International Journal of Advanced Science and Technology
Vol.80 (2015), pp.31-40
http://dx.doi.org/10.14257/ijast.2015.80.03

Effect of Stiffeners Position on Vibration Analysis of Plates

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Abstract

This paper presents the effect of position of stiffeners on the free vibration analysis of stiffened isotropic plate using Finite Element Method. In this paper, comparative study of stiffened isotropic plate has been carried out. The effect of stiffeners location, different boundary conditions, stiffener thickness to plate thickness and aspect ratios on the vibration analysis of plate has been studied. The vibration analysis of stiffened plate has been studied using Block-Lanczos algorithm. The element selected from the ANSYS software is SOLID186, 20 node solid elements. The results have been compared with the available published results.

Keywords: *Free vibration, Finite element method, Stiffened plate, Stiffeners, Boundary conditions*

1. Introduction

In aerospace and marine construction, stiffened plates find a huge application. Stiffened plates are extensively used in railway wagons, lock gates, plate girders, highway bridges, elevated roadways, aircraft wings, cargo containers, box girders *etc*. These have the slightly high stiffness to weight ratio contrast to unstiffened plates. The vibration analysis of various parameters such as the boundary conditions of the plate, along with orientation, dimensions and number of the stiffeners on free vibration characteristics of stiffened panels has been presented by S. J. Hamedani, M. R. Khedmati and S. Azkat [1]. A mathematical model for the free vibration analysis of stiffened laminated plates has been presented by G. Qing, J. Qiu and Y. Liu [2]. Free vibration analysis of laminated composite plates with elastically restrained edges by using FEM has been studied by A.K. Sharma and N.D. Mittal [3-6]. A.W. Leissa [7] attempts to present accurate analytical results and comprehensive for the free vibration of rectangular plates. Free vibration problem of skew cantilever plate has been studied by M.V. Barton [8]. Free vibration characteristic of rectangular stiffened plates having a single stiffener has been examined by using the finite difference method and it is studied by G. Aksu and R. Ali [9]. W.H. Liu, W.C. Chen [10] investigated the free vibration of a skew cantilever plate with stiffeners by means of a finite element method. The non-dimensional frequencies parameters of the modes are increased as the skew angle is increased. T. Mizusawa, T. Kajita and M. Naruoka [11] studied vibration analysis of rectangular plates with free edges by the Rayleigh-Ritz method. Accurate frequencies of rectangular plates are examined for different aspect ratios and different boundary conditions. W.H. Liu and W.C. Chen [12] analyzed the free vibration of stiffened plates with elastically edges restrained and intermediate stiffeners by using the Rayleigh-Ritz method. W. Zhang, A. Wang, N. Vlahopoulos and K. Wu [13] studied the energy finite element analysis (EFEA) formulation for vibration analysis of stiffened isotropic plates under heavy fluid loading. M. Barik and M. Mukhopadhyay [14] developed a four-node stiffened plate element and the new element has been successfully used for the static, free vibration and stability analyses of arbitrary bare and stiffened plates. S.D. Patel, S.S. Pathan and I.H. Bhoraniya

ISSN: 2005-4238 IJAST

[15] developed the vibration analysis of the rectangular plate with angle shaped stiffeners and considered the rectangular thin plate and its natural frequencies are calculated by modal analysis using ANSYS software.

In this paper, free vibration analyses of plates with different stiffeners location are investigated by finite element method. The first order shear deformation theory is used to investigate the effects of transverse shear deformation and rotary inertia. The main advantage of stiffeners is to increase the bending strength of plate with minimum additional material requirement; this makes the better performance of plate. Finite element method is a numerical tool which is used to solve structural and solid mechanics problems, which can handle the complex restraints and loading conditions. This paper aims to utilize the finite element method to find the natural frequency of stiffened plates at different boundary conditions and to study the effect of skew angle, stiffener to plate thickness ratio on the natural frequency.

2. Modelling of Plates

A thin stiffened plate is taken into consideration as shown in Figure 2 for the free vibration analysis on an isotropic plate. In the Figure 2 and 3, a and b are the geometric dimensions, e is the stiffener thickness, h is the plate thickness. In Figure 3, the stiffeners are located in the different position of the plate respectively. In this paper, four different types of stiffeners positions are studied. In stiffener 1, it is located along the top edge of the plate. Stiffener 2 is located along the top and right edge of the plate. Stiffener 3 is located along three sides of the plate. Stiffener 4 is located along all edges of the plate. The properties of plate and stiffener material are taken as Steel.

The material properties are:

Modulus of Elasticity=200E9, Poisson's Ratio=0.3, Density=7860kg/m^3, $\frac{a}{b} = 1, 2$ and $\frac{e}{h} = 0.5, 1, 1.5, 2$.

The plate and the stiffener are made up of the same material.

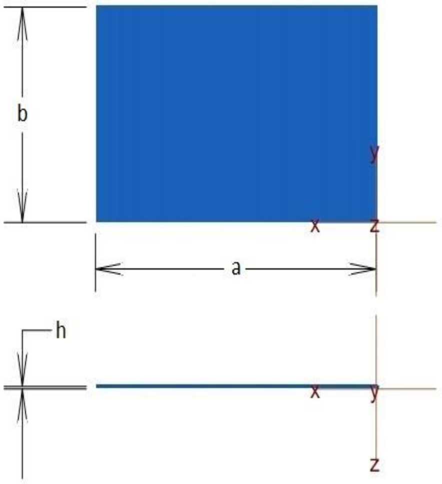

Figure 1. Rectangular Plate

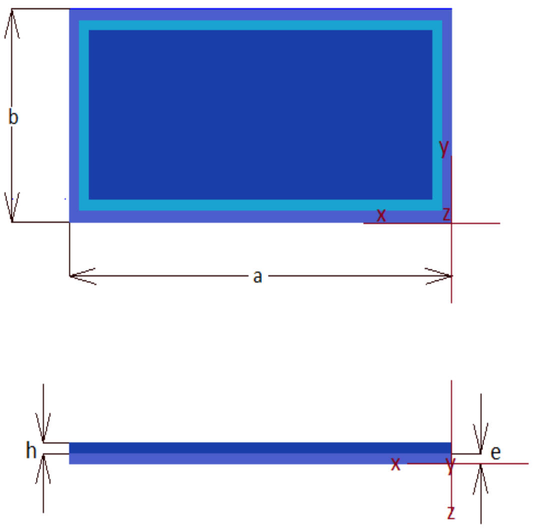

Figure 2. Rectangular Plate with Different Stiffeners Position

2.1. Element

SOLID186 is a higher order 3-D 20-node solid element that exhibits quadratic displacement behavior. Solid 186 is suitable for modelling 3-D bulk solid structures. Solid 186 is not suitable for thin structures in bending. As demonstrated in Figure the element contains 20 nodes having three degrees of freedom at each node. SOLID186 Homogenous Structural Solid is suited to modelling irregular meshes. The element may have any spatial orientation. The element supports plasticity, hyper elasticity, large deflection, and large strain capabilities.

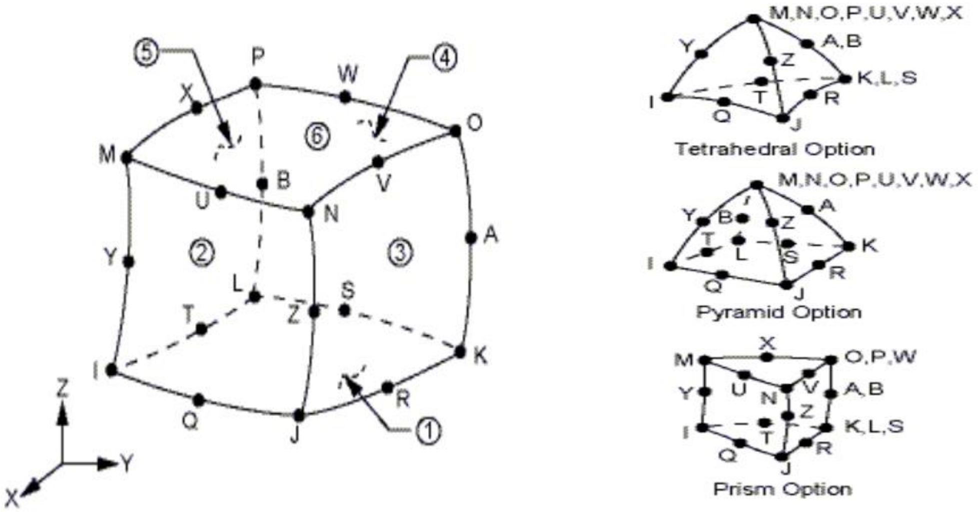

Figure 3. Solid 186

3. Numerical Results and Discussion

Different cases of stiffener locations, aspect ratios, boundary conditions and skew angle have been examined here. The modal analysis has been performed on the plate and on the stiffened plates having edges with different boundary condition *i.e.*, CFFF, CCFF and CCCC.

Table 1 shows the comparison of the variation of first ten non-dimensional frequencies with different skew angle for the aspect ratio a/b=1 and ν = 0.3 for CFFF boundary condition. The result of first three modes and non-dimensional frequencies has been compared with the reference results [7] and [10] which are found in good conformity as shown in Table 1. The percentage errors are less than 5% as compared to the reference results which are found to be in acceptable range. The results also show that as increasing the skew angle non-dimensional frequencies increases.

Table 1. Comparison of Non-Dimensional Frequencies with Respect to the Reference Results given by [7] and [10] for Skew Plates; a/b = 1 and ν = 0.3 for Boundary Condition *i.e.*, CFFF

Skew Angle	Modes	Leissa [7]	Liu and Chen [10]	Present Results	Percentage Error
0	1	3.4917	3.4750	3.4948	0.56%
	2	8.5264	8.5176	8.5678	0.58%
	3	21.429	21.3251	21.5466	1.02%
	1	-	3.5884	3.6143	0.71%

15	2	-	8.7130	8.8268	1.28%
	3	-	22.2818	22.6777	1.74%
30					
	1	-	3.9383	3.9693	0.78%
	2	-	9.4618	9.5035	0.43%
	3	-	25.4436	25.682	0.93%
45					
	1	-	4.5469	4.5982	1.11%
	2	-	11.4237	11.3674	0.49%
	3	-	27.4364	27.5349	0.35%

Table 2 shows the comparison of variation of first ten non-dimensional frequencies with different skew angle for the aspect ratio a/b=2 and ν = 0.3 for CFFF boundary condition without stiffener and the results are compared with the reference results [10] which are found in acceptable range. In Table 2, the percentage errors are less than 5 % as compared to the reference results and found that increasing the number of modes the percentage error also increases. It is also clear from the results that increasing the skew angle the natural frequency also increases.

Table 2. Comparison of Non-Dimensional Frequencies with Respect to the Reference Results given by [10] Parameters of Skew Plates without Stiffener for Different Skew Angle; a/b = 2 and ν = 0.3 for Boundary Condition i.e. CFFF

Skew Angle		$\overline{\omega}_i = \omega_i * a^2 \sqrt{\frac{\rho}{D}}$									
α		i=1	2	3	4	5	6	7	8	9	10
0	[10]	3.4292	14.5291	21.3401	47.5028	60.2624	92.1162	92.9364	119.2540	127.0960	153.35
	[Present]	3.4623	14.9084	21.8734	49.1970	62.5719	96.1780	97.8476	126.4402	134.5802	143.79
15	[10]	3.4989	14.7804	22.2180	46.8188	63.6815	88.9861	99.8597	123.9897	138.1683	147.98
	[Present]	3.5424	15.1692	22.9996	48.6025	67.0789	94.4550	104.940	135.5223	142.3041	151.20
30	[10]	3.7096	15.7359	25.0419	46.7394	73.3605	86.5410	120.2270	138.7658	146.6447	170.88
	[Present]	3.7692	16.0357	26.0830	48.6025	77.6441	90.9451	126.1508	136.8375	148.9320	155.98
45	[10]	4.0846	17.8689	31.0041	49.7094	88.6200	94.4271	142.5616	164.3036	200.8592	209.86
	[Present]	4.1548	18.1137	31.7924	51.2892	92.1249	99.5886	124.8163	145.705	179.1188	209.21

Table 3 shows the comparison of variation of first ten non-dimensional frequencies with different skew angle for the aspect ratio a/b=2 and ν = 0.3 for CFFF boundary condition with stiffener located along the upper edge of the plate and the results are compared with the reference results [10] which are found in good conformity. It is also clear from the results that increasing the skew angle the natural frequency also increases.

Table 3. Comparison of Non-Dimensional Frequencies with Respect to the Reference Results given by [10] Parameters of Skew Plates with Stiffener Located along Upper Edge for Different Skew Angle; a/b = 2 and v = 0.3 for Boundary Condition i.e. CFFF

Skew Angle		$\overline{\omega}_i = \omega_i * a^2 \sqrt{\frac{\rho}{D}}$									
α		i=1	2	3	4	5	6	7	8	9	10
0	[10]	4.3564	14.5808	26.1385	52.9751	67.9598	85.2916	111.8705	120.9210	130.5247	181.087
	[Present]	3.7931	15.2456	23.9474	51.3528	67.1135	93.5973	105.7374	130.5390	136.4266	145.569
15	[10]	4.3997	16.0985	25.8962	53.9236	68.5468	91.7526	112.8031	125.2906	136.5247	182.959
	[Present]	3.9419	15.2967	25.8010	50.1691	72.9997	101.043	101.7927	137.9573	143.8757	154.460
30	[10]	4.8835	18.7688	27.7397	54.4217	76.1127	104.707	122.5785	139.2412	162.2579	186.824
	[Present]	4.2828	16.0789	29.8140	49.3202	83.5221	97.5407	122.688	138.426	153.7140	162.397
45	[10]	6.2117	22.2936	32.8171	58.2128	91.7804	116.0766	159.9638	170.3824	195.4136	246.140
	[Present]	4.8462	18.4034	36.6359	53.1835	98.5887	109.5502	125.9968	150.7754	188.9865	210.638

Table 4 shows the first ten non-dimensional frequencies with different skew angle for the aspect ratio a/b=2, ν = 0.3 and e/h=0.5 for CCFF boundary condition with stiffener located along the upper edge of the plate. It is also examined from the results that increasing the skew angle the natural frequency also increases.

Table 4. Variation of Non-Dimensional Frequencies Parameters of Skew Plates with Stiffener Located along Top Edge for Different Skew Angle; a /b = 2 and v = 0.3 and e /h = 0.5 for CCFF External Condition

Skew Angle	$\overline{\omega}_i = \omega_i * a^2 \sqrt{\frac{\rho}{D}}$									
α	i=1	2	3	4	5	6	7	8	9	10
0	41.156	63.956	118.853	169.733	205.154	246.105	315.669	333.645	466.703	528.870
15	46.047	73.960	143.145	186.640	262.228	342.720	366.200	492.430	591.828	617.959
30	55.170	81.355	166.259	201.655	343.070	360.658	466.269	600.577	622.218	821.079
45	80.056	103.088	223.870	254.994	395.149	514.363	611.510	787.085	797.469	882.241
60	127.41	169.959	318.575	423.653	545.086	792.431	1015.23	1096.04	1374.25	1663.61

Table 5 shows the first ten non-dimensional frequencies with different skew angle for the aspect ratio a/b=2, ν = 0.3 and e/h=0.5 for CCFF boundary condition with stiffener located along all edges of the plate. It is also observed that as increasing the skew angle the natural frequency increases.

Table 5. Variation of non-Dimensional Frequencies Parameters of Skew Plates with Stiffener Located along all Edges for Different Skew Angle; a /b = 2 and ν = 0.3 and e /h = 0.5 for CCFF External Condition

Σκεω ανγλε	$\overline{\omega}_i = \omega_i * a^2 \sqrt{\frac{\rho}{D}}$									
α	i=1	2	3	4	5	6	7	8	9	10
0	38.121	60.777	103.785	144.598	155.045	199.854	243.945	258.326	324.180	359.913
15	39.786	62.077	109.462	141.197	168.368	213.332	234.176	277.414	348.624	350.365
30	45.347	66.944	127.880	144.252	202.654	233.692	256.178	319.025	342.950	422.501
45	57.094	79.172	162.315	164.549	257.022	278.631	333.563	378.056	409.097	487.297
60	81.994	111.56	215.30	237.362	330.69	433.742	470.844	568.067	587.540	654.826

Figure 4 shows the variation of first ten non-dimensional frequencies with different types of stiffeners position (stiffener 1, stiffener 2, stiffener 3 and stiffener 4) for a stiffened plate of aspect ratio a/b=2 for CCFF external boundary condition. The frequency is higher in the stiffener 1 location as compared to the other three stiffeners location. It also shows that the non-dimensional frequency increases as the number of modes are increased.

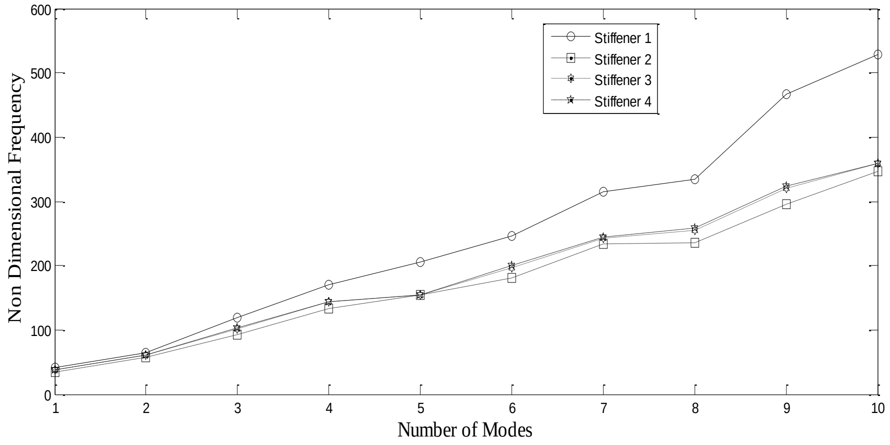

Figure 4. Variation of the Non-Dimensional Frequencies with the Different Position of Stiffeners on Isotropic Plate for CCFF External Condition (a/b=2)

Figure 5 shows the variation of first ten non-dimensional frequencies with different stiffener thickness to the plate thickness (e/h= 0.5, 1, 1.5, 2) for a stiffened plate of aspect ratio a/b=2 for CCFF external boundary condition. It is clear from the graph that increasing the stiffener thickness to the plate thickness the non-dimensional frequency also increases.

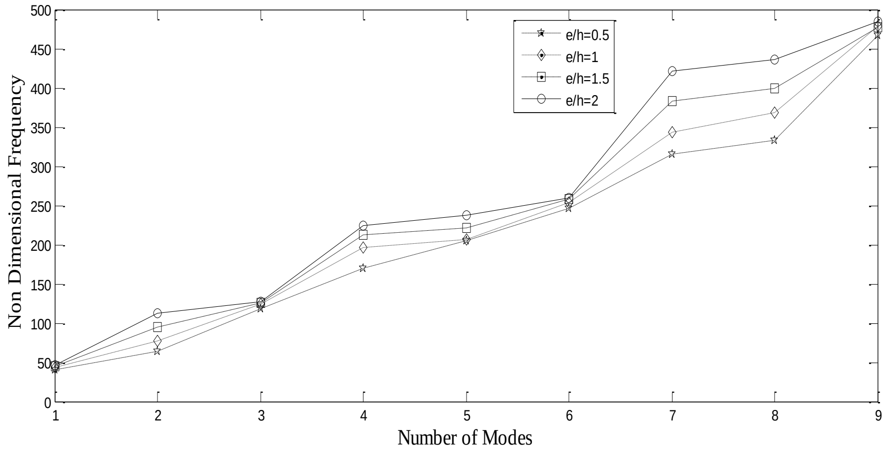

Figure 5. Variation of the Non-Dimensional Frequencies with the Stiffener to Plate Thickness (e/h= 0.5, 1, 1.5, 2) on Isotropic Plate for CCFF External Condition (a/b=2)

Figure 6 shows the variation of first ten non-dimensional frequencies with different skew angle on boundary conditions (CFFF, CCFF and CCCC) for a stiffened plate of aspect ratio a/b=2. It is clear from the graph that the fully clamped condition gives the higher non-dimensional frequency as compared to other boundary conditions.

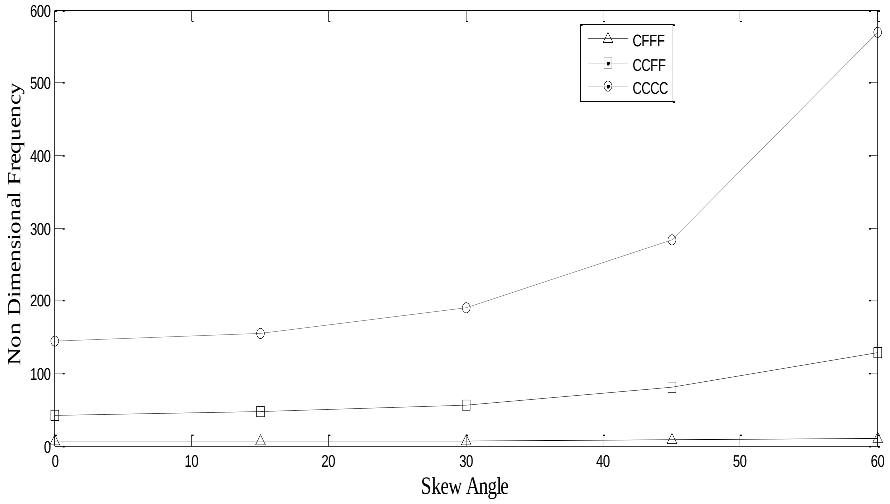

Figure 6. Variation of the non-dimensional frequencies with different skew angle on boundary condition (CFFF, CCFF and CCCC) on isotropic plate for external condition (a/b=2, e/h= 0.5)

4. Conclusion

In this paper, the effect of stiffeners position on vibration analysis of isotropic plates has been carried out using the Finite element method. From the analysis following conclusions are made: It is clear from the result that the frequency of stiffener 1 is higher than the other three cases of stiffeners and also observed that the non-dimensional frequencies increase by increasing the stiffener to the plate thickness ratio and skew angle. For fully clamped boundary condition, the non-dimensional frequencies are higher as compared to other boundary conditions.

References

[1] S. J. Hamedani, M. R. Khedmati, and S. Azkat, “Vibration analysis of stiffened plates using finite element method”, Latin American journal of solids and structures, vol. 9, **(2012)**, pp. 1 – 20.

[2] G. Qing, J. Qiu, Y. Liu, “Free vibration analysis of stiffened laminated plates”, International Journal of Solids and Structures, vol. 43, **(2005)**, pp. 1357–137.

[3] A. K. Sharma, N.D. Mittal, A. Sharma, “Free vibration analysis of moderately thick antisymmetric crossply laminated rectangular plates with elastic edge constraints”, International Journal of Mechanical Sciences, vol. 53, **(2011)**, pp. 688–695.

[4] A. K. Sharma, N.D. Mittal, “Free vibration analysis of laminated composite plates with elastically restrained edges using FEM”, Central European journal of engineering, **(2013)**, pp.306-315.

[5] A. K. Sharma, N.D. Mittal, “Review on stress and vibration analysis of composite plates”, Journal of Applied Sciences, vol. 10, no. 23, **(2010)**, pp. 3156-3166.

[6] A. K. Sharma, N.D. Mittal, “Free vibration analysis of moderately thick Anti-symmetric angle ply laminated rectangular plates with elastic edge constraints”, Mechanics of Advanced Materials and Structures, vol. 21, **(2014)**, pp. 341–348.

[7] A.W. Leissa, “The free vibration of rectangular plates”, Journal of Solids and vibration, vol. 31, no. 3, **(1973)**, pp. 257-293.

[8] M.V. Barton, “Vibration of rectangular and skew cantilever plate”, Journal of Applied Mechanics, vol. 18, **(1951)**, pp. 129-134.

[9] G. Aksu, R. Ali, “Free vibration analysis of stiffened plates using finite difference method”, Journal of Sound and vibration, Vol. 48, **(1976)**, pp. 15-25.

[10] W. H. Liu, W. C. Chen, “Vibration analysis of skew cantilever plates with stiffeners”, Journal of sound and vibration, vol. 159, no. 1, **(1992)**, pp. 1-11.

[11] T. Mizusawa, T. Kajita, M. Naruoka, “Vibration of skew plates by using B-spline functions”, Journal of sound and vibration, vol. 62, **(1979)**, pp. 301-308.

[12] W.H. Liu, W. C. Chen, “Vibration of rectangular plates with edge restraints and intermediate stiffeners”, Journal of sound and vibration, vol. 123, no. 1, **(1988)**, pp. 103-111.

[13] W. Zhang, A. Wang, N. Vlahopoulos, K. Wu, “A vibration analysis of stiffened plates under heavy fluid loading by an energy finite element analysis formulation”, Finite Elements in Analysis and Design, vol. 41, **(2005)**, pp. 1056–1078.

[14] M. Barik, M. Mukhopadhyay, “A new stiffened plate element for the analysis of arbitrary plates”, thin-Walled Structure, vol. 40, **(2002)**, pp. 625–639.

[15] S.D. Patel, S.S. Pathan, I.H. Bhoraniya, “Effect of boundary conditions and stiffeners on the natural frequencies of rectangular plate”, International Journal of Research in Engineering & Applied Sciences, vol. 2, no. 2, **(2012)**, pp. 1719-1729.

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