. Chikalthankar *et.al* [7] In this paper a Trigonometric Shear Deformation Theory (TSDT) for the analysis of orthotropic plate, taking into account transverse shear deformation effect is presented. Present theory exactly satisfies stress boundary conditions on the top and bottom of the plate. In this displacement-based, trigonometric shear deformation theory, the in-plane displacement field uses sinusoidal function in terms of thickness coordinate to include the shear deformation effect. It discuss for static flexural analysis of simply supported thick orthotropic plates for uniformly distributed loading case is compared with those of other refined theories and exact solution from theory of elasticity. Naik *et.al* [8] In this paper a new Trigonometric shear deformation theory is developed for the static flexure of thick isotropic beam, considering Trigonometric functions in terms of thickness coordinate associated with transverse shear deformation effect. The most important feature of the theory is that the transverse shear stress can be obtained directly from the constitutive relations satisfying the shear stress free surface conditions on the top and bottom of the beam. In this paper result compare for static flexure of simply supported isotropic beam subjected to various loading cases are compared with those of other refined theories and exact solution. Sayyad *et.al* [9] presents a variationally consistent an exponential shear deformation theory for the bi-directional bending and free vibration analysis of thick plates, this theory presented herein is built upon the classical plate theory. In this displacement-based, refined shear deformation theory, an exponential functions are used in terms of thickness co-ordinate to include the effect of transverse shear deformation and rotary inertia. The number of unknown displacement variables in the proposed theory are same as that in first order shear deformation theory. The simply supported thick isotropic square and rectangular plates are considered for studies. It also investigate the bending and dynamic response of thick isotropic square and rectangular plates using an exponential shear deformation theory. Suresh Kumar *et.al* [10] developed an analytical procedure, to investigate the free vibration characteristics of different laminated composite plates based on higher order shear displacement model with zig-zag function. The material properties of graphite epoxy used for each lamina of the laminated composite plate. As the number of layers increase without changing the total thickness, decreases the extensional coupling effect and thus increase the fundamental frequencies. This effect of the number of layers is most pronounced for angle-ply laminated plates. It is seen that the coupling between bending and stretching had a significant effect on the behavior of antisymmetric laminates with few Lamina. Khoa [11] presents rectangular non–conforming element which is based on Reddy's higher-order shear deformation plate theory. Although the plate theory is quite attractive but it could not be exploited as expected in finite-element analysis. This is due to the difficulties associated with satisfaction of inter-elemental continuity requirement and satisfy zero shear stress boundary conditions of the plate theory. It has four nodes and each node contains 7 degrees of freedom. It gives the size of mesh and the convergence of method have been involved by thickness ratio h/a. It is seen that the size of mesh is needed to increase and the convergent speed is reduced at higher h/a. Thai *et.al* [12] This paper presents a novel finite element formulation for static, free vibration and buckling analyses of laminated composite plates. The idea relies on a combination of node based smoothing discrete shear gap method with the higher-order shear deformation plate theory (HSDT). The formulation uses only linear approximations and its implementation into finite element programs is quite simple and efficient. Swaminathan *et.al* [13] In this paper analytical formulations and solutions for the static analysis of simply supported antisymmetric angle ply laminated composite plates using higher order shear deformation theory with nine degrees of freedom are presented. The theoretical model presented herein incorporates laminate deformations, which account for the effect of transverse shear deformation. The equations of equilibrium are obtained using Principle of Minimum Potential Energy. It is observed that higher order model with Nine DOF predicts the local behavior and transverse stresses accurately as compared to other theories for 3 D elasticity solutions. Ahmed *et.al* [14] present work on the behavior of laminated composite plates under transverse loading using an eight-node diso-parametric quadratic element based on First Order Shear Deformation Theory, the element has six degrees of freedom at each node: translations in the nodal x, y, and z directions and rotations about the nodal x, y, and z axes . The static analysis includes the parametric studies on laminated plates to estimate the maximum deflection. The parametric study represented by variation in (aspect ratio, layer orientation, layer number, dimension of the plate and mesh size). Jeffrey *et.al* [15], Rastgaar *et.al* [21] Huang *et.al* [16] and Gopichand [19] discussed analytical modeling and bending of laminated rectangular and triangular plates. Ghugal *et.al* [17] presents a trigonometric shear deformation theory for the free vibration of thick orthotropic square and rectangular plates. In this displacement based theory the in-plane displacement field uses sinusoidal function in terms of thickness coordinate to include the shear deformation effect. The cosine function in terms of thickness coordinate is used in transverse displacement to include the effect of transverse normal strain. The most important feature of the theory is that the transverse shear stress can be obtained directly from the constitutive relations satisfying the shear stress free surface conditions on the top and bottom surfaces of the plate. Governing equations and boundary conditions of the theory are obtained using the principle of virtual work. Viswanathan [18] study for Free vibration of laminated antisymmetric angle ply an-

Volume : 5 | Issue : 5 | May 2015 | ISSN - 2249-555X

nular circular plates with inclusion of first order shear deformation theory using a spline function approximation by applying a point collocation method. The equations of motion of the plates are derived using first order shear deformation theory. Bhattacharyya *et.al* [20] calculate stress, deformation, and to study on the vibration of plate under external stimuli. Dharma Raju *et.al* and Klaus [22, 24] paper an analytical procedure is developed to investigate the Thermal characteristics of laminated composite plates under thermal loading based on higher-order displacement model with zig-zag function, without enforcing zero transverse shear stresses on the top and bottom faces of the laminated plates. This function improves slope discontinuities at the interfaces of laminated composite plates. the influence of the thermal field is very predominant and induces a high transverse normal stress at the interfaces, which may cause failure of the weak adhesive bond. Ghugal *et.al* [23] The transverse displacements of orthotropic and antisymmetric two layer cross-ply laminated plates subjected to non-linear thermal load in combination with transverse mechanical load is presented using trigonometric shear deformation theory for various aspect ratios. Effect of change of aspect ratio on orthotropic and two layer antisymmetric cross ply laminated plates under uniform non-linear thermal load across the thickness of plate and uniform transverse mechanical load has been studied by using trigonometric shear deformation theory. The results obtained by this theory are compared with classical plate theory, first order shear deformation theory and higher order shear deformation theory. It is observed from this investigation that the classical plate theory is sufficient for transverse displacements when the laminates are subjected to pure non-linear thermal load without consideration of transverse mechanical load. Singh *et.al* and Patel *et.al* [25] [26] Temperature and moisture variations often represent a significant factor, and sometimes the predominant causes of failure of composite structures. Hygrothermal analysis of laminated composite plates has been done by using an efficient higher order shear deformation theory. Akavci [27] The bending analysis of cross-ply rectangular thick plates resting on elastic foundation has been done by using first order shear deformation theory. Torabizadeh *et.al* [28], Reddy *et.al* [29], and Bui [30] discussed bending and buckling analysis of composite plate. Banakar *et.al* [31] discuss Mechanical Properties of Angle Ply Laminated Composites. Sayyad [32] present a refined shear deformation theory is developed for the static flexure and free vibration analysis of thick isotropic beams, considering sinusoidal, hyperbolic and exponential functions in terms of thickness co-ordinate associated with transverse shear deformation effect. Rotation of normal is taken as combined effect of shear slope and bending slope at the neutral axis. He *et.al* [33] gives review on the study of tapered laminated composite structures with various plate theories which are already mentioned above, these tapered structures are mainly used in aircraft industry. Patel and Vadaliya [34] present a review to the recently developed finite element analysis which is based on various laminated theories for the free vibrations and dynamics, buckling and large deformation analysis of composite plates. Reddy *et.al* [35] carried out a number of finite element analysis for various side to thickness ratios, aspect ratios and modulus ratio to study the effect of transverse shear deformation on deflection and stresses of laminated composite plates subjected to uniformly distributed loads.

From the Literature Review we can use Higher order shear deformation Theory for analysis of composite Laminate Plate. We can analyze bending, shear, thermal, hygrothermal, bending effects on composite plate. Finite element method is also significantly used for the analysis of vibration and dynamics, buckling and failure damage analysis.

3. Methods for analysis of Composite Laminated plate:
Following Methods are used for analysis of composite laminated plate which are generally used.

3.1 Analytical methods:
Analysis by using Different theories such as Classical Plate Theory, First Order Shear Deformation Theory, Higher Order Shear Deformation Theories etc.

3.2 Computational Techniques
A brief summary of Analytical methods is given as follows,

3.1.1 Classical Plate Theory:
Classical plate theory (CPT), which is also known as Love-Krichhoff plate. Theory, in which it is assumed that lines which are normal to neutral surface before deformation remain straight and normal to neutral surface after deformation. CPT has been used for variety of problems. In this theory, effects of transverse stresses are not accounted for. Thick plate analysis, transverse stresses play an important role, Since CPT does not include transverse stresses effects, it fails to accurately analyze thick plates. This deficiency is more pronounced in composite plates, which have relatively low shear modulus compared to in-plane modulus. Despite of its limitation to take into account shear deformations; CPT was extended for composite plate analysis because of its simplicity.

Assumptions:
- Arbitrary number of layer of orthotropic laminae
- Laminates are perfectly bonded, no slip relative to each other
- Bond between the laminae is thin
- No shear deformation
- Plate acts as a single layer
- Plate is thin
- Displacements are small
- Plate has constant thickness
- Normal to the midplane before deformation remain straight and normal to the midplane during and after deformation ($\gamma_{xz}, \gamma_{yz}, \varepsilon_{zz} = 0$)

3.1.1.2 First Order Shear Deformation Theory (FSDT):
A new theory was proposed known as Reissner-Mindlin plate theory and also known as first order shear Deformation Theory [FSDT]. In this theory the in-plane displacement very linearly through the cross section and the normal to the midplane before deformation need not b normal to midplane after deformation. It means that the normals are allowed to rotate. This theory uses a shear correction factor in the analysis. FSDT contains five unknowns. This theory is widely used for the plate analysis. This theory has been applied to static, free vibration, transient and low velocity impact analysis. Finite element model have been developed and used to solve the plate problems with various boundary conditions. This theory is simple to use and predicts good global behavior. It predicts constant shear stress across the cross section. It may be noted that the shear correction factor is problem dependent.

3.1.3 Higher Order Shear Deformation Theories:
A new class of plate theories was developed using polynomials to express the displacements. These theories are also

Volume : 5 | Issue : 5 | May 2015 | ISSN - 2249-555X

called as Higher Order shear Deformation.

The role of transverse shear is very important in composites, as the material is weak in shear due to its low shear modulus compared to extensional rigidity. Hence, an accurate understanding of their structural behavior is required, such as deflections and stresses.

Analysis of laminated composite plate can be done with the help of MATLAB and ANSYS software.

4. Conclusion:

From the study of analysis of composite beam, we can conclude that for bending, buckling analysis and effect of thermal and hygrothermal analysis higher order shear deformation theory is more effective as compared to other methods of analysis of composite beams. By using finite element model of the plate for the various side to thickness ratio, aspect ratio and modular ratio can give more accurate results.

REFERENCE

1. R. R. Borkar, A. S. Sayyad, S. M. Ghumare. Assessment of Refined Beam Theories For The Bending Analysis of Composite Beam. International Journal of Advanced Technology In Civil Engineering, Issn: 2231 –5721, Volume-2, Issue-1, 2013., Pg 73-78 | 2. A. S. Sayyad. Comparison of Various Refined Beam Theories For The Bending And Free Vibration Analysis of Thick Beams. Applied And Computational Mechanics 5 (2011) Pg 217–230 | 3. T. Kant, K. Swaminathan. Analytical Solutions For The Static Analysis of Laminated Composite and Sandwich Plates Based On A Higher Order Refined Theory. Composite Structures 56 (2002) 329–344 | 4. Dharma Raju.T, Suresh Kumar.J. Transient Analysis of Composite Laminated Plates Using Higher-Order Shear Deformation Theory With Zig-Zag Function. International Journal of Applied Engineering Research, Dindigul Volume 2, No 2, 2011., 562-569 | 5. T. Dharma Raju and J. Suresh Kumar. Bending Analysis of Composite Laminated Plates Using Higher-Order Shear Deformation Theory With Zig-Zag Function. Arpn Journal of Engineering And Applied Sciences. Vol. 6, No. 12, December 2011, 106-110 | 6. I.I. Sayyad, S.B. Chikalthankar And V.M. Nandedkar. Bending And Free Vibration Analysis of Isotropic Plate Using Refined Plate Theory. Bonfring International Journal of Industrial Engineering And Management Science, Vol. 3, No. 2, June 2013,40-46 | 7. S.B.Chikalthankar, I.I.Sayyad, V.M.Nandedkar. Analysis of Orthotropic Plate By Refined Plate Theory. International Journal of Engineering And Advanced Technology (Ijeat) Issn: 2249 – 8958, Volume-2, Issue-6, August 2013, 310-315 | 8. Uday P. Naik, Atteshamuddin S. Sayyad and Pratap N.Shinde. Refined Beam Theory For Bending of Thick Beams Subjected To Various Loading. Elixir Appl. Math. 43 (2012) 7004-7015 | 9. A. S. Sayyada,, Y. M. Ghugal. Bending and Free Vibration Analysis of Thick Isotropic Plates By Using Exponential Shear Deformation Theory. Applied and Computational Mechanics 6 (2012) 65–82 | 10. J. Suresh Kumar, T. Dharma Raju and K. Vijaya Kumar Reddy. Vibration Analysis of Composite Laminated Plates Using Higher-Order Shear Deformation Theory With Zig-Zag Function. Indian Journal of Science and Technology, Vol. 4 No. 8 (Aug 2011), 960-966 | 11. Ngo Nhu Khoa. Finite Element Analysis of Laminated Composite Plates Using High Order Shear Deformation Theory. Vietnam Journal of Mechanics, Vast, Vol. 29, No. 1 (2007),Pp. 47 – 57 | 12. Chien H. Thai A, Loc V. Tran A, Dung T. Tran C, T. Nguyen-Thoi A,B, H. Nguyen-Xuan. Analysis of Laminated Composite Plates Using Higher-Order Shear Deformation Plate Theory and Node-Based Smoothed Discrete Shear Gap Method. Applied Mathematical Modelling 36 (2012) 5657–5677 | 13. K. Swaminathan and Govind R. Sangwai. Higher Order Refined Model With 9 Dof For The Transverse Stress Analysis of Antisymmetric Angle Ply Laminated Composite Plates. International Journal of Earth Sciences and Engineering Issn 0974-5904, Vol. 02, No. 04, August 2009, Pp. 367-375 | 14. Junaid Kameran Ahmed, V.C. Agarwal, P.Pal, Vikas Srivastav. Static and Dynamic Analysis of Composite Laminated Plate. International Journal of Innovative Technology and Exploring Engineering (Ijitee) Issn: 2278-3075, Volume-3, Issue-6, November 2013.56-60 | 15. Jeffrey V. Kouri & Satya N. Atluri. Analytical Modelling of laminated Composites. Composites Science and Technology 46 (1993)335-344 | 16. Mei Huang, Takeshi Sakiyama, Hiroshi Matsuda, Chihiro Morita. An Analysis of bending problem of laminated Rectangular and Triangular plates. Reports of the Faculty of Engg., Nagasaki University, Vol 32, No.58, 115-123 | 17. Y. M. Ghugal. and A. S. Sayyad. Free Vibration of Thick Orthotropic Plates Using Trigonometric Shear Deformation Theory. Latin American Journal of Solids and Structures 8(2011) 229 – 243 | 18. K.K.Viswanathan, Member, Iaeng Saira Javed and Zainal Abdul Aziz. Free Vibration of Antisymmetric Angle-Ply Laminated Annular Circular Plate. Proceedings of The World Congress on Engineering 2013 Vol III, Wce 2013, July 3 - 5, 2013, London, U.K. | 19. D. Gopichand, T. N. Charyulu. Analysis of FRP Composite Cylinders. International Journal of Mechanical Engg. Robotics Research, Vol. 1, No. 3, Oct. 2012, 486-498. | 20. Bhattacharyya A. and Mukhopadhyay B. Classical Plate Theory: Asymptotic Approach. International Journal of Physics and Mathematical Sciences. 2013 Vol. 3 (2) April-June, Pp.115-121 | 21. Rastgaar Aagaah M., Nakhaie Jazar G., Nazari G., Alimi M. Third Order Shear Deformation Theory for Modelling of Laminated Composite Plates. International Congress and Exposition on Experimental and Applied Mechanics, Costa Mesa, CA, June 2004, 7-10 | 22. T.Dharma Raju1 and J. Suresh Kumar. Thermal Analysis of Composite Laminated Plates Using Higher-Order Shear Deformation Theory With Zig-Zag Function. International Journal of Science & Emerging Technologies Vol-2 No. 2 November, 2011, 53-57 | 23. Yuwaraj M. Ghugal 1, Sanjay K. Kulkarni. Effect of Aspect Ratio On Transverse Displacements For Orthotropic and Two Layer Laminated Plates Subjected To Non-Linear Thermal Loads and Mechanical Loads. International Journal of Civil and Structural Engineering Volume 3, No 1, 2012, 186-196 | 24. Klaus Rohwer, Raimund Rolfes, Holger Sparr. Higher-Order Theories For Thermal Stresses In Layered Plates. International Journal of Solids and Structures 38 (2001) 3673-3687 | 25. S.K. Singh, A. Chakrabarti. Hygrothermal Analysis of Laminated Composite Plates By Using Efficient Higher Order Shear Deformation Theory. Journal of Solid Mechanics Vol. 3, No. 1 (2011) Pp. 85-95 | 26. B.P. Patel, M. Ganapathi , D.P. Makhecha. Hygrothermal Effects On The Structural Behaviour of Thick Composite Laminates Using Higher-Order Theory. Composite Structures 56 (2002) 25–34 | 27. S. Seren Akavci. The First Order Shear Deformation Theory For Symmetrically Laminated Composite Plates On Elastic Foundation. The Arabian Journal For Science and Engineering, Volume 32, October 2007, 341-348 | 28. M. A. Torabizadeh, A. Fereidoon. Navier type Bending Analysis of General Composite Laminates Under Different Type of Thermomechanical Loading. MECHANIKA 2013, Vol 19 (4),380-389 | 29. Ajay Kumar Reddy, B. Sidda Reddy, Dr. K. Tirupaathi Reddy, N. Upendra. Buckling Analysis of Laminated Composite Plates Using Higher Order Theory. International Journal of Engg. Science & Tech. Vol (5) No. 10, Oct 2013, 1769-1779 | 30. Tinh Quoc Bui. Buckling Analysis of Simply Supported Composite Laminates Subjected to an In plane Compression Load by a Navel Mesh- Free Method. Vietnam Journal of Mechanics, VAST, Vol 33, No 2 (2011), pp. 65-78 | 31. Prashanth Banakar, H.K. Shivanand and H.B. Niranjan. Mechanical Properties of Angle Ply Laminated Composites- A Review. International Journal of Pure and Applied Sciences and Technology 9(2) (2012), Pp. 127-133 | 32. A.S. Sayyad. Static Flexure and Free Vibration Analysis of Thick Isotropic Beams Using Different Higher Order Shear Deformation Theories. Int. J. of Appl. Math and Mech. 8 (14):2012, 71-87. | 33. K. He, S.V. Hoa , R. Ganesan. The study of tapered laminated composite structures: a review. Composites Science and Technology 60 (2000) 2643-2657 | 34. Niral R. Patel, A. D. Vadaliya. A Review on Recent Development In Finite Element Analysis For Laminated Composite Plates. PARIPEX -Indian Journal of Research Volume 2 Issue 4 April 2013 | 35. B. Sidda Reddy, A. Ramanjaneya Reddy, J. Suresh Kumar and K. Vijaya Kumar Reddy. Bending analysis of laminated composite plates using finite element method. International Journal of Engineering, Science and Technology Vol. 4, No. 2, 2012, pp. 177-190 | 36. Timoshenko, S. P. and Krieger, S. W., "Theory of Plates and Shell", 1959,McGraw Hill, New York. | 37. Reddy JN. Mechanics of laminated composite plate: theory and analysis. New York: CRC Press; 1997.