ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 1.852

IJESRT
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

Analytical and Experimental Study of Buckling Behavior of Cylindrical Panels

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Abstract

Thin walled structural components such as plates and shells are used in several applications like aerospace, naval, nuclear plant, pressure vessels, mechanical and civil structures due to their high strength to weight ratio. The safety assessment of such structural components required to carefully access the buckling collapse which can be strongly limiting the load with standing capacity. The effects of the length, sector angle on the buckling load of cylindrical panels have been studied experimentally by applying compressive load in the axial direction on the panels using the universal testing machine. Then the cylindrical panel is modeled and analyzed using ANSYS software. The experimental as well as the numerical analysis is repeated for different length, sector angle and loads. The comparison between experimental and simulation results in terms of displacement for various load has discussed.

Keywords: Buckling, cylindrical panels, Experimental test result, ANSYS result.

Introduction

The shell structures are important in various engineering fields. The buckling load is usually the most criterions in designing of a long thin shell. The buckling of cylindrical panels widely used in aerospace, mechanical, civil and marine engineering structures, are concerned by many of the engineers. Investigation of the cylindrical panels usually based on a numerical method like the finite elements, the analytical methods for special cases and the experimental tests. Cylindrical panels are often subjected to defects and damage from both in-service and manufacturing events. Delimitation is the most important of these defects. Examples include the transition from a diamond mode collapse pattern for thin axially compressed circular cylindrical shells to an axisymmetric collapse mode for thick shells. The buckling of railroad tracks induced by constrained thermal expansion of the rails and the localized collapse of tubes subject to bending. The effect of thickness, length, sector angle under buckling load plays vital role while using cylindrical panels for engineering applications. Hence this project work deals with the effect of those parameters on the buckling load and buckling behavior of cylindrical panels for engineering applications. The compressive axial load is applied for analyzing the buckling behaviors of cylindrical panels.

Experimental study

Some specimens with different lengths and sector angles have been prepared. All the specimens have been manufactured from one tube branch and so they have the same radius and thickness. The buckling test is performed using universal testing machine for applying axial loads on panels and two load cells with capacity of 1000 kN for different applications. The results can be transmitted to a computer.

Work piece material selection

Material specification

The work piece material used for the current work is 6063 Aluminium alloy and its dimensions are thickness 2mm, diameter of 60mm, and length varying from 100mm to 250 mm in terms of 50mm. The above mentioned dimensions combined with different the sector angle such as 90º, 120º, 180º, and 355 º.

Diameter (D)	=	60 mm
Sector angle (Ɵ)	=	90°, 120°, 180°, 355°
Length (L)	=	100, 150, 250 mm
Thickness (t)	=	2 mm

Experismental testing

Buckling Test

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For the buckling test, an axial load was applied on the panels and by measuring the axial displacement, the load-displacement diagram was determined. These tests were performed for different panels with clamped condition. In all tests the straight edges are free and clamped supports were applied on arc edges of panels. Figure 4.1

Figure 4.1 Specimen Tested in UTM

Load Vs Displcement Effect

The load-displacement for each panel was graph. The peak values of ultimate strength for different sector angle and various lengths is shown in Fig 4.2, 4.3, 4.4, 4.5

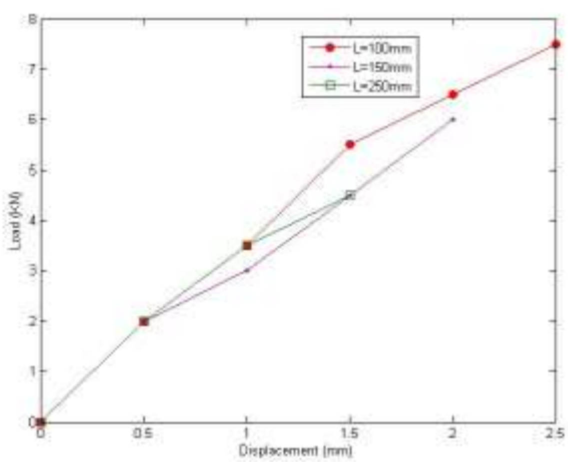

Figure 4.2 Load Vs displacement (Ө=90º)

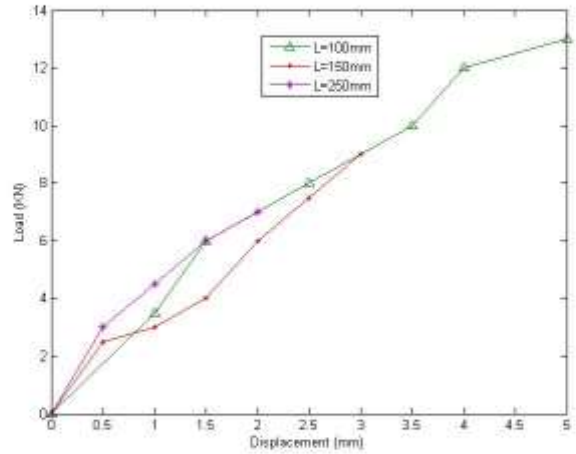

Figure 4.3 Load Vs displacement (Ө=120º)

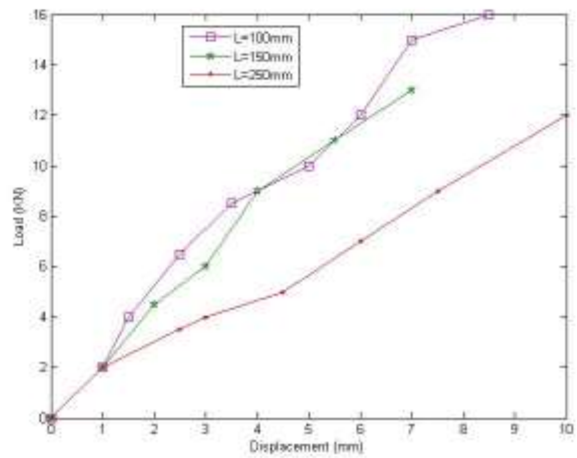

Figure 4.4 Load Vs displacement (Ө=180º)

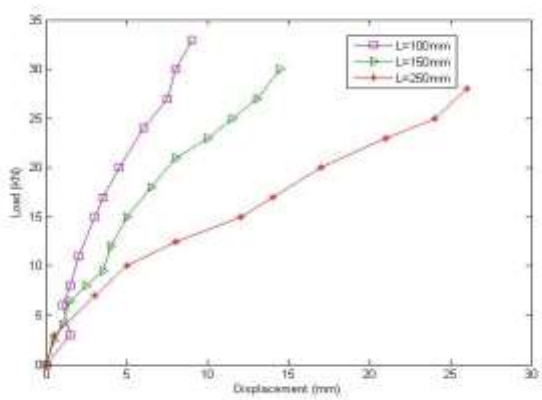

Figure 4.5 Load Vs displacement (Ө=355º)

Length Effect

For investigation of the length effect, the buckling test was performed on some panels with the load and different lengths. Figure 4.6 shows the

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variation of the buckling load in terms of the length for different sector angles.

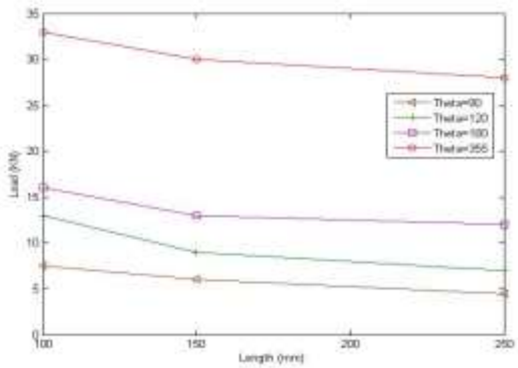

Fig 4.6 Buckling load Vs length (for different angle 90º, 120º, 180º, 355º)

Sector Angle Effect

Deformations of tested panels have been shown in figure 4.7 (a), (b), (c), (d) The experimental tests show that by decreasing the panel length, the buckling load increased

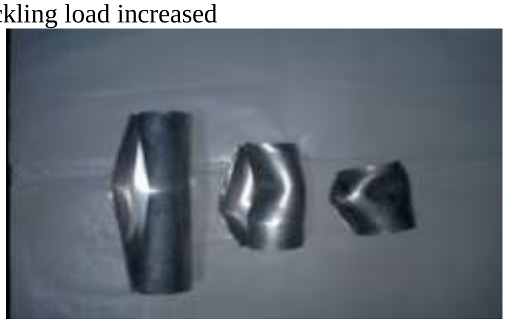

Fig 4.7 (a) Ɵ =355º

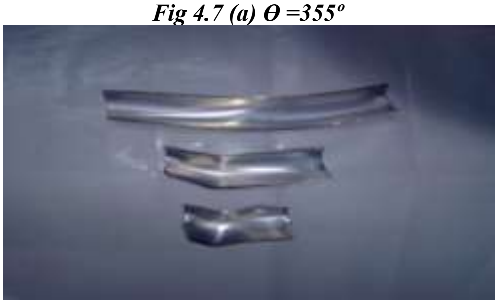

Fig (b) Ɵ =180º

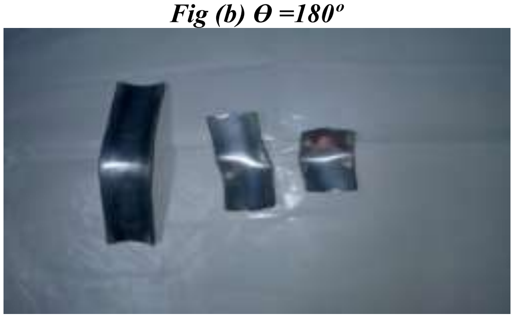

Fig 4.7 (c) Ɵ =120º

Fig 4.7 (d) Ɵ =90º

4.7 Fig buckling mode shape of panels with different sector angle and different length (L=250,150,100 mm), (a) Ɵ=355º, (b) Ɵ=180º, (c) Ɵ=120º, (d) Ɵ=90º

Experimental Result

Table 4.1 Experimental Result

Sect. angle	Ɵ=90°		Ɵ=120°		Ɵ=180°		Ɵ=355°	
Leng. (mm)	Load (kn)	Max. Disp. mm	Load (kn)	Max Disp mm	Load (kn)	Max Disp mm	Load (kn)	Max Disp mm
100	7.5	2.5	13	5	16	8.5	33	9
150	6	2	9	1	13	7	30	14.5
250	4.5	1.5	7	2	12	10	28	26

Numerical analysis

Buckling Analysis

Displacement Analysis of Cylindrical Panels Using ANSYS

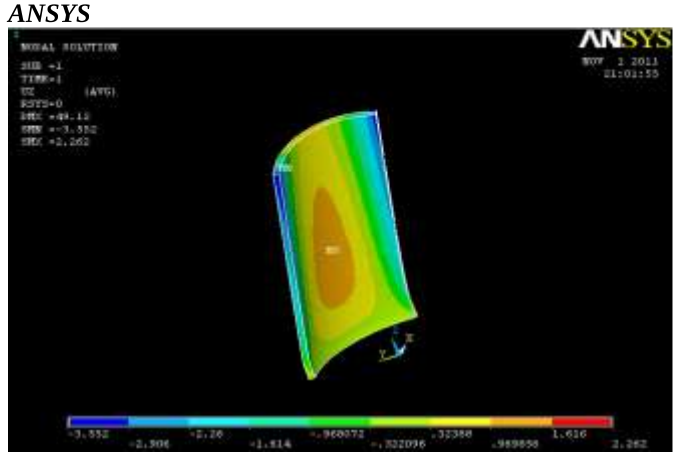

Fig 5.1 Displacement for sector angle Ɵ=90° & L=100mm

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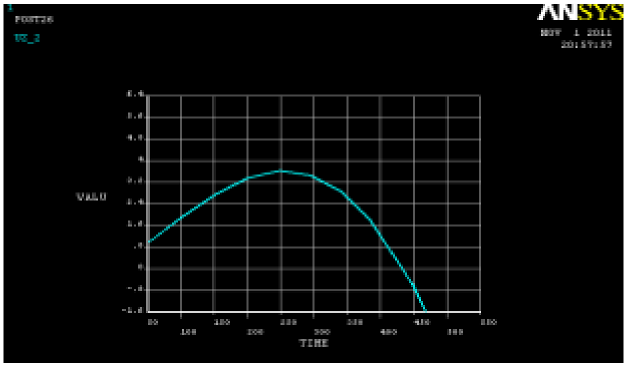

Fig 5.2 Load Vs Displacement for sector angle Ө=90° & L=100mm

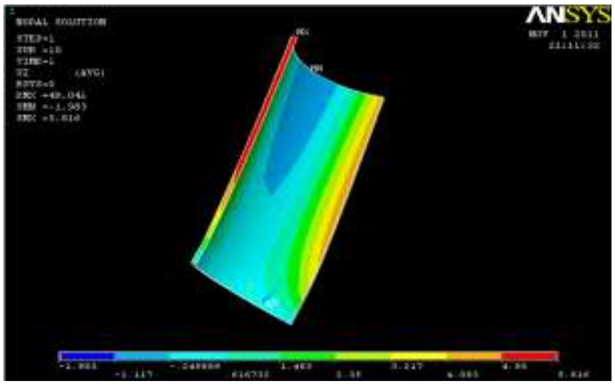

Fig 5.3 Displacement for sector angle Ө=120°& L= 100mm

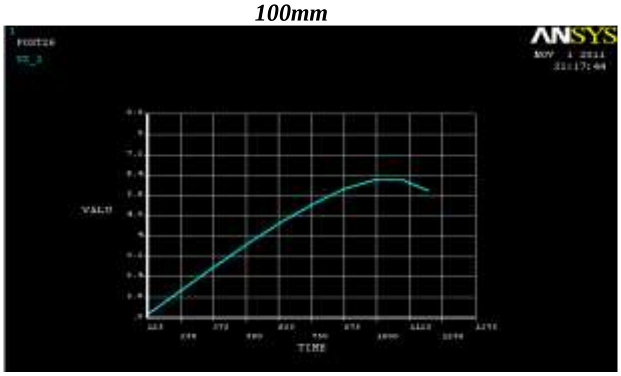

Fig 5.4 load Vs Displacement for sector angle Ө=120° & L=100mm

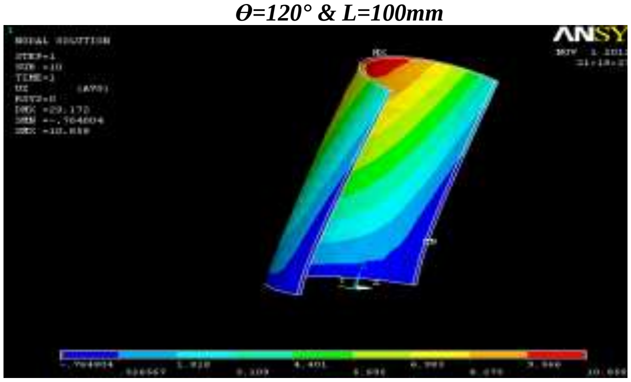

Fig 5.5 Displacement for sector angle Ө=180° & L=100mm

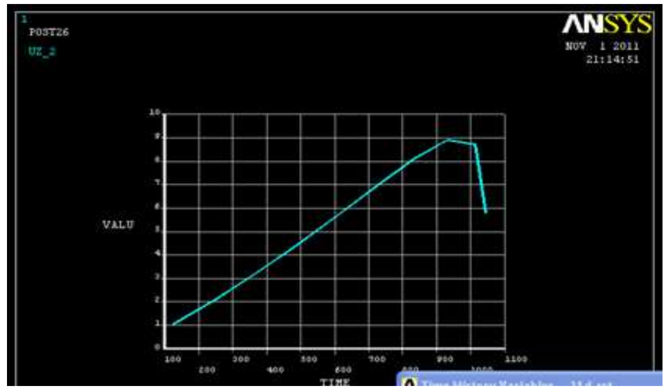

Fig 5.6 Load Vs Displacement for sector angle Ө=180° & L=100mm

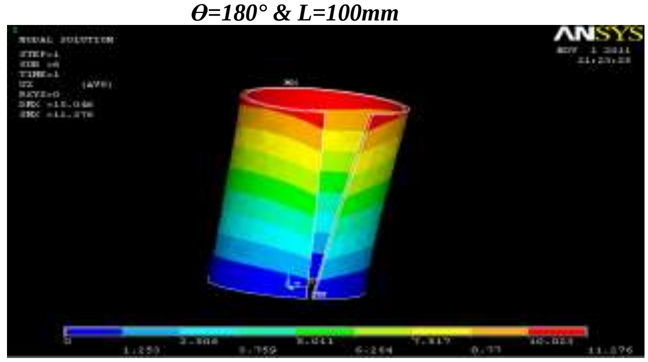

Fig 5.7 Displacement for sector angle Ө=355° & L=100mm

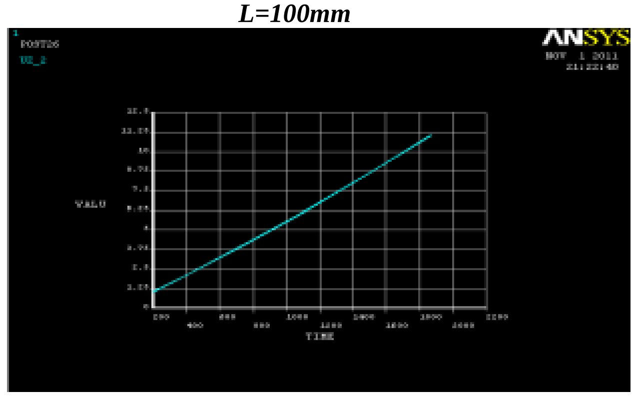

Fig 5.8 Load Vs Displacement for sector angle Ө=355° & L=100mm

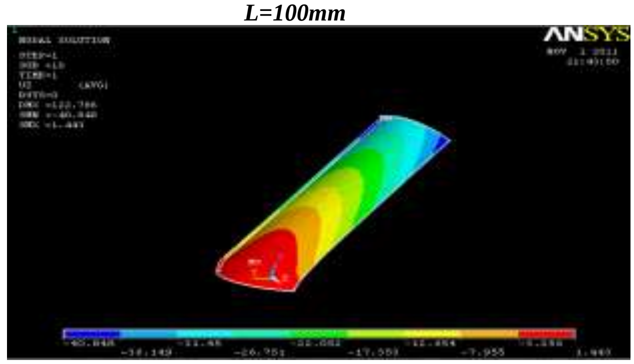

Fig 5.9 Displacement for sector angle Ө=120° & L=150mm

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Scientific Journal Impact Factor: 3.449
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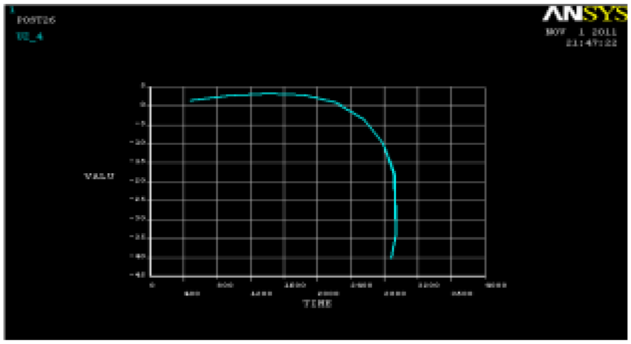

Fig 5.10 Load Vs Displacement for sector angle Ө=120° & L=150mm

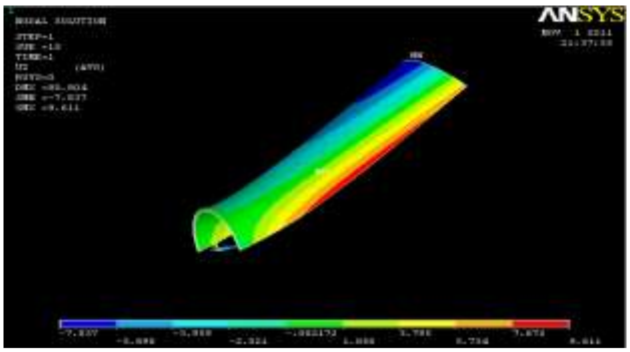

Fig 5.11 Displacement for sector angle Ө=180° & L=150mm

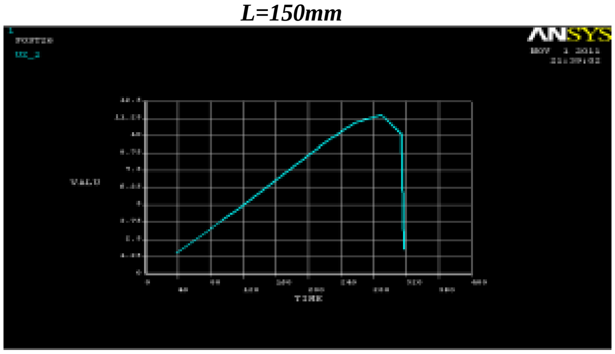

Fig 5.12 Load Vs Displacement for sector angle Ө=180° & L=150mm

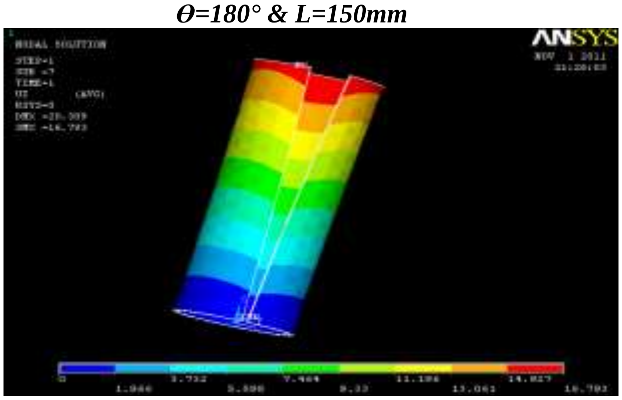

Fig 5.13 Displacement for sector angle Ө=355° & L=150mm

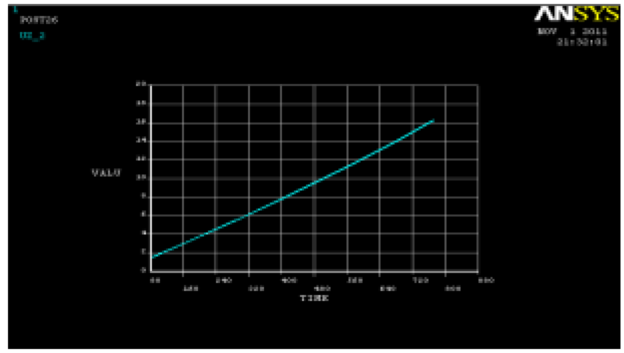

Fig 5.14 Load Vs Displacement for sector angle Ө=355° & L=150mm

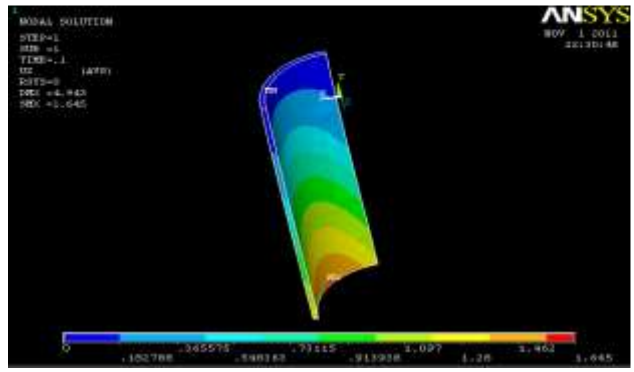

Fig 5.15 Displacement for sector angle Ө=90° & L=250mm

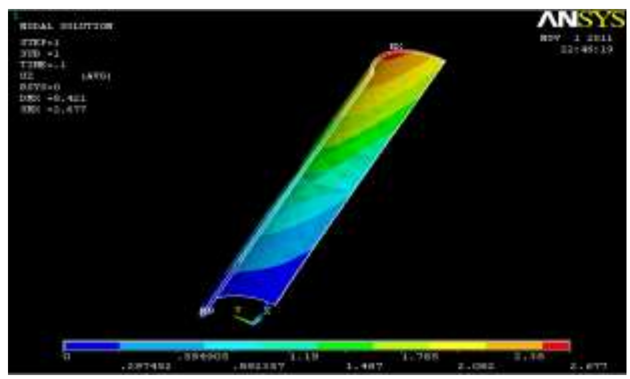

Fig 5.16 Displacement for sector angle Ө=120° & L=250mm

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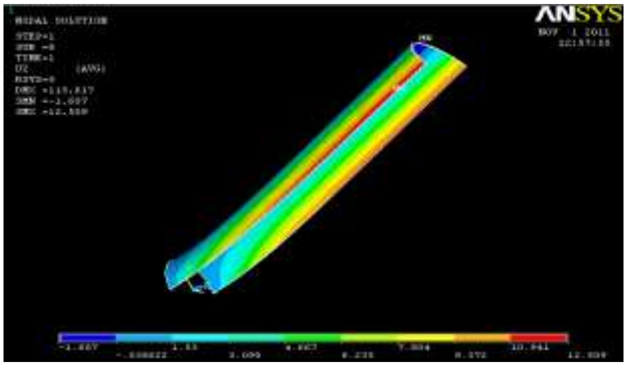

Fig 5.17 Displacement for sector angle Ɵ=180° & L=250mm

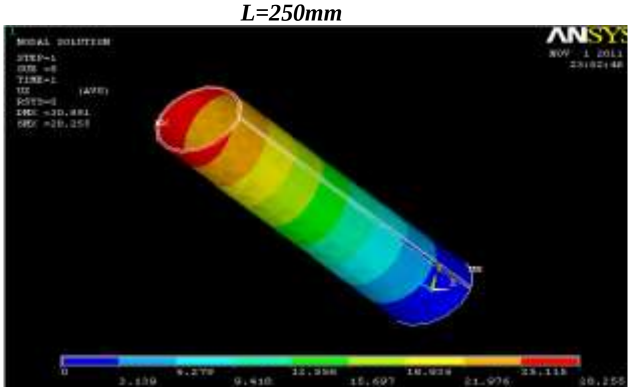

Fig 5.18 Displacement for sector angle Ɵ=355° & L=250mm

Analytical Result

Sect. angle	Ɵ=90°		Ɵ=120°		Ɵ=180°		Ɵ=355°	
Leng. (mm)	Load (kn)	Max. Disp. mm	Load (kn)	Max Disp mm	Load (kn)	Max Disp mm	Load (kn)	Max Disp mm
100	7.5	2.262	13	5.916	16	10.010	33	11.276
150	6	2.46	9	1.443	13	9.611	30	16.793
250	4.5	1.645	7	2.677	12	12.509	28	28.255

Results and discussion

The Buckling load decreases slightly with increase in length. This reduction is more for shorter lengths. Also by increasing the sector angle of a panel, the buckling load increases. Displacement of cylindrical panel for different lengths and various sector angle (90°, 120 °, 180 °, 355 °) was analyzed using ANSYS and compared with experimental result. The experimental result is less than the allowable value. The following graphs are shown in comparison with experimental and analytical results for various cylindrical panel angles.

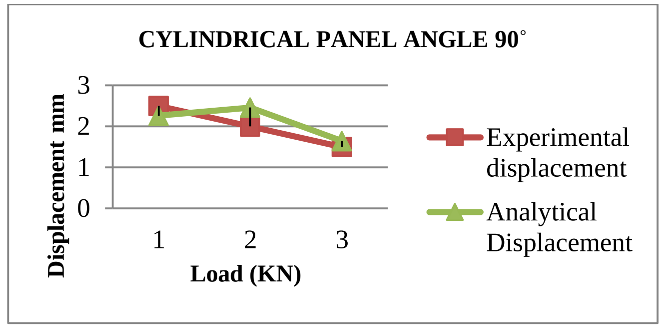

FIG 6.1 Cylindrical Panel angle 90°

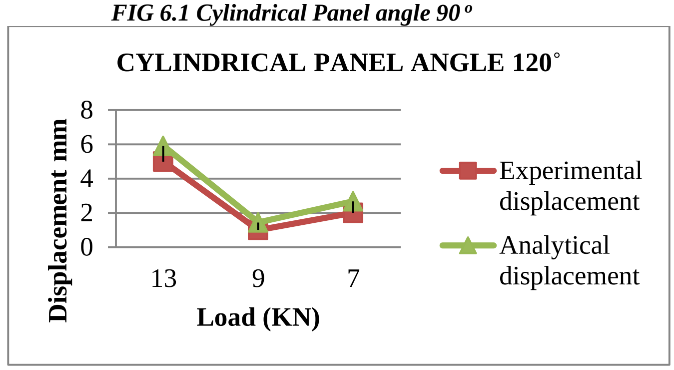

Fig 6.2 Cylindrical Panel angel 120°

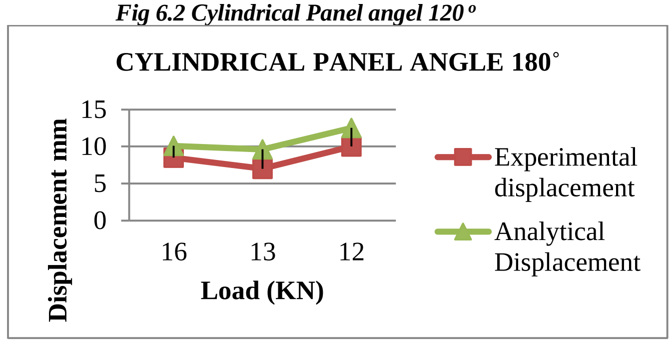

Fig 6.3 Cylindrical Panel angle 180°

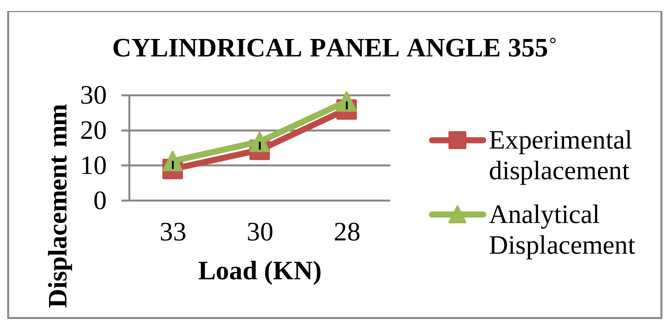

Fig 6.4 Cylindrical Panel angle 355°

Conclusion

From this work the experimental and analytical results shows that

1.The length and sector angle on the buckling load of cylindrical panels have been studied experimentally by applying compressive load in the axial direction on the panels using Universal testing machine.

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
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2.By increasing the length of the panels the buckling load decreases slightly. It is increasing for short panels.
3.The buckling load increases by increasing the sector angle.
4.The experimental and simulation were compared in terms of displacement for various load, different length and sector angle of panels.
The experimental and simulation results are closely too related to each other.

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