BUCKING LOAD ON A SIMPLY SUPPORTED COMPOSITE PLATE USING BIAXIAL COMPRESSION FOR VARIOUS ASPECTS AND MODULE RATIOS

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Abstract- **The usage of a numerical approach is performed in order to examine the buckling load in rectangular laminated plates that are loaded in a biaxial direction. A Fortran program that is based on finite elements (FE) has been developed for the purpose of performing buckling analysis on thin rectangular laminated plates within the framework of classical laminated plate theory (CLPT). This was done in order to fulfill the objective of doing the analysis. Buckling stresses of composite plates that are generally stacked have been the subject of research that has been carried out. The use of the energy strategy, which is characterized by a finite element model, is what allows for the analysis and resolution of the problem. This method, which includes the use of quadrilateral components, makes use of a model that consists of four nodes. There are three degrees of freedom for each unique element at each node in the network. When it comes to degrees of freedom, the following are the degrees of freedom that are involved: rotation, lateral displacement, and rotation around the axes, and similarly. The technique that is now being carried out is subjected to analysis and verification with other works that are available in the literature. This is done in order to ensure that the approach is accurate. This demonstrates that the finite element method that was used is trustworthy since it has a high degree of concordance with the data that is not just available but also readily available.**

Index Terms- **Finite element, Fortran program, Buckling load, Simply supported, Composite plate.**

I. INTRODUCTION

In solid mechanics, when a plate is compressed across and/or in a plane, it changes shape in two ways: flexural deformation happens when cross-sections rotate, and shear deformation happens when sections or layers slide across each other. The deformation depends on two factors: the ratio of thickness to length and the ratio of elastic to shear moduli. When the thickness-to-length ratio is low, the plate is considered thin and deforms mostly by bending. On the other hand, when both the thickness-to-length and modulus ratios are high, the plate deforms mostly by shear. The higher ratio of in-plane modulus to transverse shear modulus makes shear deformation effects stronger in composite laminates when they are stressed in both directions compared to isotropic plates under the same loading conditions. It is not possible to solve the three-dimensional laminate theories where each layer is thought of as a uniformly uneven and nonhomogeneous medium (Reddy). Anisotropy in layered composite structures often leads to complicated responses when loaded in different ways, creating complicated connections between types of displacement like stretching, bending, and shear. Unless there are specific circumstances, it is not possible to fully answer a problem in three dimensions because it is too complicated, requires too much computing power, and creates too much data, especially for hybrid structures. There are a lot of ideas out there that deal with horizontal shear and normal loads, like the ones Mindlin came up with in 1951. We can't look at all of these here. Classical works that lay the groundwork for the current case will be the only ones that are looked at. Phan and Reddy say that these theories can be broken down into two main groups based on the fields they assume: (1) theories that are based on stress and (2) theories that are based on movement. Theories based on stress are based on stress fields that are thought to change linearly with the width of the plate, while theories based on displacement are based on a field of displacement. This study is talked about in Yang, Norris, and Stavsky; Whitney and Pagano; and Phan and Reddy. Different ideas about plate analysis have been made based on different assumptions about displacement fields. There are three main types of theories: individual layer theories (IL), equivalent single layer theories (ESL), and three-dimensional elasticity solution methods. By making certain assumptions, these groups can be further broken down into sub-theories. The second group includes the first-order shear deformation theory (FSDT), the higher-order shear deformation theory (HSDT), and the classical laminated plate theory (CLPT). See Seloodeh and Karami Noor Omurtag (2000) and Huang and Thambiratnum for more information. The Dorgruoglu and The research in this study used the classical laminated plate theory (CLPT), which doesn't take into account crosswise shear deformations. This idea says that the laminate is under plane stress, that each lamina has linear flexibility, and that the layers stick together completely. In the standard layered plate theory, the line that is normal to the mid-surface stays straight and parallel to the mid-surface both before and after it changes shape.

Because of this, this theory can be used to study how thin laminates buckle. We made a Fortran program and checked that the finite element solutions for biaxial buckling of thin laminated rectangular plates are correct and converge. We did this by comparing them to different theory and experimental solutions and by creating new numerical data.

II. RESEARCH OBJECTIVE

As part of this study, the following goals are carefully looked at: A look at a number of plate theories and methods used to guess how layered plates will behave when they are stressed to the point of breaking. Coming up with a theory model to predict bending loads in a thin layered plate is a new and original way of doing things. An improvement and use of the finite element method to look at reinforced rectangular plates when they are under bending stress.

It might be worth doing more study on what happens to layered plates when they are coupled between bending and extension and/or turning.

III. METHODS

In this study, the finite element method is used to guess the bending loads and ways that bonded rectangle plates will move. Four-noded components are used in this way of thinking about things. The four-noded bilinear rectangle parts of a plate make up these parts. At each node, there are three degrees of freedom for each part. The degrees of freedom are the movement (w) from side to side and the rotations (phi) and shifts (shi) around the x and y axes. The energy method is where the finite element technique gets its ideas. The following steps can be used to sum up the numerical method:

- The element's choice and shape play a role.
- In order to create both element stiffness and differential matrices, a finite element model was made using the energy method.
- Using the rules of non-dimensionality to change the element matrices into their non-dimensional forms.
- Putting together the element stiffness and differential matrices to get the global matrices that go with them.
- Adding border conditions that are needed for the edges of the plates.
- The problem can be fixed with the right tools. In this case, FORTRAN and ANSYS were used.

IV. CONVERGENCE STUDY

There is a convergence analysis that can be done to find the best number of plate elements in any direction (i.e. mesh size or discretization) that should be used to get an accurate calculation of the bending loads. A number of factors are taken into account in order to figure out the right number of finite elements. Some of these things to think about are the material's properties, the plate's size, the lamination method, the border conditions, and the computer's RAM's store space. One could notice that the number of limited components needed goes up as the number of modes goes up. Because of this, it makes sense to think that the higher forms will need more parts. All the studies talked about in this thesis were done with the idea that the plate had been subjected to support conditions that were the same or similar on all four sides. Along with a clamped – clamped (CC) edge condition, a simply – simply supported (SS) edge condition is also used, as well as a clamped – simply supported (CS) edge condition. You can find out more in the table below.

Table 1: Boundary conditions.

Boundary Conditions	Plate dimensions in y – coordinate $x = 0, x = a$	Plate dimensions in x – coordinate $y = 0, y = b$
CC	$w = \phi = \psi = 0$	$w = \phi = \psi = 0$
SS	$w = \psi = 0$	$w = \phi = 0$
CS	$w = \phi = \psi = 0$	$w = \phi = 0$

A study of the convergence of the non-dimensional buckling load of a simply supported square isotropic plate made of stainless steel with a length to thickness ratio of twenty (a/h=20) is shown in the table 2 below. The material parameters that are being considered are as follows: material 1:

$E_y/E_x = 1.0\,, G_{xy}/E_x = G_{yz}/E_x = G_{xz}/E_x = 0.4\,, v_{xy} = 0.25$

From the data in Table, we can see that the bending parameter values tend to get closer together as the number of elements in the mesh grows (that is, as the mesh size shrinks over time). So far, it looks like a mesh that is put over the plate is enough for the job (i.e., there is a difference of less than 1.32% between this mesh result and the smallest mesh result that is currently available). It was found that a mesh size of is enough to correctly predict the first seven types of bending stress after a lot of thought. The only types of bending that work in real life are the first three.

Table 2 : Convergence study of non – dimensional modes of buckling of simply supported (SS) isotropic square plate with a/h=20.

Mesh Size	Mode Sequence Number						
	1	2	3	4	5	6	7
2 × 2	30.69	76.89	83.18	83.49	94.71	94.95	101.78
3 × 3	32.64	79.12	79.18	117.58	179.04	189.78	191.05
4 × 4	33.60	82.38	82.44	123.22	165.70	166.35	192.53
5 × 5	34.10	84.08	84.14	127.71	168.69	168.92	202.10
6 × 6	34.39	85.10	85.15	130.85	170.41	170.52	208.35
7 × 7	34.58	85.75	85.79	133.03	171.55	171.61	212.50
8 × 8	34.70	86.19	86.23	134.57	172.34	172.39	215.79
9 × 9	34.78	86.50	86.53	135.68	172.92	172.97	218.07
10 × 10	34.84	86.72	86.75	136.52	173.35	173.40	219.78

There were a lot of comparisons that were done in order to figure out whether or not the present FE strategy is correct, authentic, and suitable to the circumstance that is now taking place. Both the theoretical data, as well as the results of the ANSYS simulation, are included into the final analysis and comparison.

V. RESULTS AND DISCUSSION

It is possible to compare Table3's non-dimensional critical bending load with those found by Yu and Wang Mohammadi et al. (2009) and Moktar for a flat plate made of material 1 that has different aspect ratios. The table shows that the current results are very similar to those of Yu and Wang Mohammadi et al. (2009) and Mohammadi et al. (2009).

Table 3 : Comparison of the non – dimensional critical buckling load for an isotropic plate.

Aspect Ratio a/b	References Value	References Value	References Value	Present Study
0.5	12.33	12.3370	12.3370	12.3
1.0	19.74	19.7392	19.7392	19.7

Table 4 (below) shows an analysis of how plate aspect ratio and modulus ratio affect non-dimensional critical loads. A study found that the non-dimensional bending force for symmetric laminates goes up as the module ratio goes up. In relation to the results shown here, both (Osman and Elmardi, 2017) and (Reddy 2004) were talked about. A lot of agreement was found during the testing process, especially as the aspect ratio went up and the modulus ratio went down slowly.

Table 4 : Buckling load for (0/ 90/ 90/ 0) simply supported (SS) plate for different aspect and moduli ratios under biaxial compression.

Aspect Ratio a/b	Modular Ratio	Biaxial Compression				
	E_1/E_2	5	10	20	25	40
0.5	Present	10.864	12.122	13.215	13.726	14.000
	Ref.	-	12.307	-	13.689	-
	Ref.	11.120	12.694	13.922	14.248	14.766
1.0	Present	2.790	3.130	3.430	3.510	3.645
	Ref.	-	3.137	-	3.502	-
	Ref.	2.825	3.174	3.481	3.562	3.702
1.5	Present	1.591	1.602	1.611	1.613	1.617
	Ref.	-	1.605	-	1.606	-
	Ref.	1.610	1.624	1.634	1.636	1.641

Table 5 illustrates the impact that plate aspect ratio and modulus ratio have on the non-dimensional critical buckling loads of simply supported (SS) antisymmetric cross-ply rectangular laminates when they are subjected to biaxial compression. This table illustrates the connection that exists between these two categories of factors. The use of the material's qualities was the decision that was made. A decrease in the non-dimensional buckling stress for antisymmetric laminates has been shown to occur in conjunction with an increase in the modulus ratio. It is true that this is the situation. For the purpose of comparison, the data presented here were compared with those presented in (Reddy 2004). It was discovered that the validation approach generated a reasonable degree of agreement, especially when the aspect ratio was raised and the modulus ratio was lowered.

Table 5 : Buckling load for (0/ 90/ 90/ 0) simply supported (SS) plate for different aspect and moduli ratios under biaxial compression.

Aspect Ratio a/b	Modular Ratio	Biaxial Compression				
	E_1/E_2	5	10	20	25	40
0.5	Present	4.000	3.706	3.535	3.498	3.442
	Ref.	3.764	3.325	3.062	3.005	2.917
1.0	Present	1.395	1.209	1.102	1.079	1.045
	Ref.	1.322	1.095	0.962	0.933	0.889
1.5	Present	1.069	0.954	0.889	0.875	0.853
	Ref.	1.000	0.860	0.773	0.754	0.725

Buckling loads for symmetrically laminated composite plates with a layer orientation of (0/90/90/0) have been determined for three alternative aspect ratios ranging from 0.5 to 1.5 and two modulus ratios of material 2 (40 and 5). These results were obtained for a total of three different alternative aspect ratios. The findings are shown in Tables 6 and 7, respectively. Due to the fact that this finding has been made, the buckling load becomes more substantial as the aspect ratio increases under biaxial compression stress. It is the case that the buckling load is at its largest when the boundary conditions are clamped – clamped (CC) and clamped – simply supported (CS), while it is at its lowest when the boundary conditions are simply – simply supported (SS). According to the tables, it is possible to see that the values of buckling loads that were identified by the present study are much closer to the values that were discovered in (Osman and Elmardi, 2017). This is something that can be noted.

Table 6 : Buckling load for (0/ 90/ 90/ 0) plate with different boundary conditions and aspect ratios under biaxial compression.

Aspect Ratio a/b	Comparisons of Results	Boundary Conditions		
		CC	SS	CS
0.5	Present	1.0742	0.4143	0.9679
	Ref.	1.0827	0.4213	1.0022
1.0	Present	1.3795	0.4409	1.0723
	Ref.	1.3795	0.4411	1.0741
1.5	Present	1.6402	0.4400	1.2543
	Ref.	1.6367	0.4391	1.2466

Table 7 : Buckling load for (0/ 90/ 90/ 0) plate with different boundary conditions and aspect ratios.

Aspect Ratio a/b	Comparisons of Results	Boundary Conditions		
		CC	SS	CS
0.5	Present	1.7786	0.6787	1.6325
	Ref.	1.8172	0.6877	1.6838
1.0	Present	2.1994	0.6972	1.8225
	Ref.	2.2064	0.6985	1.8328
1.5	Present	2.7961	0.8943	1.7643
	Ref.	2.8059	0.8962	1.7618

VI. CONCLUSIONS

A finite element model has been constructed in order to compute the buckling loads of laminated plates that have a rectangular cross-section. This was done in order to ensure consistency. Buckling loads are studied and confirmed in comparison to previous studies that have already been published in the relevant literature. This is done in order to guarantee that the approach that is currently being used results in correct results. Additional comparisons were carried out, and the results that were supplied by the ANSYS software as well as the findings from the experiments were compared with all of the other findings. This demonstrates that the finite element method that was used is trustworthy since it has a high degree of concordance with the data that is not just available but also readily available.

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