Effect of Stiffeners on Natural Frequencies of Plate

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Abstract - *The free flexural vibration of a stiffened rectangular plate is investigated by using the finite element method (FEM). In the present model, the plates having fixed boundary conditions are considered to analyze the natural frequencies of stiffened plates and results shows good agreement with earlier published results.*

Key Words: Free vibration, Finite element method, Stiffened plate, Stiffeners, Boundary conditions

1. INTRODUCTION

Man has always been inspired from the nature be it art or engineering. Perhaps one of the derivatives of such inspiration is stiffened engineering structures. Sea shells, leaves, trees, vegetables all of these are in fact stiffened structures. An observation of structures created by nature indicates that, in most cases strength and rigidity depend not only on the material but also upon its form. This fact was probably noticed long ago by some shrewd observers and resulted in the creation of artificial structural elements having high bearing capacity mainly due to their form such as girders, arches and shells.

Stiffeners in a stiffened plate makes it possible to sustain highly directional loads, and introduce multiple load paths which may provide protection against damage and crack growth under the compressive and tensile loads. The biggest advantage of the stiffeners is the increased bending stiffness of the structure with a minimum of additional material, which makes these structures highly desirable for loads and destabilizing compressive loads. In addition to the advantages already found in using them, there should be no doubt that stiffened plates designed with different techniques bring many benefits like reduction in material usage, cost, better performance, etc.

Plates reinforced by stiffeners represent a class of structural components that are widely used in many engineering applications such as ship decks, bridges, Automobile super structure, Aircraft, industrial structures and buildings, railway wagons highway bridges, elevated roadways etc.

Devesh Pratap Singh Yadav, Avadesh Kumar Sharma and Vaibhav Shivhare[1] studied the free vibration analyses of plates with different stiffeners location by finite element method. Dipam S. Patel, S. S. Pathan and I. H. Bhoraniya[2] studied the vibration analysis of the bare plate and stiffened plates keeping all the edges of the plate as simply supported. Dayi Ou, Cheuk and Ming Mak[3] did numerical studies to analyse the natural frequencies of concentrically/eccentrically stiffened plates with different boundary condition. Gábor M. Vörös[4] performed detailed numerical evaluation to prove the efficiency of the proposed stiffener plate/shell coupling method. J.V. Mohanachari, D. Mohana Krishnudu, P. Hussain, Dr. S. Sudhakar Babu[5] studied limited component examination of Stiffened plate of different Materials. Tom Irvine[6] used the Rayleigh method to determine the fundamental bending frequency of rectangular plate. Shahed Jafarpour Hamedani, Mohammad Reza Khedmati, and Saeed Azkat[7] presented the vibration analysis of stiffened plates, using both conventional and super finite element approach. Abhijeet Mukhergee, and Madhujit Mukhopadhyay[8] studied the effect of neglecting the eccentricity in a stiffened plate. T. P. Holopainen[9] proposed new FE model for free vibration analysis of eccentrically stiffened plates. T. Nguyen-Thoi, T. Bui-Xuan, P. Phung-Van, H. Nguyen-Xuan, P. Ngo-Thanh[10] presented the static, free vibration and buckling analyses of eccentrically stiffened plates by the cell-based smoothed discrete shear gap method (CS-FEM-DSG3) using triangular elements.

2. INTRODUCTION TO THE PROBLEM

A normal plate, and stiffened plate with stiffeners attached parallel to z-axis along with the notations for significant dimensions is shown in Fig. 1(a), 1(b), 1(c), and 1(d). It is assumed that the stiffeners are always parallel to the edges of the plate and they are rigidly connected to the plate. The formulation is further based on the following assumption.

1. Plate and stiffener materials are isotropic, homogeneous, and linearly elastic.
2. Thicknesses of the plate and stiffener are uniform.
3. The thickness of the plate is sufficiently small compared to the lateral dimensions, so that the effect of shear deformation and rotary inertia may be neglected.

The material properties considered are as follows,
Modulus of elasticity (E) = 1.1721E11 N/m², Poisson's Ratio (μ) =0.3, Density (ρ) = 2670 kg/m³ for single stiffener and Modulus of elasticity (E) = 68.9 GPa, Poisson's Ratio (μ) =0.3, Density (ρ) =2670 kg/m³ for double and three stiffeners.

Where,
b_1 = length and width of plate
h_1 = thickness of plate
b_2 = width of stiffeners
h_2 = thickness of stiffeners
Length of stiffeners is same as the length of plate.

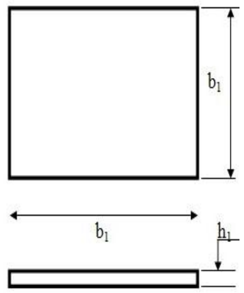

Fig.1(a): Square plate

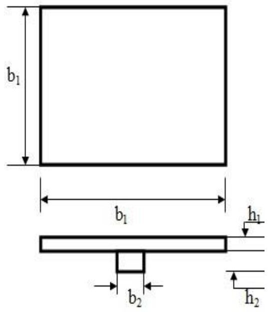

Fig.1(b): Square Plate with stiffener

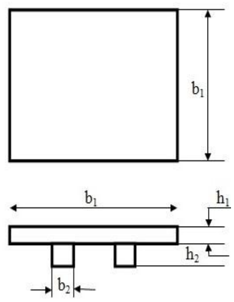

Fig. 1(c): Square with two stiffeners

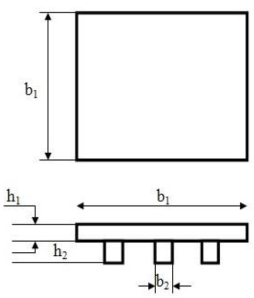

Fig. 1(d): Square Plate with three stiffeners

3. NATURAL FREQUENCIES OF PLATE WITH AND WITHOUT STIFFENERS

The analysis uses the approach of finite element methodology and comparing the result with the analytical method carried out by the researchers. The fig. 1(a), fig. 1(b), fig. 1(c) and fig. 1(d) shows the geometry of the plate with and without stiffener.

Following cases are considered for analysis.
Case 1: Square plate with and without single stiffener.
Case 2: Square plate with and without double stiffeners.
Case 3: Square plate with and without three stiffeners

3.1 SQUARE PLATE WITHOUT SINGLE STIFFENER

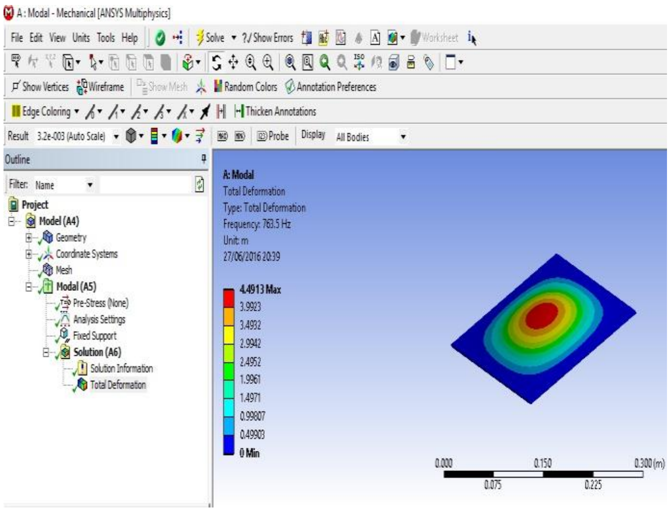

Fig. 2: Deformation & natural frequency for the square plate without stiffener

The variation for the natural frequencies at various modes for square plate without single stiffener is shown in the fig 3, and it has been observed that the natural frequency for the plate without stiffener is same at mode 2 and 3 and increases in the mode 3 to 6.

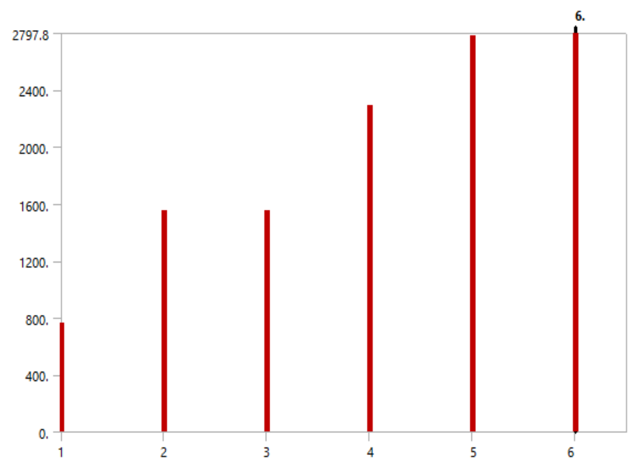

Fig. 3: Natural frequencies at various modes of square plate without single stiffener

3.2 SQUARE PLATE WITH SINGLE STIFFENER

Fig. 4 shows the deformation & natural frequency for plate with single stiffener.

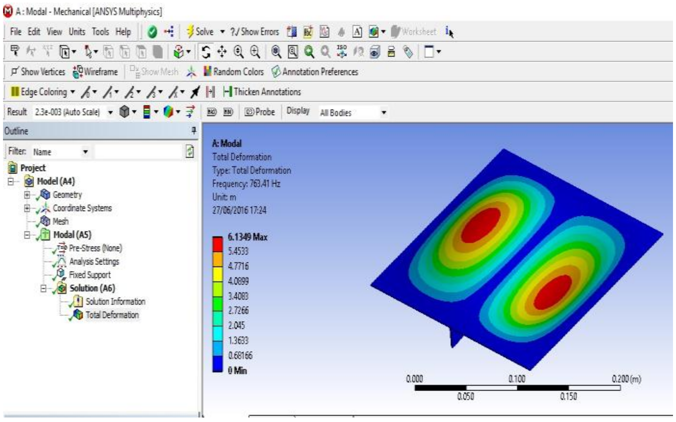

Fig. 4: Deformation & natural frequency for plate with single stiffener

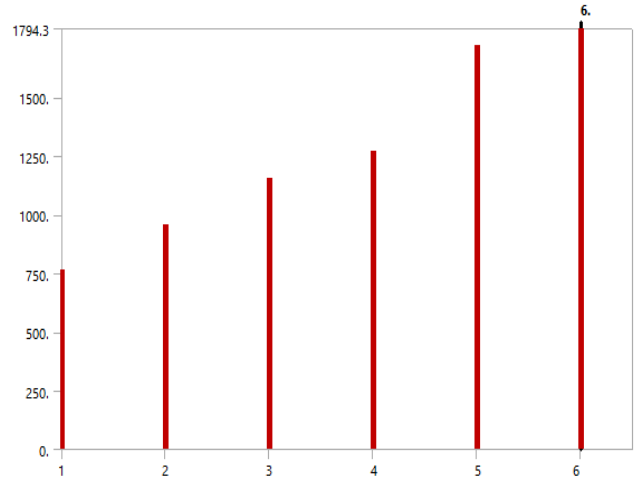

Fig. 5: Natural frequencies at various modes of square plate with single stiffeners

The variation for the natural frequency at various modes is shown in the fig. 5.

3.3 SQUARE PLATE WITHOUT DOUBLE STIFFENER

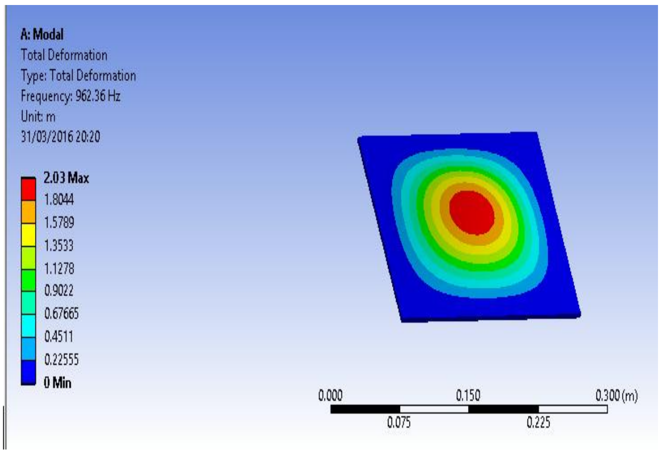

Fig 6: Deformation & natural frequency for the square plate without double stiffeners

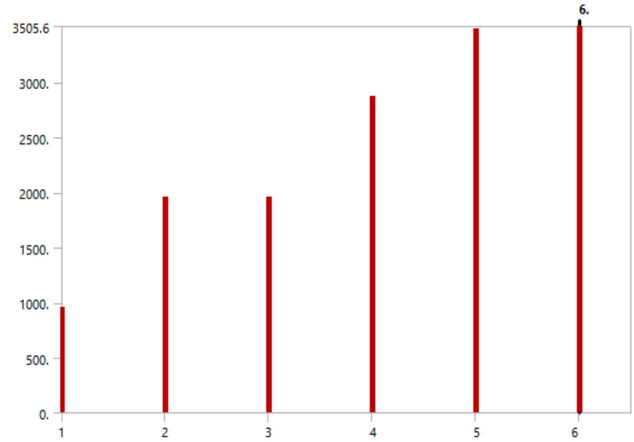

Fig. 7: Natural frequencies at various modes of square plate without double stiffeners

The variation for the natural frequencies at various modes for square plate without double stiffener is shown in the fig 7, and it has been observed that the natural frequency for the plate without double stiffener is same at mode 2 and 3 and at mode 5 & 6 the frequencies is nearly same.

3.4 SQUARE PLATE WITH DOUBLE STIFFENERS

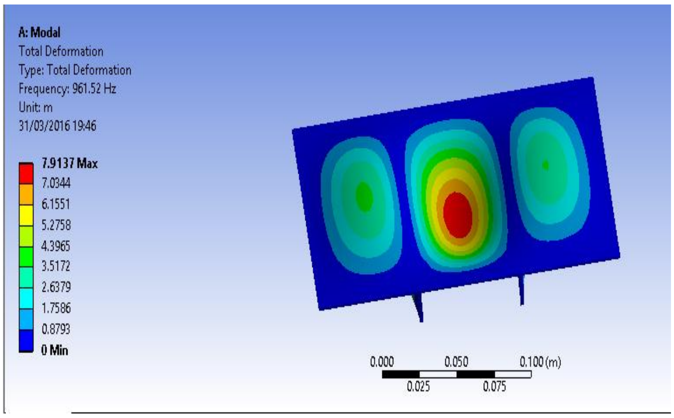

Fig. 8: Deformation & natural frequency for plate with double stiffener

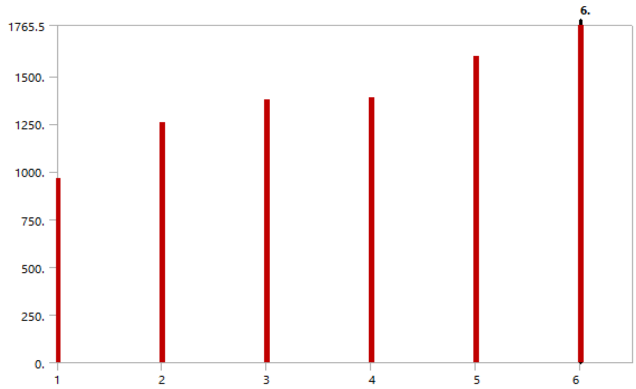

Fig. 9: Natural frequencies at various modes of square plate with double stiffeners

The variation for the natural frequencies at various modes for square plate with double stiffener is shown in the fig 9, and it has been observed that the natural frequency for the plate without double stiffener is same at mode 3 and 4 and increases in the mode 5 and 6.

3.5 SQUARE PLATE WITHOUT THREE STIFFENERS

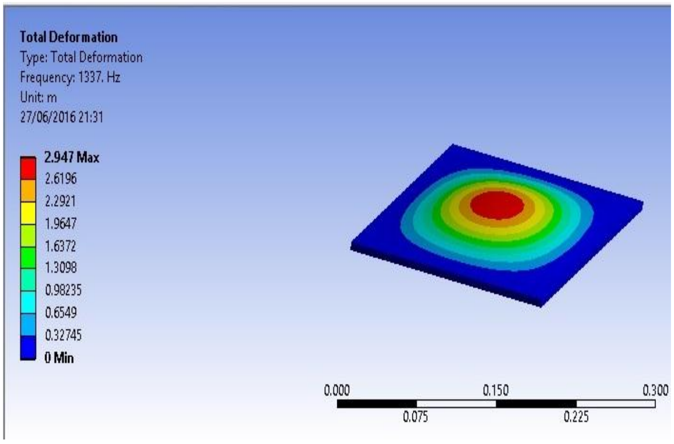

Fig 10: Deformation & natural frequency for the square plate without three stiffeners

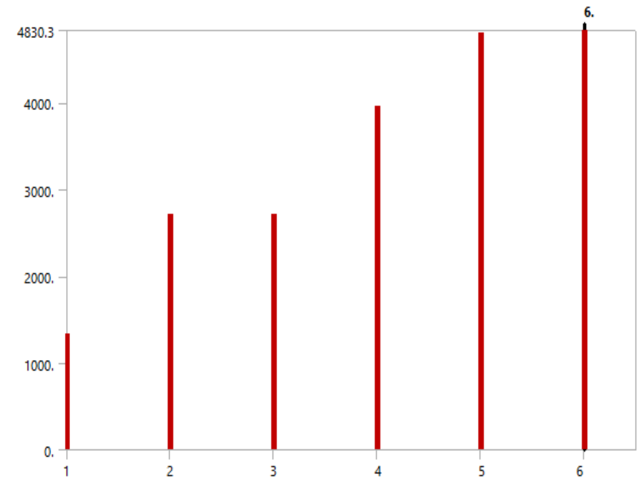

Fig. 11: Natural frequencies at various modes of square plate without three stiffeners

The variation for the natural frequencies at various modes for square plate without three stiffeners is shown in the fig 11, and it has been observed that the natural frequency for the plate without three stiffeners is same at mode 2 and 3 and at mode 5 and 6 the frequency is nearly same.

3.6 SQUARE PLATE WITH THREE STIFFENERS

Fig. 12 shows the deformation & natural frequency for the square plate with three stiffeners.

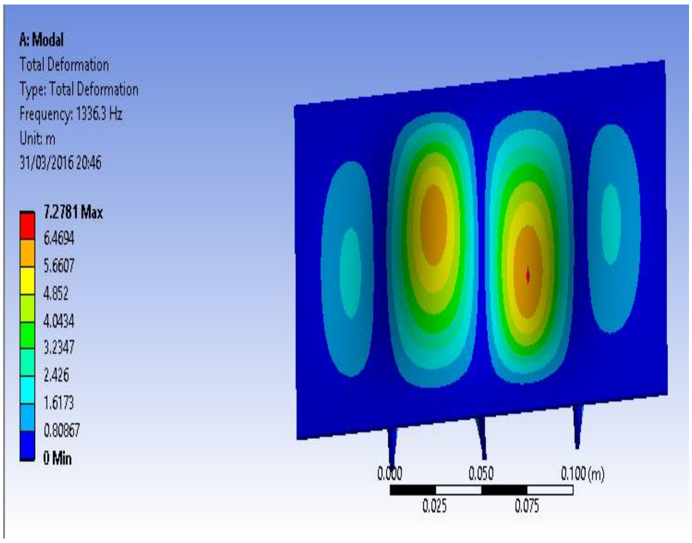

Fig 12: Deformation & natural frequency for the square plate with three stiffeners

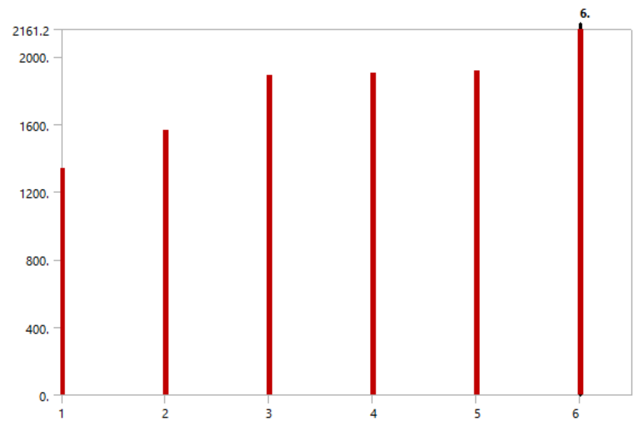

Fig. 13: Natural frequencies at various modes of square plate with three stiffeners

The variation for the natural frequencies at various modes for square plate with three stiffeners is shown in the fig 13, and it has been observed that the natural frequency for the plate with three stiffeners increases is nearly same at mode 3, 4 and 5.

After observing the result for both plate (i.e. square plate with and without stiffener), it has been observed that for same natural frequency, volume required for the square plate without stiffener is more than the volume required for the square plate with stiffener. Hence, it is necessary to provide the stiffener.

The results are compared with the Static, free vibration and buckling analyses of stiffened plates carried out by CS-FEM-DSG3 using triangular elements by T. Nguyen-Thoi, T. Bui-Xuan, P. Phung-Van, H. Nguyen-Xuan, P. Ngo-Thanh[10]. The results for single and double stiffeners are shown in tables 3.1 and 3.2 respectively.

Table 3.1: Frequencies of the square plate with single stiffener

Frequen	CS-DSG3	Oslon & Hazel[10]		Mukherjee & Mukhopadhyay[1] (Hz)	Frequency from Present Analysis (Hz)
		Experimental (Hz)	FEM (Hz)		
1	717.9	689	718.1	711.8	763.41
2	756.6	725	751.4	768.2	960.15
3	997.2	961	997.4	1016.5	1154.1
4	1010.4	986	1007.4	1031.9	1272.8
5	1424.5	1376	1419.8	1456.2	1723.8
6	1430.1	1413	1424.3	1476.5	1794.3

Table 3.2: Frequencies of the square plate with double stiffener

Frequency	CS-DSG3	Oslon & Hazel[10]		Holopainen[10] (Hz)	Frequency from Present analysis (Hz)
		Experimental (Hz)	FEM (Hz)		
1	931.3	909	965.3	943.8	961.52
2	1239.4	1204	1272.3	1237.9	1257.1
3	1319.7	1319	1364.3	1331.0	1377.1
4	1405.5	1506	1418.1	1361.2	1388.1
5	1567.5	1560	1602.9	1561.5	1600.7
6	1741.6	1693	1757.1	1706.1	1765.5

From table 3.1 and 3.2, it is observed that the frequency of the plate with of single and double stiffeners nearly matches with the results evaluated by the researchers.

The results for single, double and three stiffeners with and without stiffener for the same natural frequency are shown in table 3.3.

Table 3.3: Comparison of mass required by different plate for same natural frequency with and without stiffeners

Sr. No.	Types Of Stiffeners	Thickness (mm)	Frequency (Hz)	Mass Required (Kg)
1	Square plate without single stiffener	2.711	763.41	0.29887
2	Square plate with single stiffener	1.778	763.50	0.15997
3	Square plate without double stiffener	4.500	961.36	0.49611
4	Square plate with two stiffener	1.778	961.52	0.17994
5	Square plate without three stiffener	6.250	1337.0	0.68903
6	Square plate with three stiffener	1.778	1336.3	0.19991

From table 3.3, it is observed that, for same natural frequency, mass required for plate without stiffener is more than the mass required with stiffeners. Hence, it is necessary to provide the stiffeners to have the required natural frequency.

4. CONCLUSIONS

In the analysis of square plate with and without stiffener, it has been observed that for same natural frequency, volume and mass required for the square plate without stiffener is more than the volume required for the square plate with stiffener. Hence, stiffeners are recommended to have required natural frequency for particular applications.

According to the work of DIPAM S. PATEL, S. S.PATHAN, and I. H. BHORANIYA on Influence of stiffeners on the natural frequencies of rectangular plate, it is suggested that addition of the stiffener to the plate has an effect of shifting natural frequencies of the plate towards higher side, hence it also supports the present investigation.

REFERENCES

1. Devesh Pratap Singh Yadav, Avadesh Kumar Sharma and Vaibhav Shivhare, "Effect of Stiffeners Position on Vibration Analysis of Plates," International Journal of Advanced Science and Technology Vol.80, pp.31-40 (2015).

2. Dipam S. Patel, S. S. Pathan, I. H. Bhoraniya, "Influence of Stiffeners on the Natural Frequencies of Rectangular Plate with Simply Supported Edges," International Journal of Engineering Research & Technology (IJERT). ISSN: 2278-0181 Vol. 1 (2012).

3. Dayi Ou, Cheuk Ming Mak, "Free flexural vibration analysis of stiffened plates with general elastic boundary supports," ISSN 1 746-7233, England, UK, World Journal of Modelling and Simulation. Vol. 8 No. 2, pp. 96-102 (2012).

4. Gábor M. Vörös, "Finite element analysis of stiffened plates," Mechanical Engineering 51/2 105–112 (2007).

5. J.V. Mohanachari, D. Mohana Krishnudu, P. Hussain, Dr. S. Sudhakar Babu, "Structural and Free Vibration Analysis of Stiffened Plate with Different Materials," Journal of Advancement In Engineering and Technology ISSN: 2348-2931 Vol. 3 (2015).

6. Tom Irvine, "The Natural Frequency of a Rectangular Plate with Fixed-Free Boundary Conditions." (2011), www.vibrationdata.com.

7. Shahed Jafarpour Hamedani, Mohammad Reza Khedmati, and Saeed Azkat, "Vibration analysis of stiffened plates

using Finite Element Method," Latin American Journal of Solids and Structures Vol. 9 pp 1 – 20 (2012).

8. Abhijeet Mukhergee, Madhujit Mukhopadhyay, "Finite element free vibration of eccentrically stiffened plates," Computers and Structures, Vol. 30, No. 6, pp 1303 – 1317, (1988).

9. T. P. Holopainen, "Finite element free vibration analysis of eccentrically stiffened plates," Computers and Structures, Vol. 56 No. 6, pp 993 – 1007, (1995).

10. T. Nguyen-Thoi, T. Bui-Xuan, P. Phung-Van, H. Nguyen-Xuan, P. Ngo-Thanh, "Static, free vibration and buckling analyses of stiffened plates by CS-FEM-DSG3 using triangular elements," Computers and Structures, Vol. 125, pp 100 – 113, (2013).