Available online at www.elixirpublishers.com (Elixir International Journal)

Civil Engineering

Elixir Civil Engg. 116C (2018) 50336-50342

ISSN: 2229-712X

Force Development Pattern in Thick and Thin Plate, Computational FEM Analysis

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ARTICLE INFO

Article history:
Received: 22 February 2018;
Received in revised form:
19 March 2018;
Accepted: 29 March 2018;

Keywords
Kirchhoff–Love theory,
Mindlin–Reissner theory,
SAAD-PRO V8i,
FEM (Finite Element Method).

ABSTRACT

It is important to make structure safe and secure for inhabitants till its useful life. Being part of construction designing it becomes upmost important to design structure safe and stable. A complete structure consisting of various element like beam, column, foundation as well as slabs one such member slab commonly considered as plate has studied over here for the change in behaviour with respect to thickness. Initially a plate is analyse using classical cosine series expansion method manually, it results is check with computational model analysis so as to find out % error, as the error is in permissible limit so further analysis work is done computationally using STAAD-PRO V8i software for 7 cases with a thickness of 5mm to 250mm of plate. On the basis of analysis related to bending moment, shear stresses, deflections, principal stresses comparative observation tables are prepare. Result shows that in thin plate forces are carried in the form of principal stresses and deflections are high. While in thick plate moment and shear stresses are predominant but deflection is very less. This study shows where to concentrate while designing the plate for practical purpose.

1. Introduction

A plate is a planer structure with a very small thickness in comparison to the planer dimensions. If the width to thickness ratio of the plate is 8 to 10 then plate is classified as thick plate. Mindlin-Reissner theory is used for the analysis of such thick plates. If the width to thickness ratio of the plate is 8 to 100 then plate is classified as thin plate. It is intermediate plate also Kirchhoff–Love theory is use for analysis of such thin plates. If this ratio is 80 to100 then it is called membrane. The forces applied on a plate are perpendicular to the plane of the plate. Therefore, plate resists the applied load by means of bending in two directions and twisting moment. A plate theory takes advantage of this disparity in length scale to reduce the full three- dimensional solid mechanics problem to a two dimensional problem. The load carrying action of plates resembles that of beams or cables to a certain extent. Hence plates can be approximated by a grid work of beams or by a network of cables, depending on the flexural rigidity of the structures. Plates are of wide use in engineering industry. Many structures such as ships and containers require complete enclosure of plates without use of additional covering which consequently saves the material and labour. Now a days, plates are generally used in architectural structures, bridges, hydraulic structures, pave ments, containers, airplanes, missiles, ships, instruments and machine parts. Plates are usually subdivided based on their structural action. The aim of plate theory is to calculate the deformation and stresses in a plate subjected to loads. The analyses of plates are categorized into two types based on thickness to breadth ratio: thick plate and thin plate analysis. In any structure each element plays an individual role for dissolving action and maintaining stability of structure, however the skill of designing is in determining the nature of force development in the structural member with change in geometry and there after deciding on the basis of analysis result. One such important structural element is slab/ plate with change in near thickness the nature of failure changes and thus it is very important to study the effect of forces on plate with different thickness.

2. Literature Review

Michael Lee (1). Author provide a viable method to establish the correlation between the deflection and stress results of a shaped (distorted) plate analyzed as a thin shell when compared to the original (flat) thin plate analytical solution. This project analyses an elastic loading of plates with different shapes which are obtained from the loading of the previous (plate) iteration with less deflection. Thus, a relationship between the increasing plate distortion and the resulting stress and deflections can be established. Joseph E (2). Study the reports on a theoretical investigation of the convergence properties of several finite element approximations in current use and assesses the magnitude of the principal errors resulting from their use for certain classes of structural problems. The results of the study provide basic information on the effect of inter element compatibility, unequal size elements, discrepancies in triangular element approximations, flat element approximations to curved structures, and the number of elements required for a desired degree of accuracy. Ray W. Clough et.al (3). A study is made of the relative accuracy provided by seven different types of finite element in the approximation analysis of plate bending. The Kirchhoff plate bending theory is assumed and stiffness matrices for three rectangular and four triangular element are considered. The result of investigation demonstrates the

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rectangular element are somewhat more accurate than the triangular element. Vanam B .C. L (4) Author analyze the static analysis of an isotropic rectangular plate with various boundary conditions and various types of load applications. In this paper, finite element analysis has been carried out for an isotropic rectangular plate by considering the master element as a four noded quadrilateral element. Numerical analysis (finite element analysis, FEA)has been carried out by developing programming in mathematical software MATLAB and the results obtained from MATLAB are giving good agreement with the results obtained by classical method exact solutions. Later, for the same structure, analysis has been carried out using finite element analysis software ANSYS. Wei Zhang et.al (5).Author investigates the elasto plastic buckling behavior of thick rectangular plates by using the Differential Quadrature (DQ) method. Mindlin plate theory is adopted to take the transverse shear effect into considerations. Both incremental theory and deformation theory are employed. Due to the material non-linearity, iteration processes are involved for obtaining solutions. Huu Tai Thai et.al (6). Author introducing analytical solutions for bending, buckling, and vibration analyses of thick rectangular plates with various boundary conditions are presented using two variable refined plate theory. The theory accounts for parabolic variation of transverse shear stress through the thickness of the plate without using shear correction factor. C.E. İmrak et.al (7).Author presents exact solution for Rectangular plates under uniform load, x = ±a, y = ±b, An exact solution in which each term of the series is trigonometric and hyperbolic, and identically satisfies the boundary conditions on all four edges. The solution has three terms in which the first term corresponds to the case of a strip and the other two terms denote the effects of the edges. The method used to obtain the solution is simple and straight forward. In order to illustrate the method the numerical values of the deflections are calculated and compared with those of the previous papers. It is found that there is a reasonable agreement between the results of them and those of this paper.

3. Verification Problem and Case Consideration

3.1. Manual Calculation for Maximum Deflection In Plate Using Classical Cosine Series Expansion Method

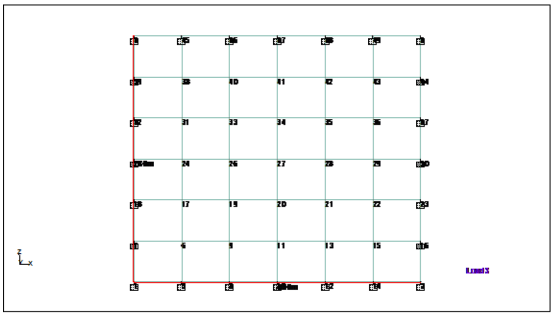

Fig.3.1. Plan of Rectangular plate which is fixed in all sides.

3.1.1. Case 1: 5mm plate

- Size of plate : 4.5 × 3.6m
- Thickness : 5mm (0.005m)
- Material : RC Concrete
- Density of concrete : 24.02 KN/ m3
- Poisons ratio μ: 0.17
- Modulus of elasticity : 21.718×10^6 KN/m^2
- Load Calculation :

1. Self wt of plate = density× area× thickness
= 24.02× 4.5× 3.6×0.005 = 1.94 KN
2. Self wt per unit area = 1.94/4.5×3.6 = 0.119 KN /m^2
3. Assume Live load on plate = 1.5 KN /m^2
4. Total Load = 0.119 + 1.5 = 1.61 KN /m^2
5. Factored Load = 1.5 × 1.61 = 2.41 KN /m^2

Maximum Deflection for rectangular plate fixed at all sides under action of uniformly distributed load q kn/m^2

$$W_{\substack{x=0\\y=0}} = \alpha \frac{pb^4}{D},$$

Table No. 3.1. Deflection Coefficient (α) values for various ratio of b/a.

b/a	$w(0,0)$ pb^4/D	Evans pb^4/D	Taylor & Govindjee pb^4/D
1.0	0.00126725	0.00126	0.00126532
1.2	0.00172833	0.00172	0.00172487
1.4	0.00207217	0.00207	0.00206814
1.6	0.00230399	0.00230	0.00229997
1.8	0.00244989	0.00245	0.00244616
2.0	0.00253625	0.00254	0.00253297
∞	0.00260417	0.00260	0.00260417

Where,
α = 0.00181833 for (b/a) = 2.25/1.8 =1.25
q = Factored load per unit area on plate
D = Flexural rigidity

$$D = \frac{E\,t3}{12\,(1-\mu 2)} = 0.232$$

by putting values in above formula we get maximum deflection at centre
W_{max} = 484.09 mm

3.1.2. Case 2: 10mm plate

- Size of plate : 4.5 × 3.6m
- Thickness : 10mm (0.01m)
- Material : RC Concrete
- Density of concrete : 24.02 KN/ m3
- Poisons ratio μ: 0.17
- Modulus of elasticity : 21.718×10^6 KN/m^2
- Load Calculation :

1. Self wt of plate = density× area× thickness
= 24.02× 4.5× 3.6×0.01 = 3.89KN
2. Self wt per unit area = 3.89/4.5×3.6 = 0.24KN /m^2
3. Assume Live load on plate = 1.5 KN /m^2
4. Total Load = 0.24 + 1.5 = 1.74 KN /m^2
5. Factored Load = 1.5 × 1.74 = 2.61 KN /m^2

Maximum Deflection for rectangular plate fixed at all sides under action of uniformly distributed load q kN/m^2

$$W_{\substack{x=0\\y=0}} = \alpha \frac{pb^4}{D},$$

Where,
α = 0.00181833 for (b/a) = 2.25/1.8 =1.25
q = Factored load per unit area on plate
D = Flexural rigidity

$$D = \frac{E\,t3}{12\,(1-\mu 2)} = 1.863$$

by putting values in above formula we get maximum deflection at centre
W_{max} = 65.28mm

3.1.3. Computational FEM Analysis for 5mm plate

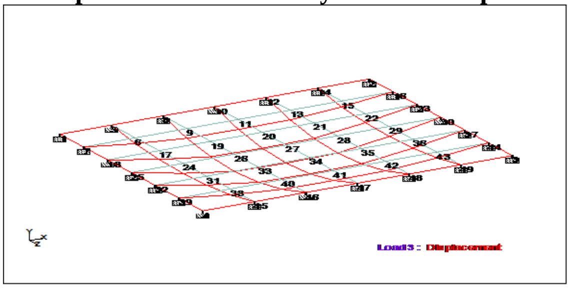

Fig.3.2. Deflection occurs in 5mm plate.

As such 5mm thickness of plate is analyze on STAAD-PRO V8i software showing the result of maximum deflection occurs at node no. 27 is 426.121mm.

3.1.4. Computational FEM Analysis for 10mm plate

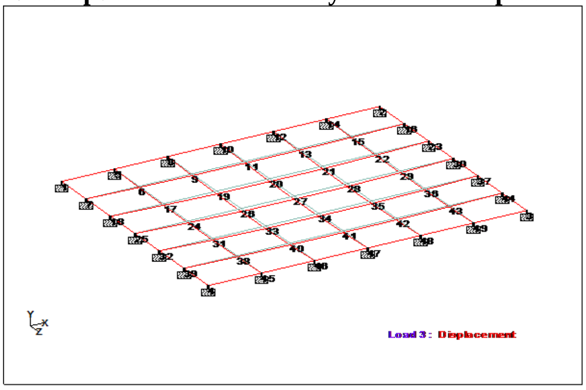

Fig. 3.3. Deflection occurs in 10mm Plate.

Similarly 10 mm thickness of plate is analyze on STAAD-PRO V8i software showing the result of maximum deflection occurs at node no. 27 is 57.18 mm.

3.1.5. Comparative Table

Sr. No.	Type	Thickness (mm)	Maximum Deflection(mm)	% Difference
1.	Manual	5mm	484.09	`
	Computational		426.12	13.60%
2.	Manual	10mm	65.28	
	Computational		57.18	14.16%

Since the % difference is very less further all cases are done computational on STAAD-PRO V8i software.

4. Observations and Remark

To find out the behavior of plate with change in thickness various plate model are created and analyze. To study the moment, stresses, deflection development pattern for this the various cases under consideration are -

Case 1:Rectangular plate of size 4.5×3.6m with thickness of 5mm.

Case 2:Rectangular plate of size 4.5×3.6m with thickness of 10mm.

Case 3:Rectangular plate of size 4.5×3.6m with thickness of 50mm.

Case 4:Rectangular plate of size 4.5×3.6m with thickness of 100mm.

Case 5:Rectangular plate of size 4.5×3.6m with thickness of 150mm.

Case 6:Rectangular plate of size 4.5×3.6m with thickness of 200mm.

Case 7:Rectangular plate of size 4.5×3.6m with thickness of 250mm.

The various values along X and Y direction are study and results are tabulated in table as below

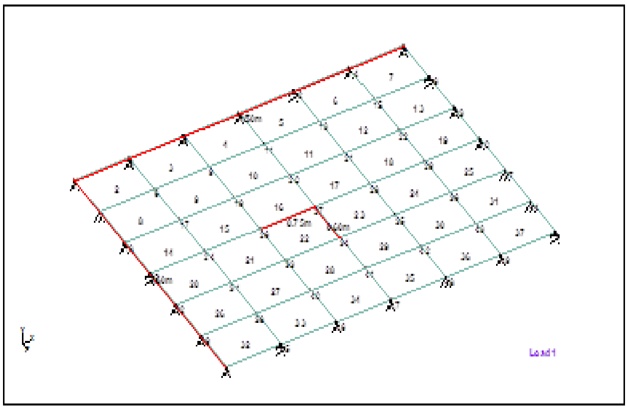

Fig.4.1. Isometric view of plate.

Table No. 4.1. Moment Development.

Node No.27	Location	Mx (KNm/m)	My (KNm/m)	Mxy (KNm/m)
Case 1	at Centre	0.038	0.190	0.053
Case 2		0.040	0.204	0.057
Case 3		0.064	0.315	0.087
Case 4		0.099	0.455	0.126
Case 5		0.146	0.599	0.164
Case 6		0.210	0.747	0.201
Case 7		0.295	0.898	0.239
Node No. 26,28				
Case 1	at a distance of 0.75m from centre along X-axis	0.069	0.184	0.071
Case 2		0.074	0.198	0.076
Case 3		0.117	0.305	0.117
Case 4		0.176	0.439	0.169
Case 5		0.246	0.572	0.222
Case 6		0.333	0.705	0.275
`Case 7		0.439	0.836	0.328
Node No.24,29				
Case 1	at a distance of 1.5m from centre along X-axis	0.123	0.114	0.058
Case 2		0.132	0.123	0.062
Case 3		0.205	0.188	0.095
Case 4		0.297	0.267	0.135
Case 5		0.392	0.341	0.172
Case 6		0.488	0.409	0.205
Case 7		0.585	0.472	0.234
Node No.20,34				
Case 1	at a distance of 0.6m from centre along Z-axis	-0.027	-0.188	0.069
Case 2		-0.029	-0.202	0.074
Case 3		-0.049	-0.311	0.114
Case 4		-0.056	-0.448	0.164
Case 5		-0.059	-0.584	0.214
Case 6		-0.048	-0.719	0.264
Case 7		-0.016	-0.850	0.312
Node No. 11,4				
Case 1	at a distance of 1.2 m from centre along Z-axis	-0.092	-0.561	-0.187
Case 2		-0.099	-0.602	-0.201
Case 3		-0.118	-0.875	-0.299
Case 4		-0.216	-1.340	-0.446
Case 5		-0.274	-1.753	-0.582
Case 6		-0.323	-2.167	-0.716
Case 7		-0.360	-2.578	-0.848
Node No. 19,21,33,35				
Case 1	from end support at a	0.050	-0.170	-0.048
Case 2		0.054	-0.182	-0.052

Case 3	distance of 1.5m along X-axis & 1.2m along Z-axis.	0.086	-0.281	-0.079
Case 4		0.133	-0.407	-0.111
Case 5		0.193	-0.576	-0.138
Case 6		0.270	-0.626	-0.158
Case 7		0.366	-0.728	-0.171
Node No. 9,13,40,42				
Case 1	from end support at a distance of 1.5m along X-axis & 0.6m along Z-axis.	-0.050	-0.547	0.143
Case 2		-0.053	-0.587	0.153
Case 3		-0.080	-0.904	0.235
Case 4		-0.108	-1.298	0.333
Case 5		-0.125	-1.679	0.422
Case 6		-0.129	-2.052	0.502
Case 7		-0.139	-2.411	0.569
Node No. 17,22,31,36				
Case 1	from end support at a distance of 0.75m along X-axis & 1.2m along Z-axis.	0.072	-0.062	0.100
Case 2		0.077	-0.066	0.108
Case 3		0.118	-0.102	0.167
Case 4		0.165	-0.148	0.246
Case 5		0.205	-0.196	0.331
Case 6		0.235	-0.245	0.424
Case 7		0.252	-0.296	0.528
Node No. 6,15,38,43				
Case 1	from end support at a distance of 0.75m along X-axis & 0.6m along Z-axis.	0.048	-0.226	0.079
Case 2		0.051	-0.242	0.085
Case 3		0.078	-0.374	0.132
Case 4		0.111	-0.540	0.196
Case 5		0.140	-0.707	0.268
Case 6		0.164	-0.876	0.349
Case 7		0.180	-1.048	0.442

When we observe the values of Table No. 6.1.it can be seen that plate center moments value increases with increase in thickness i.e. (Mx =0.038KNm/m for 5mm plate and 0.295KNm/m for 250mm plate). Similarly for My and Mxy value also increases with thickness. When the distance increases from center of plate i.e. 0.75m in X-direction the moment values Mx becomes double where as My and Mxy values there are negligible changes. Similarly when Z-direction is considered the values are negative in nature and increases with increases in thickness

Table No. 4.2. Shear Stress Development.

Node No.27	Location	SQx (N/mm^2)	SQy (N/mm^2)
Case 1	at Centre	-0.014	-0.159
Case 2		-0.007	-0.085
Case 3		-0.002	-0.026
Case 4		-0.002	-0.019
Case 5		-0.001	-0.017
Case 6		-0.001	-0.015
Case 7		-0.001	-0.015
Node No.26,28			
Case 1	At a distance of 0.75m from centre along X-axis	-0.014	-0.152
Case 2		-0.067	-0.081
Case 3		-0.002	-0.025
Case 4		-0.002	-0.018
Case 5		-0.001	-0.016
Case 6		-0.001	-0.014
Case 7		-0.001	-0.014
Node No.24,29			
Case 1	at a distance of 1.5m from centre along X-axis	-0.002	-0.091
Case 2		-0.001	-0.049
Case 3		-0.000	-0.015
Case 4		0.000	-0.011
Case 5		0.000	-0.009
Case 6		0.001	-0.008
Case 7		0.001	0.007
Node No.20,34			
Case 1	at a distance of 0.6m from centre along Z-axis	-0.013	-0.159
Case 2		-0.007	-0.085
Case 3		-0.002	-0.026
Case 4		-0.002	-0.018
Case 5		-0.002	-0.017
Case 6		-0.001	-0.015
Case 7		-0.001	-0.015
Node No.11,41			
Case 1	at a distance of 1.2 m from centre along Z-axis	-0.009	-0.472
Case 2		-0.005	-0.253
Case 3		-0.002	-0.075
Case 4		-0.001	-0.056
Case 5		-0.001	-0.049
Case 6		-0.001	-0.046
Case 7		-0.001	-0.044
Node No. 19,21,33,35			
Case 1	from end support at a distance of 1.5m along X-axis & 1.2m along Z-axis.	-0.011	-0.150
Case 2		-0.006	-0.080
Case 3		-0.002	-0.025
Case 4		-0.001	-0.018
Case 5		-0.001	-0.015
Case 6		0.000	-0.014
Case 7		0.000	-0.013
Node No. 9,13,40,42			
Case 1	from end support at a distance of 1.5m along X-axis & 0.6m along Z-axis.	-0.019	-0.453
Case 2		-0.010	-0.243
Case 3		-0.003	-0.075
Case 4		-0.002	-0.054
Case 5		-0.002	-0.046
Case 6		-0.001	-0.043
Case 7		-0.001	-0.040
Node No. 17,22,31,36			
Case 1	from end support at a distance of 0.75m along X-axis & 1.2m along Z-axis.	-0.168	-0.054
Case 2		-0.090	-0.029
Case 3		-0.028	-0.009
Case 4		-0.021	-0.006
Case 5		-0.018	-0.006
Case 6		-0.018	-0.005
Case 7		-0.017	-0.005
Node No. 6,15,38,43			
Case 1	from end support at a distance of 0.75m along X-axis & 0.6m along Z-axis	-0.129	-0.172
Case 2		-0.069	-0.092
Case 3		-0.021	-0.029
Case 4		-0.016	-0.021
Case 5		-0.014	-0.018
Case 6		-0.013	-0.016
Case 7		-0.013	-0.016

Table No. 6.2 shows the shear development values from which it can be shows that shear in X direction (SQx = -0.001 N/mm^2 for plate of thickness 250 mm and -0.014 N/mm^2 for plate of 5mm). For Y direction (SQy = -0.159 N/mm^2 plate of thickness 250 mm and -0.015 N/mm^2 for plate of 5mm) with increase in distance from center there is increase in the shear value SQy . Overall it can be observe that shear in X and Y-direction is more for plate with maximum thickness i.e. in terms of minus.

Table No. 4.3. Deflection.

Node No.27	Location	Resultant Deflection in (mm)	Rotational Deflection in (mm)		
			Rx	Rx	Rx
Case 1	at Centre	426.121	0.000	0.000	-0.000
Case 2		57.181	0.000	0.000	-0.000
Case 3		0.721	0.000	0.000	-0.000
Case 4		0.138	0.000	0.000	-0.000
Case 5		0.059	0.000	0.000	-0.000
Case 6		0.034	0.000	0.000	-0.000
Case 7		0.024	0.000	0.000	-0.000
Node No.26,28					
Case 1	At a distance of 0.75m from centre along X-axis	405.924	0.000	0.000	-0.072
Case 2		54.468	0.000	0.000	-0.010
Case 3		0.685	0.000	0.000	-0.000
Case 4		0.131	0.000	0.000	-0.000
Case 5		0.055	0.000	0.000	-0.000
Case 6		0.032	0.000	0.000	-0.000
Case 7		0.022	0.000	0.000	-0.000
Node No.24,29					
Case 1	at a distance of 1.5m from centre along X-axis	232.140	0.000	0.000	-0.398
Case 2		31.148	0.000	0.000	-0.053
Case 3		0.391	0.000	0.000	-0.001
Case 4		0.074	0.000	0.000	-0.000
Case 5		0.031	0.000	0.000	-0.000
Case 6		0.018	0.000	0.000	-0.000
Case 7		0.012	0.000	0.000	-0.000
Node No.20,34					
Case 1	at a distance of 0.6m from centre along Z-axis	378.181	0.000	0.000	-0.000
Case 2		50.745	0.000	0.000	-0.000
Case 3		0.639	0.000	0.000	-0.000
Case 4		0.122	0.000	0.000	-0.000
Case 5		0.052	0.000	0.000	-0.000
Case 6		0.030	0.000	0.000	-0.000
Case 7		0.021	0.000	0.000	-0.000
Node No.11,41					
Case 1	at a distance of 1.2 m from centre along Z-axis	235.225	0.000	0.000	-0.000
Case 2		31.565	0.000	0.000	-0.000
Case 3		0.398	0.000	0.000	-0.000
Case 4		0.076	0.000	0.000	-0.000
Case 5		0.032	0.000	0.000	-0.000
Case 6		0.019	0.000	0.000	-0.000
Case 7		0.013	0.000	0.000	-0.000
Node No. 19,21,33,35					
Case 1	from end support at a distance of 1.5m along X-axis & 1.2m along Z-axis.	380.312	0.000	0.000	-0.061
Case 2		48.415	0.000	0.000	-0.008
Case 3		0.609	0.000	0.000	-0.000
Case 4		0.116	0.000	0.000	-0.000
Case 5		0.049	0.000	0.000	-0.000
Case 6		0.028	0.000	0.000	-0.000
Case 7		0.020	0.000	0.000	-0.000
Node No. 9,13,40,42					
Case 1	from end support at a distance of 1.5m along X-axis & 0.6m along Z-axis.	225.346	0.000	0.000	-0.035
Case 2		30.238	0.000	0.000	-0.005
Case 3		0.380	0.000	0.000	-0.000
Case 4		0.073	0.000	0.000	-0.000
Case 5		0.031	0.000	0.000	-0.000
Case 6		0.018	0.000	0.000	-0.000
Case 7		0.012	0.000	0.000	-0.000
Node No. 17,22,31,36					
Case 1	from end support at a distance of 0.75m along X-axis & 1.2m along Z-axis.	209.636	0.000	0.000	-0.351
Case 2		28.128	0.000	0.000	-0.047
Case 3		0.234	0.000	0.000	-0.001
Case 4		0.044	0.000	0.000	-0.000
Case 5		0.019	0.000	0.000	-0.000
Case 6		0.011	0.000	0.000	-0.000
Case 7		0.007	0.000	0.000	-0.000
Node No. 6,15,38,43					
Case 1	from end support at a distance of 0.75m along X-axis & 0.6m along Z-axis	138.546	0.000	0.000	-0.2060
Case 2		18.589	0.000	0.000	-0.028
Case 3		0.234	0.000	0.000	-0.000
Case 4		0.044	0.000	0.000	-0.000
Case 5		0.019	0.000	0.000	-0.000
Case 6		0.011	0.000	0.000	-0.000
Case 7		0.007	0.000	0.000	-0.000

When Table No. 6.3.is observed for deflection values it can be seen that maximum deflection occurs at center plate is of 426.121mm for minimum thickness i.e. 5mm. With increase in thickness from 5mm to 10 mm the deflection values decreased by 90%. i.e 57.181mm. Similarly there is rapid fall when the thickness changes to 10mm to 50mm. i.e. 0.721mm. The rotational deflection is almost negligible.

Table No 4.4. Principal Stresses Development.

PlateNo.16	Positions	S_{max} (N/mm^2)	S_{min} (N/mm^2)	T_{max} (N/mm^2)
Case 1	Top	4.969	0.832	2.068
	Bottom	-0.832	-4.969	2.068
Case 2	Top	1.334	0.223	0.555
	Bottom	-0.223	-1.334	0.555
Case 3	Top	0.086	0.014	0.035
	Bottom	-0.014	-0.086	0.014
Case 4	Top	0.035	0.005	0.014
	Bottom	-0.005	-0.035	0.010
Case 5	Top	0.024	0.004	0.010
	Bottom	-0.004	-0.024	0.008
Case 6	Top	0.021	0.003	0.009
	Bottom	-0.003	-0.021	0.009
Case 7	Top	0.020	0.003	0.008
	Bottom	-0.003	-0.020	0.008
PlateNo.10				
Case 1	Top	3.66	0.521	1.567
	Bottom	-0.521	-3.655	1.567
Case 2	Top	0.981	0.139	0.420
	Bottom	-0.139	-0.981	0.420
Case 3	Top	0.063	0.009	0.027
	Bottom	-0.009	-0.063	0.027
Case 4	Top	0.026	0.003	0.011
	Bottom	-0.003	-0.026	0.011
Case 5	Top	0.018	0.002	0.007
	Bottom	-0.002	-0.018	0.007
Case 6	Top	0.015	0.002	0.0065
	Bottom	-0.002	-0.015	0.0065
Case 7	Top	0.014	0.002	0.0064
	Bottom	0.002	-0.014	0.0064
Plate No. 4				
Case 1	Top	1.614	-0.102	0.858
	Bottom	0.102	-1.614	0.858
Case 2	Top	0.433	-0.027	0.230

	Bottom	0.027	-0.433	0.230
Case 3	Top	0.028	-0.001	0.014
	Bottom	0.001	-0.025	0.014
Case 4	Top	0.011	-0.0007	0.006
	Bottom	0.0007	-0.011	0.006
Case 5	Top	0.008	-0.0005	0.004
	Bottom	0.0005	-0.008	0.004
Case 6	Top	0.0069	-0.0004	0.0037
	Bottom	0.0004	-0.0069	0.0037
Case 7	Top	0.0066	-0.0004	0.0035
	Bottom	0.0004	-0.0066	0.0035
PlateNo.15				
Case 1	Top	23.021	3.838	9.591
	Bottom	-3.838	-23.021	9.591
Case 2	Top	6.176	1.029	2.573
	Bottom	-1.029	-6.176	2.573
Case 3	Top	0.384	0.064	0.160
	Bottom	-0.064	-0.384	0.160
Case 4	Top	0.141	0.023	0.059
	Bottom	-0.023	-0.141	0.059
Case 5	Top	0.085	0.014	0.035
	Bottom	-0.014	-0.085	0.035
Case 6	Top	0.062	0.010	0.025
	Bottom	-0.010	-0.062	0.025
Case 7	Top	0.049	0.008	0.020
	Bottom	-0.008	-0.049	0.020
Plate No. 9				
Case 1	Top	17.928	2.187	7.870
	Bottom	-2.187	-17.928	7.870
Case 2	Top	4.809	0.586	2.111
	Bottom	-0.586	-4.809	2.111
Case 3	Top	0.299	0.036	0.131
	Bottom	-0.036	-0.299	0.131
Case 4	Top	0.111	0.013	0.048
	Bottom	-0.013	-0.111	0.048
Case 5	Top	0.067	0.007	0.029
	Bottom	-0.007	-0.067	0.029
Case 6	Top	0.049	0.005	0.021
	Bottom	-0.005	-0.049	0.021
Case 7	Top	0.039	0.003	0.017
	Bottom	-0.003	-0.039	0.017
Plate No. 3				
Case 1	Top	9.083	-1.618	5.351
	Bottom	1.618	-9.083	5.351
Case 2	Top	2.437	-0.434	1.436
	Bottom	0.434	-2.437	1.436
Case 3	Top	0.158	-0.027	0.090
	Bottom	0.027	-0.152	0.090
Case 4	Top	0.057	-0.111	0.034
	Bottom	0.011	-0.057	0.034
Case 5	Top	0.035	-0.0075	0.021
	Bottom	0.007	-0.0353	0.021
Case 6	Top	0.026	-0.006	0.016
	Bottom	0.006	-0.0026	0.016
Case 7	Top	0.022	-0.0058	0.013
	Bottom	0.005	-0.0022	0.013
PlateNo.14				
Case 1	Top	-4.710	-27.951	11.620
	Bottom	27.951	4.710	11.620
Case 2	Top	-1.264	-7.500	3.118
	Bottom	7.500	1.264	3.118
Case 3	Top	-0.079	-0.469	0.195
	Bottom	0.469	0.079	0.195
Case 4	Top	-0.029	-0.176	0.073
	Bottom	0.176	0.029	0.073
Case 5	Top	-0.018	-0.109	0.045
	Bottom	0.109	0.018	0.045
Case 6	Top	-0.014	-0.083	0.034
	Bottom	0.083	0.014	0.034
Case 7	Top	-0.011	-0.069	0.028
	Bottom	0.069	0.011	0.028
Plate No. 8				
Case 1	Top	-3.082	-21.209	9.063
	Bottom	21.209	3.082	9.063
Case 2	Top	-0.827	-5.691	2.432
	Bottom	5.691	0.827	2.432
Case 3	Top	-0.051	-0.356	0.152
	Bottom	0.356	0.051	0.152
Case 4	Top	-0.019	-0.134	0.057
	Bottom	0.134	0.019	0.057
Case 5	Top	-0.012	-0.083	0.035
	Bottom	0.083	0.012	0.035
Case 6	Top	-0.009	-0.063	0.026
	Bottom	0.063	0.009	0.026
Case 7	Top	-0.007	-0.052	0.022
	Bottom	0.052	0.007	0.022
Plate No. 2				
Case 1	Top	0.608	-9.585	5.096
	Bottom	9.585	-0.608	5.096
Case 2	Top	0.163	-2.572	1.367
	Bottom	2.572	-0.163	1.367
Case 3	Top	0.010	-0.161	0.085
	Bottom	0.161	-0.010	0.085
Case 4	Top	0.003	-0.060	0.032
	Bottom	0.060	-0.003	0.032
Case 5	Top	0.002	-0.037	0.020
	Bottom	0.030	-0.002	0.020
Case 6	Top	0.0018	-0.028	0.015
	Bottom	0.028	-0.0018	0.015
Case 7	Top	0.0015	-0.023	0.012
	Bottom	0.023	-0.0015	0.012

Table No. 4.4 shows the value of principal stresses in which it can be seen that stresses at top as well as bottom is maximum for plate with 5mm thickness as compare to the plate with 250mm thickness. The shear stress value (T_{max}) is again maximum for plate with minimum thickness. On the basis of this observations value conclusions are drawn in next chapter.

5. Conclusions

To study the behavior of plate with change in thickness subjected to same boundary conditions and load, 7 cases of plate modeling with thickness from 5mm, 10mm, 50mm, 100mm, 150mm, 200mm, 250mm is analyzed computationally. From the various values as observed in tables in chapter no.5. Various things can be conclude like The plate with less thickness has shown that the moment along X and Y-axis as well as twisting moment (Mxy) is having less value as compare to plate with more thickness. Even when the shear stress value are marked it can be seen that shearing is predominant with increase in thickness. The values of principal stresses are high for plate with less thickness. However deflection is maximum for plate which have very less thickness this shows that when the forces are acting on thin plate it get transfer in the form of prominent principal stresses and negligible shear stresses where as for the thick plates bending and shear stress development is more as compared to in-plane forces.

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