Finite Element Parametric Analysis of Stiffened Plates for Deflection Reduction Using ANSYS APDL

B. R. Endigeri[1], Kalva Somashekhar[2], Shashidhar Hosamani[3]

[1]Mechanical Engineering Department, BEC-Bagalkot, Karnataka, Bagalkot, India
Email: *brendigeri[at]*rediffmail.com

[2]Mechanical Engineering Department, BEC, Bagalkot, Karnataka, Bagalkot, India
Email: *somu0084[at]gmail.com*

[3]Mechanical Engineering Department, BEC-Bagalkot, Karnataka, Bagalkot, India
Email: *shashidharhosamani5[at]gmail.com*

Abstract: ***This study presents a finite element analysis of stiffened plates subjected to point loads and uniformly distributed loads using ANSYS APDL. A square aluminum plate with fixed boundary conditions is analyzed to evaluate maximum deflection for different stiffener configurations while maintaining constant material volume. Parametric studies are conducted by varying stiffener length, thickness, and height. Different stiffener layouts including single stiffeners, cross stiffeners, and diamond-shaped stiffeners are examined. Results show that the addition of stiffeners significantly reduces plate deflection compared with a bare plate. The optimum configuration is obtained for a stiffener with length 640 mm, height 50 mm, and thickness 10 mm, which produces the minimum deflection under uniform loading conditions. The findings demonstrate that proper stiffener geometry can substantially improve structural rigidity while maintaining material efficiency.***

Keywords: Finite Element Method, Stiffened Plate, Deflection Analysis, ANSYS APDL, Structural Optimization, Parametric Study, Plate Structures.

1. Introduction

In this study we are using a thin flat plate in which thickness is negligible compared to its width and length. Plate is characterized based on its dimensions, if width to thickness ratio is greater than 100 the plate is said as very thin. The plate is said to be moderately thin if the ratio lies between 20 and 100 [1]. The plate is said to be thick if the width to thickness ratio lies between 3 and 20, it is very thick if the ratio is less than 3.

The economical design of plate can be obtained by using stiffeners instead of increasing thickness of plate [2]. Stiffeners are sections used to stiffen the primary plate or member. Stiffened plates are widely used in different fields of engineering technology, viz. ships, aircrafts, airplanes, chemical industry structures etc. stiffened plates have typical properties such as light weight, high strength structural elements [3]. Stiffeners increase the rigidity of base structures by increasing their cross sectional moment of inertia [4]. The optimum locations of the ribs for a given set design constraints were studies by Hasan [5]. The authors found the best design of stiffened plates when stiffeners were used on either side of square plate. The stiffened clamped plate subjected to a pressure was studied Youssef et al. This investigation finds out the optimum height which was found to be in between 40 and 50mm.

The stiffened plates for various types of loadings and stiffeners shape were investigated by Virag [6]. Author concluded that the trapezoidal stiffener is the most economic one. The cost saving can be 69% when compared with various ribs.

The finite element method (FEM) consists of the following five steps:

1) Preprocessing: subdividing the problem domain into finite elements.
2) Element formulation: development of equations for elements.
3) Assembly: obtaining the equations of the entire system from the equations of individual elements.
4) Solving the equations.
5) Post processing: determining quantities of interest, such as stresses and strains, and obtaining visualizations of the response.

A square pate of size 1000*1000*10 is considered in the present study and the different dimensions and types of stiffeners are used to be attached with the plates used. However, volume of material used as plate also remains constant, her in this paper different types of stiffeners are being used to strengthen the base plate. In this paper the properties of base plate and stiffener remained constant to aluminum metal with young's modulus 71.7 GPa and poison's ratio 0.33. The flat plate stiffener is shown in fig (1).

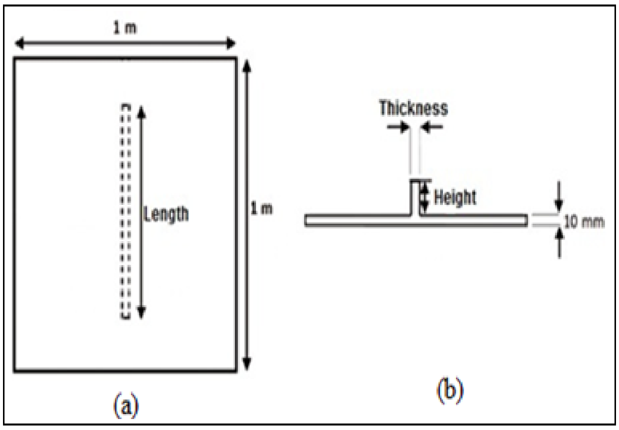


Figure 1

In this problem an investigation is carried out for the maximum deflection point for the bare plate, where Uniform distribution load is varied from $1KN/m^2$ to $5KN/m^2$. The plate is fixed at four sides.

DATA: Material properties are-Young's modulus - 71.9 GPa, and Poisson's ratio - 0.33. Element used - solid 187, Volume of material - 1000*1000*10.

Table 1: Table for Problem 1

Load-kPa	1	2	3	4	5
Max. Deflectiion-mm	0.187083	0.374167	0.56125	0.748333	0.935416

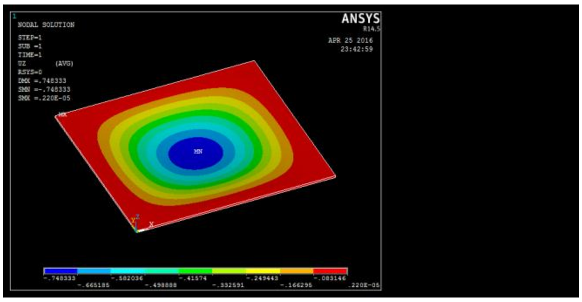


Figure 2: Figure For Problem 1

Analysis: As load increases deflection increases.

Problem 2: In this problem an investigation is carried out for the maximum deflection point for bare plate, where Point load is varied from 1KN to 5KN. The plate is fixed at four sides.

DATA: Material properties are-Young's modulus -71.7 GPa, and Poisson's ratio-0.33. Element used- solid 187, Volume of material - 1000*1000*10.

Table 2: Table For Problem 2

Load-kN	1	2	3	4	5
Max. Deflectiion-mm	0.834299	1.6686	2.5029	3.3372	4.1715

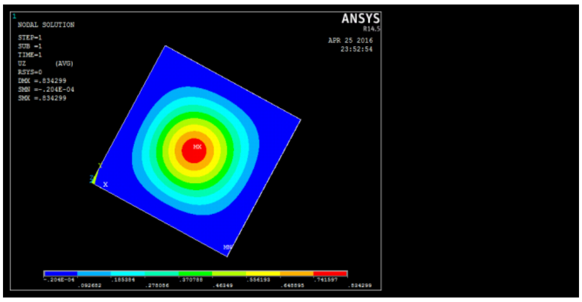


Figure 3: Figure For Problem 2

Analysis: As the stress increases deflection increases.

Comparison for two problems 1 and 2: From two problems we conclude that for point load deflection will be maximum compared to uniformly distributed load.

Problem 3: In this problem analysis is carried on the deflection of the plate, by applying uniformly distributed load where the volume of the plate is constant (1000*1000*10) and the volume of stiffener is constant i.e. 320,000 mm^3. The stiffener is added as shown in figure (1). In this problem height of stiffener is kept constant and the length is varied to obtain minimum deflection in the plate.

DATA: Material properties are-Young's modulus -71.9 GPa, and Poisson's ratio-0.33. Element used- solid 187, Volume of material – 10320000 mm^3.

Table 3: Table For Problem 3 With Deflections in mm

Thickness (mm)	Length (mm)	Height (mm)	Load applied kPa				
			1	2	3	4	5
10	800	40	0.098853	0.195776	0.29366	0.391551	0.489439
10	711.11	45	0.09065	0.179531	0.2692	0.359062	0.448829
10	640	50	0.08974	0.177735	0.2666	0.355471	0.444339
10	581.819	55	0.09336	0.184845	0.2777	0.369689	0.46211
10	533.33	60	0.098975	0.196011	0.277267	0.369689	0.462112

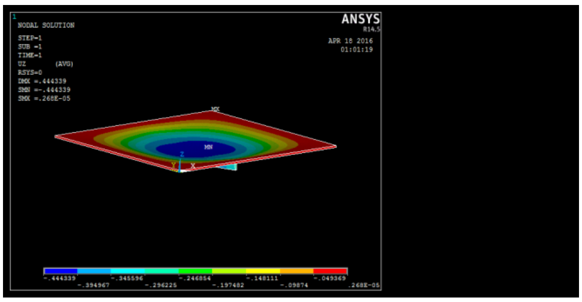
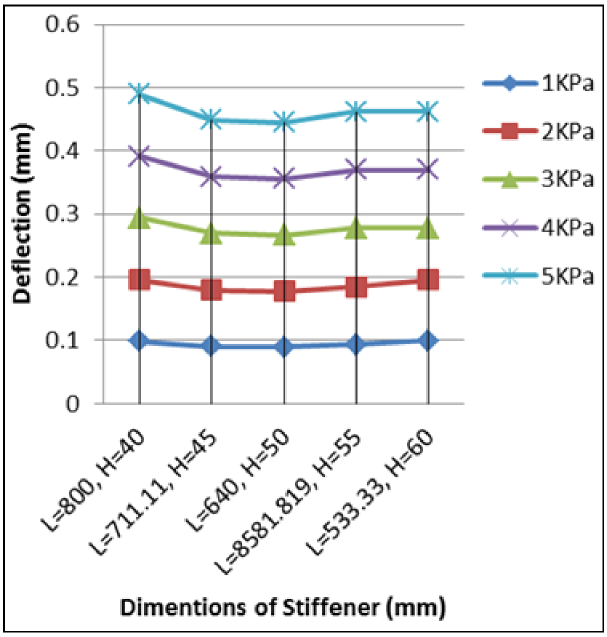


Figure 4: Figure For Problem 3



Graph 1: Graph Showing Deflection For Problem 3

Analysis: It is analyzed that when UDL is applied for the plate with fixed edge conditions, where the volume of the stiffener is constant, for the stiffener with length 640mm, thickness 10mm and height 50mm the deflection in the plate is minimum for loads of 1kPa, 2kPa, 3kPa, 4kPa, 5kPa.

Problem 4: In this problem analysis is carried on the deflection of the plate, by applying uniformly distributed load where the volume of the plate is constant (1000*1000*10) and the volume of stiffener is constant i.e. 320,000 mm^3. The stiffener is added as shown in figure (1). In this problem length of stiffener is kept constant (650mm) and the thickness is varied as 12mm, 14mm, 16mm, 18mm, and 20mm.

DATA: Material properties are - Young's modulus -71.7 GPa, and Poisson's ratio-0.33. Element used- solid 187, Volume of material - 10320000 mm^3.

Table 4: Table For Problem 4

Thickness (mm)	Length (mm)	Height (mm)	Load applied kPa				
			1	2	3	4	5
12	650	41.0256	0.09594	0.191881	0.287821	0.383762	0.479702
14	650	35.1648	0.103115	0.20623	0.309345	0.41246	0.515576
16	650	30.7692	0.109058	0.218117	0.327175	0.43623	0.545292
18	650	27.3504	0.114425	0.22885	0.343276	0.457701	0.572126
20	650	24.6154	0.118827	0.237654	0.356481	0.47308	0.594135

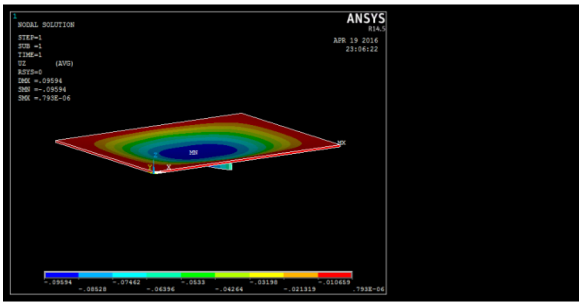
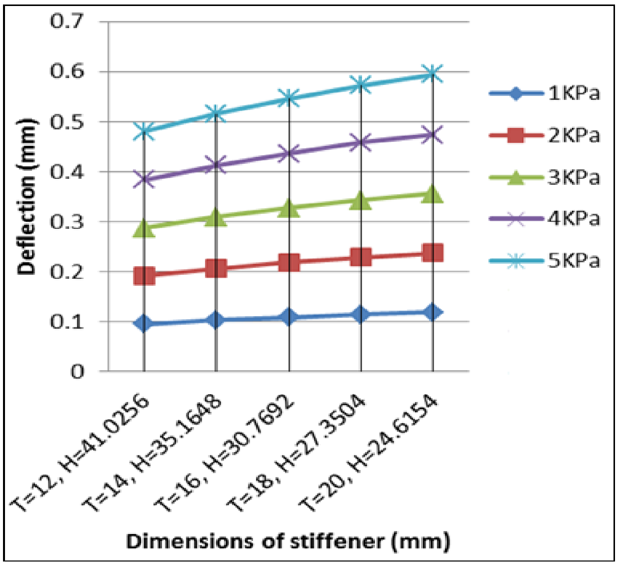


Figure 5: Figure For Problem 4



Graph 2: Graph Showing Deflection for Problem 4.

Analysis: It is analyzed that when UDL is applied for the plate with fixed edge conditions, where the volume of the stiffener is constant, the stiffener with length-650mm, height-41.0256mm, thickness-12mm, the deflection in the plate is minimum for loads of 1kPa, 2kPa, 3kPa, 4kPa, 5kPa.

Problem 5: In this problem analysis is carried on the deflection of the plate, by applying uniformly applied load where the volume of the plate is constant (1000*1000*10) and the volume of stiffener is constant i.e. 320,000 mm^3. The stiffener is added as shown in figure (1). In this problem height of stiffener is kept constant and length of stiffener is used as 750mm, 700mm, 650mm, 600mm, and 550mm.

DATA: Material properties are-Young's modulus -71.7 GPa, and Poisson's ratio-0.33. Element used- solid 187, Volume of material -10320000 mm^3.

Table 5: Table For Problem 5

Thickness (mm)	Length (mm)	Height (mm)	Load applied kPa				
			1	2	3	4	5
10.6700	750	40	0.09626	0.192591	0.288779	0.385059	o.481299
11.4286	700	40	0.09586	0.191752	0.287627	0.383503	0.479379
12.3077	650	40	0.097129	0.194258	0.291388	0.388517	0.485646
13.3300	600	40	0.100132	0.200264	0.300397	0.400529	0.500661
14.5400	550	40	0.104166	0.208332	0.312498	0.41654	0.52083

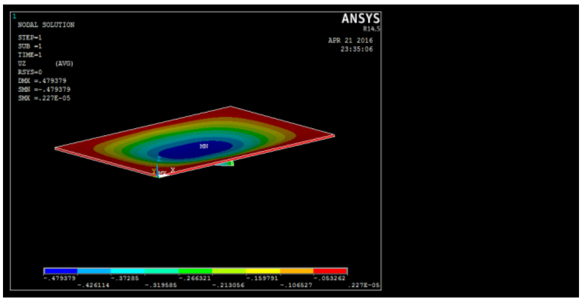
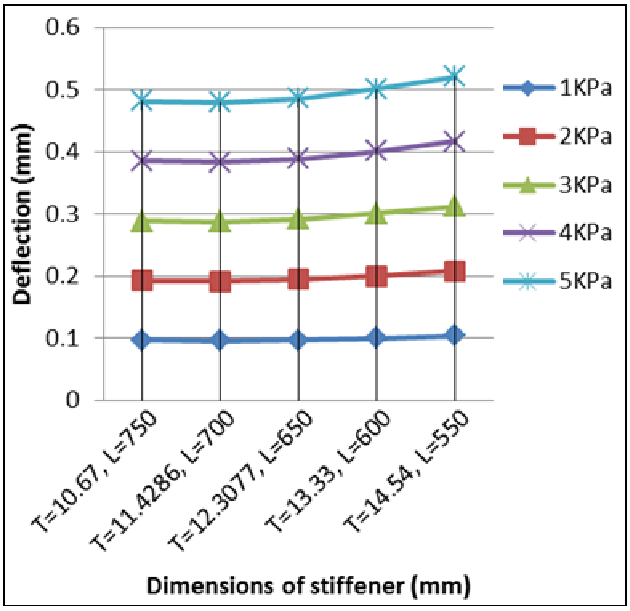


Figure 6: Figure For Problem 5



Graph 3: Graph Showing Deflection for Problem 5

Analysis: It is analyzed that when uniformly distributed load is applied with fixed edge conditions, where the volume of the stiffener is constant, and the stiffener with length - 700 mm, height - 40mm and thickness- 11.4286. The deflection in the plate is minimum for loads of 1kPa, 2kPa, 3kPa, 4kPa and 5kPa.

Problem 6: In this problem analysis is carried on the deflection of the plate, by applying uniformly applied load where the volume of the plate is constant (1000*1000*10) and the volume of stiffener is constant i.e. 320,000 mm^3. In this problem stiffener is added in the form '+' sign and the length of the stiffener will be decreased from 1000mm to 350mm in decrements of 50 and thickness is kept constant, hence height varies correspondingly.

DATA: Material properties are-Young's modulus -71.7 GPa, and Poisson's ratio-0.33, Element used- solid 187, Volume of material – 10320000 mm^3.

Table 6: Table for Problem 6

Thickness (mm)	Length (mm)	Height (mm)	Load applied kPa				
			1	2	3	4	5
10	1000	16.0804	0.116191	0.232382	0.348574	0.464765	0.580956
10	950	16.93121	0.13703	0.27406	0.411091	0.548121	0.685151
10	900	17.87709	0.139356	0.278713	0.418067	0.557425	0.696782
10	850	18.93491	0.138229	0.276458	0.414687	0.552915	0.691144
10	800	20.12578	0.134695	0.26939	0.404086	0.538781	0.673476
10	750	21.47651	0.129452	0.258904	0.388356	0.517807	0.647259
10	700	23.02158	0.123269	0.246539	0.369808	0.493077	0.616346
10	650	24.80620	0.116953	0.233906	0.350859	0.467811	0.584764
10	600	26.89075	0.111412	0.222824	0.334237	0.445649	0.557061
10	550	29.35779	0.107499	0.214997	0.322496	0.42995	0.537493
10	500	32.3232	0.10622	0.21244	0.31866	0.42488	0.531101
10	450	35.955	0.10817	0.216035	0.324052	0.43207	0.540087
10	400	40.5063	0.113169	0.226338	0.339507	0.452676	0.565845
10	350	46.37681	0.121222	0.242444	0.363666	0.484888	0.60611

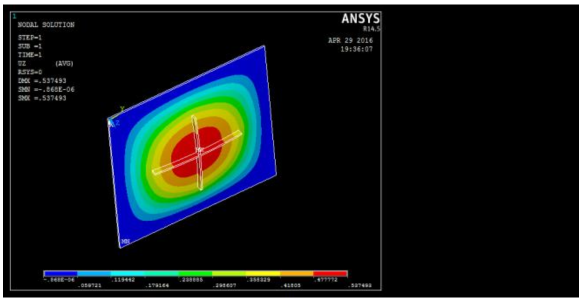


Figure 7: Figure for Problem 6

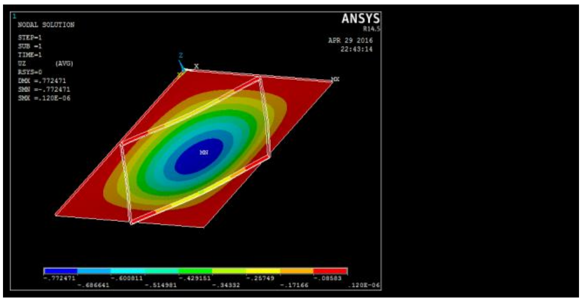
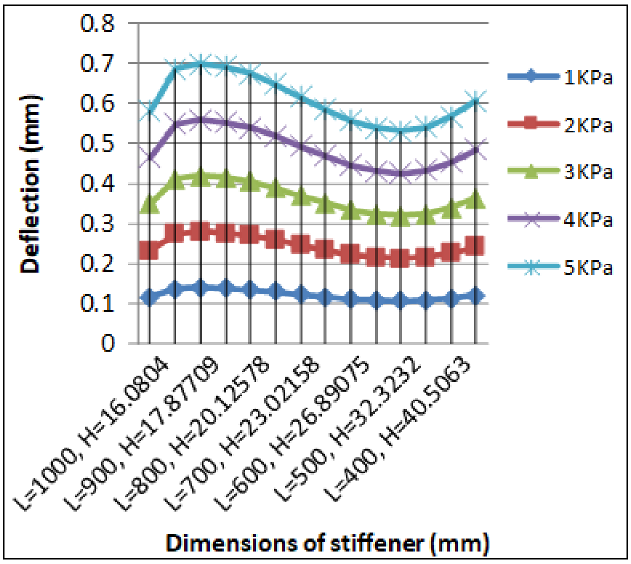


Figure: Figure for Problem 7



Graph 4: Graph Showing Deflection for Problem 6.

Analysis: Deflection is minimum at length=500mm, height = 32.3232mm, thickness = 10mm and maximum at length = 900mm, height = 17.87709mm, thickness = 10mm. we can say that variation of deflection is higher at higher loads i.e. clear results are obtained at higher loads.

Problem 7: In this problem analysis is carried on the deflection of the plate, by applying uniformly applied load where the volume of the plate is constant (1000*1000*10) and the volume of stiffener is constant i.e. 320,000 mm^3. The stiffener is added as shown in figure (2) i.e. in the form of diamond shape.

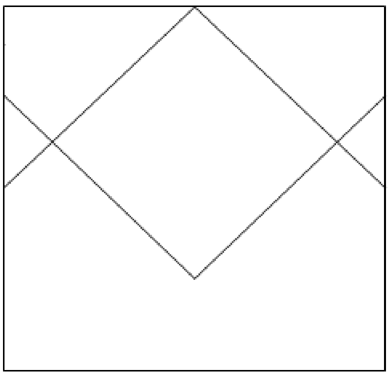


Figure 8: Figure Showing Diamond Stiffener.

Table 7: Table For Problem 7

Load kPa	Max. displacements-mm
1	0.154484
2	0.308989
3	0.463483
4	0.617977
5	0.772471

Analysis: From the results it is analyzed that as the uniformly distributed load increases for the fixed edge conditions of plate, however, this type of stiffener is not economical as compared to earlier stiffener provided in problem 3. Where the deflection is 0.4443399 for 5kPa uniformly distributed load but in this problem the deflection is 0.772471mm for 5kPa uniformly distributed load.

2. Conclusion

From the above results we can conclude that,

1) The deflection for bare plate under uniform loading conditions is 0.934516mm for 5kN/m^2.
2) The deflection for bare plate under point load conditions is 4.1715mm for 5kN. This means that deflection will be maximum for point load conditions.
3) For all the values of above examples as the load increases deflection goes on increases that means deflection is maximum for higher loads.
4) From above results we can say that as the length, height and thickness of stiffeners changes deflection of stiffened plate goes on changes. However, for certain values of length, height, thickness deflection is minimum. The values for which deflection is minimum are L=640mm, height=50mm, thickness=10mm (from problem 3). Such type of stiffener is recommended.
5) From the above results we can say that, the deflections are maximum for diamond shape stiffener, with fixed edge conditions (problem 7). Such type of stiffener is not recommended.
6) From the above results we can say that the deflection of stiffened plate with fixed edge conditions varies with varying shapes of stiffeners. So we can say that stiffener mentioned in problem3 is recommended for minimum deflection. Clear results are obtained for higher loads.

References

[1] Charles R. Steele, Chad D. Balch, Introduction to the Theory of Plates, Lecture notes, Stanford University

[2] Deepak Kumar Singh, S K Duggal, P.Pal, Study on "Analysis of Stiffened Plates using FEM-A Parametric study".

[3] Mazin Victor Yousif, Nazar Kais M. Naief, Yahya M. Hamad, "Optimum height of plate stiffener under pressure effect", The 1stRegional Conference of Eng. Sci. NUCEJ Spatial ISSUE (2008), vol.11, No.3, pp. 459-468

[4] Dandapati Hareesh, Kintali Vinod" FEM Analysis on Stiffened plates using ANSYS", National Institute of Technology Rourkela -769 008 (India).

[5] Mohammed M. Hasan, "Optimum design of stiffened square plates for longitudinal and square ribs", University of Anbar (2007)

[6] Zoltan Virag, "Optimum design of stiffened plates for different load and shapes of ribs", Journal of Computational and Applied Mechanics (2004).