POST BUCKLING BEHAVIOR OF THIN WALLED SILO STRUCTURE.

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ABSTRACT

Silos are special structures subjected to many different unconventional loading conditions, which result in unusual failure modes. Failure of a silo can be devastating as it can result in loss of the container, contamination of the material it contains, loss of material, cleanup, replacement costs, environmental damage, and possible injury or loss of life. The high rate of structural failure in these structures is a strong indication of the extensive range of issues that must be understood by the designer and the complexity of their behavior. This paper presents a numerical investigation into the buckling and post-buckling of silos under axial compression using a time-integrated finite element model. The numerical results generated herein are compared with test data and are found to be in good agreement. Since stiffeners have the vital role to support the pressure vessel and to maintain its stability, it should be designed in such a way that it can afford the vessel load and internal pressure of the vessel due to liquid contained in the vessel. A model of vertical pressure vessel and stiffeners is created in ANSYS. Stresses are calculated using mathematical approach and ANSYS software. The analysis reveals the zone of high localized stress at the junction part of the pressure vessel and stiffeners due to operating conditions. The results obtained by both the methods are compared with allowable stress value for safe designing. The analyses provide significant new insight into the mechanisms underpinning collapse behavior of the shells. The tests which are carried out on cylindrical silo models, the measurement of the initial imperfections and the numerical analysis of the shells are presented.

Keyword : - *ANSYS, Axial pressure, post-buckling, Silos, Stiffeners*

1. INTRODUCTION

Large steel silos are typical kind of thin walled structures which are widely used for storing huge quantities of granular solids in industry and agriculture. Silos are widely used in agricultural, mining and manufacturing industries to store grain (maize and soya beans), fluids (oil and fuel), cement and platinum ores. The sizes of engineered silos may vary from capacities less than 10 tones to the largest containing as much as 1,00,000 tones. These steel silos are usually with large diameter to thickness ratios, which is particularly vulnerable to buckling due to internal pressure, wind pressure. The critical load capacity of cylindrical shells, subjected to uniform pressure, depends on two geometric slender ratios of “length to radius” (L/R) and Radius to thickness”(R/T). Therefore, the geometric imperfections would influence the buckling and postbuckling behavior of these structures. The experimental studies show that the buckling strength of ideal shells without geometric imperfections is much more than that of imperfect shells. Therefore the imperfection sensitivity of these structures must be considered carefully and properly.

2. BUCKLING AND POST BUCKLING

A. Buckling

Buckling is that mode of failure when the structure experiences sudden failure when subjected to compressive stress. When a slender structure is loaded in compression, for small loads it deforms with hardly any noticeable change in the geometry and load carrying capacity. At the point of critical load value, the structure suddenly experiences a large deformation and may lose its ability to carry load. This stage is the buckling stage. The structural instability of buckling can be categorized as; Bifurcation buckling Limit load buckling In Bifurcation buckling, the deflection when subjected to compressive load, changes from one direction to a different one. The load at which bifurcation occurs is the Critical Buckling Load. The deflection path that occurs prior to the bifurcation is called as the Primary Path and that after bifurcation is called as secondary or post buckling path. In Limit Load Buckling, the structure attains a maximum load without any previous bifurcation, i.e. with only a single mode of detection.

B. Post Buckling

Post buckling stage is a continuation of the buckling stage. After the load reaches its critical value the load value may not change or it may start decreasing, while deformation continues to increase. In some cases the structure continues to take more loads after certain amount of deformation, to continue increasing deformation which eventually results in a second buckling cycle. Post buckling analysis being nonlinear, we obtain far more information than we obtain from linear Eigen-value analysis. The non-linear load-displacement relationship, which can be a result of the stress strain relationship with a nonlinear function of stress, strain and time. The changes in geometry due to large displacements; irreversible structural behaviour upon removal of external loads; change in the boundary conditions such as change in the contact area and the influence of loading sequence on the behaviour of the structure, requires a nonlinear structural analysis. The nonlinear structural analysis depends upon the various structural non linearities. The structural nonlinearities can be classified as, a geometric nonlinearity, a material nonlinearity and a contact or a boundary nonlinearity.

3. CALCULATED DIMENSIONS OF SILO

Thickness of shell = 12 mm

Diameter of shell = 7200 mm

Thickness of nozzle = 6 mm

Diameter of nozzle = 300 mm

Thickness of reinforcing pad = 6 mm

Diameter of reinforcing pad = 648 mm

Thickness of flat head = 134.72 mm

Internal radius of flat head = 10 mm

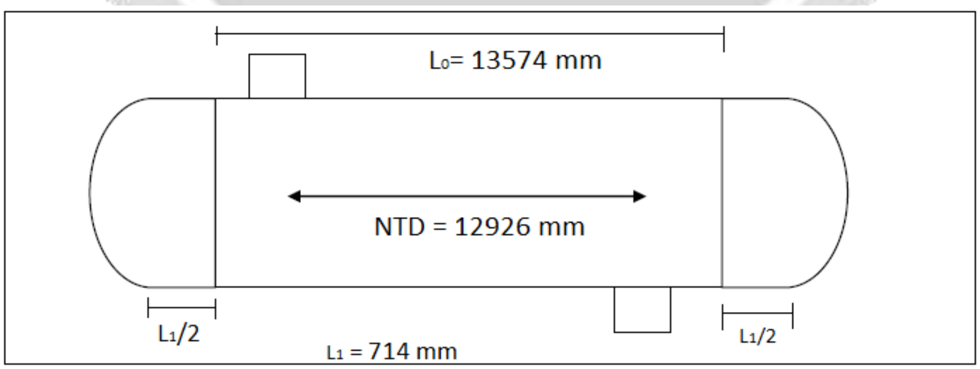

Fig -2: Line Diagram with Dimensions of Silos

4. ANALYSYS BY USING ANSYS SOFTWARE:

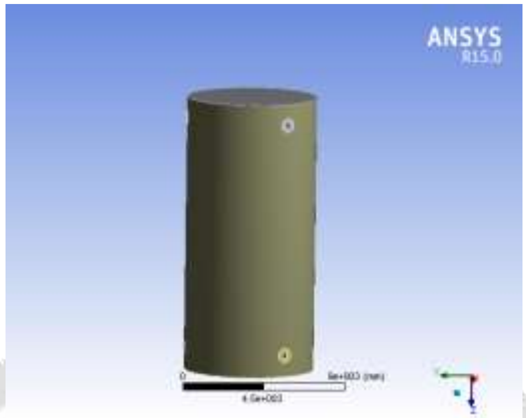

Fig 1:

Fig.2 Model (F4, G4, H4) > Static Structural (F5) > Standard Earth Gravity

TABLE 1
Model (F4, G4, H4) > Static Structural (F5) > Loads

Object Name	*Fixed Support*	*Pressure*
State	Fully Defined	
Scope		
Scoping Method	Geometry Selection	Named Selection
Geometry	1 Face	
Named Selection		Presure
Definition		
Type	Fixed Support	Pressure
Suppressed	No	
Define By		Normal To
Magnitude		-2.107 MPa (ramped)

Fig.3 Model (F4, G4, H4) > Static Structural (F5) > Pressure

1. Solution (F6)

TABLE 2

Model (F4, G4, H4) > Static Structural (F5) > Solution

Object Name	*Solution (F6)*
State	Solved
Adaptive Mesh Refinement	
Max Refinement Loops	1.
Refinement Depth	2.
Information	
Status	Done

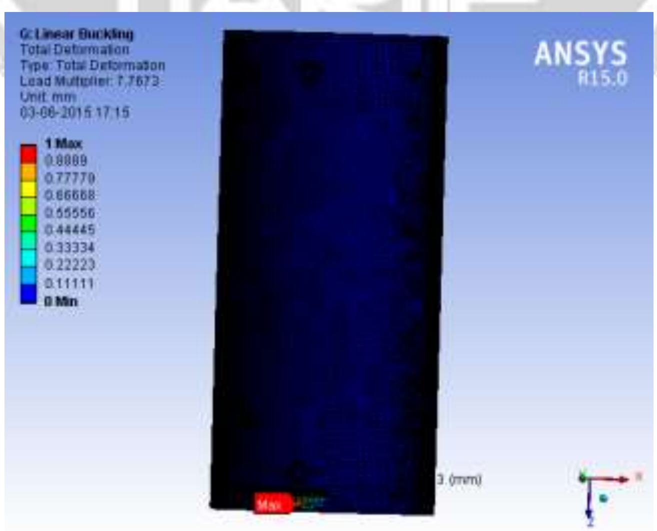

Fig.3(a) Model (F4, G4, H4) > Linear Buckling (G5) > Solution (G6)

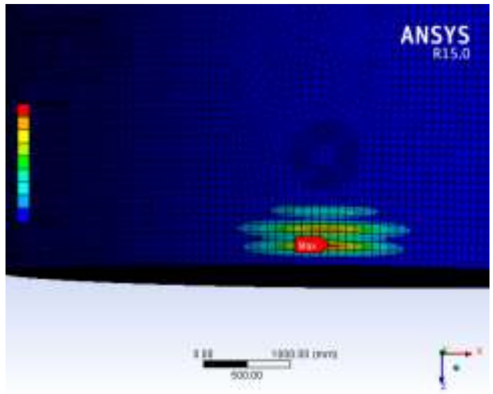

Fig.3(b) Model (F4, G4, H4) > Linear Buckling (G5) > Solution (G6)

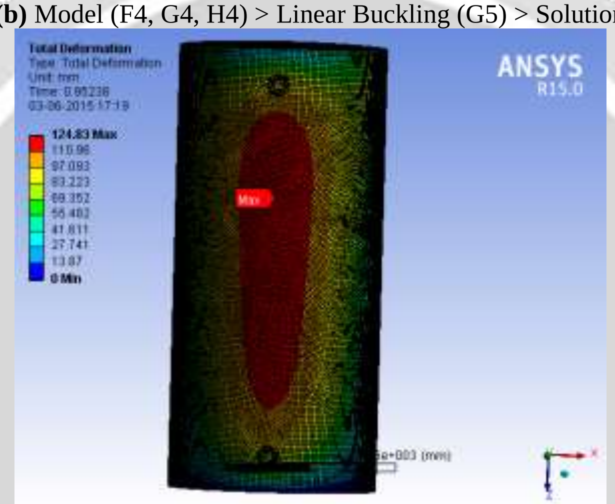

Fig.4 Model (F4, G4, H4) > Static Structural 2 (H5) > Solution (H6) > Total Deformation

TABLE3
Model (F4, G4, H4) > Static Structural 2 (H5) > Solution (H6) > Total Deformation

Time [s]	Minimum [mm]	Maximum [mm]
4.7619e-002		6.2419
9.5238e-002		12.483
0.14286		18.722
0.19048		24.961
0.2381		31.2
0.28571		37.438
0.33333	0.	43.675
0.38095		49.912
0.42857		56.15
0.47619		62.387
0.52381		68.625
0.57143		74.863
0.61905		81.103

0.66667		87.344
0.71429		93.587
0.7619		99.832
0.80952		106.08
0.85714		112.33
0.90476		118.58
0.95238		124.83
1.		131.09
2.		131.5
3.		131.91
4.		132.32
5.		132.73
6.		133.14
7.		133.55
8.		133.97
9.		134.38
10.		134.79
11.		135.2
12.		135.61
13.		136.02
14.		136.43
15.		136.84
16.		137.25
17.		137.66
18.		138.07
19.		138.48
20.		138.89
21.		139.3

***1.* Material Data**

Structural Steel

TABLE4

Structural Steel > Constants

Density	1.e-006 kg mm^-3
Coefficient of Thermal Expansion	1.2e-005 C^-1
Specific Heat	4.34e+005 mJ kg^-1 C^-1
Thermal Conductivity	6.05e-002 W mm^-1 C^-1
Resistivity	1.7e-004 ohm mm

4. CONCLUSIONS

This paper has presented a FEM investigation of internally loaded vertical silo. It is commonly known that linear buckling analysis is not a very accurate method. Nonlinear buckling analysis is more accurate but it uses iteration which increases computing time significantly. FEA plays important role in Design optimization for structural parts.

High costs in prototypes preparation, specialized set up are some of the drawbacks of the physical test. The most noticeable points from this study are summarized below:

Design calculations of the silo and its components done by using ASME code for given loading conditions. From the results obtained after linear and nonlinear analysis, we calculated critical buckling capacity of silo equal to 16 MPa, which is very higher value than actual internal pressure value 0.2498 MPa for which silo is designed. Hence, we can conclude that silo is safe against buckling failure.

6. REFERENCES

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