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BUCKLING ANALYSIS OF THIN SHELLS

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ABSTRACT

A wide range of applications are there for shell structures in engineering field such as storage tanks(silos), missile and aircraft fields etc. Silos are tall structures used to store bulk solids in quantities ranging from a few tones to hundreds or thousands of tones. Although the behavior of shells has been studied extensively for several decades, the influence of thickness variation on its stability has not gained sufficiently attention and remains mysterious. These structures are mostly failing by buckling under external pressure. The buckling load is usually the most used criteria in designing of a long thin shell. This paper represents a study on the influence of thickness of shell on the buckling behavior of a typical steel silo under the influence of earthquake loads.

KEYWORDS: Buckling Analysis, Steel Silo, Stiffeners, Non Linear Analysis

INTRODUCTION

The buckling strength is one of the basic and important properties of silos. Determination of buckling behavior of steel silo is necessary because it helps to estimate the load at which the silo may buckle. Buckling failure is a sudden and dramatic failure, hence it plays an important role in the functioning of silos. The steel silo that considered for study is stiffened in both horizontal and vertical directions. In the stability of the stiffened silos, there are two types of buckling- Local buckling and Global buckling. Global buckling results in the sudden failure of the structure.

The common cross-section of steel silos is circular that may be either ground supported or elevated. Steel silos possess many advantages over cast-in-situ concrete silos. Its quality can be controlled, their erection time is considerably shorter and it is relatively easy to disassemble. And also moving and rebuilding it in another location is easy. But there are some disadvantages for the steel silos. Main disadvantage is the excessive wear of steel walls which gives necessity of lining on the walls. The steel walls are prone to condensation also, which can damage the store products which are moisture sensitive such as grain and cement etc.

By considering the structural configuration, loads nature and boundary conditions, steel silos are very complicated. So the conventional methods of analysis are not enough to solve the complexities involved in it. Since the sizes of silos are very big, conducting experimental studies is not viable. Therefore analytical investigations are adopted and carried out using Finite Element Method (FEM), a numerical technique for representing and simulating physical systems. The geometry to be analyzed is replaced with a set of elements, consisting of nodes with a finite number of degrees of freedom. These nodes form a grid called the mesh. Certain material and structural properties are assigned to the mesh, which define how the structure will react to the applied loading conditions. The silo is modelled and analysed in ANSYS 14.5, which can give a complete solution that takes virtual prototyping to a new level of accuracy, realism and efficiency.

Figure 1: Buckled Silo

ANSYS supports two types of buckling analysis – **non linear and linear analysis**.

Non-linear Buckling Analysis is the more accurate technique and is usually used for design or evaluation of actual structures. This employs a non linear static analysis with gradually increasing loads to seek the load level at which the structure becomes unstable. This technique can consider initial imperfections, plastic behavior, gaps, and large deflection response of the model. The post-buckled performance of the model can be studied by deflection controlled loading.

Eigen Value Buckling Analysis gives the theoretical buckling strength of an ideal linear elastic structure. This method resembles to the text book approach of elastic buckling analysis: for instance, an Eigen value buckling analysis of a column will match the classical Euler solution. But imperfections and non linearities are there in real-world structures which wont give their theoretical elastic buckling strength. So the Eigen value buckling often yields unconservative result, hence not using in actual day-to-day engineering analysis.

Procedure for Non Linear Buckling:

- Building the model
- Obtaining the modal solution
- Obtain the static solution
- Expanding the solution
- Reviewing the results

Characteristics of Steel Silos Modeled

The steel silo is modelled through ANSYS finite element software with real dimensions and usage is storing cement. It consists of a cylindrical portion, external stiffeners (both in circumferential and longitudinal directions), a bottom hopper and a roof with an opening at the top. The cylindrical portion rests on staging support. Stiffening rings are provided for strengthening silo walls against collapse. Figure 2 depicts various parts of the silo selected for study. Silo walls are strengthened against collapse using stiffening rings.

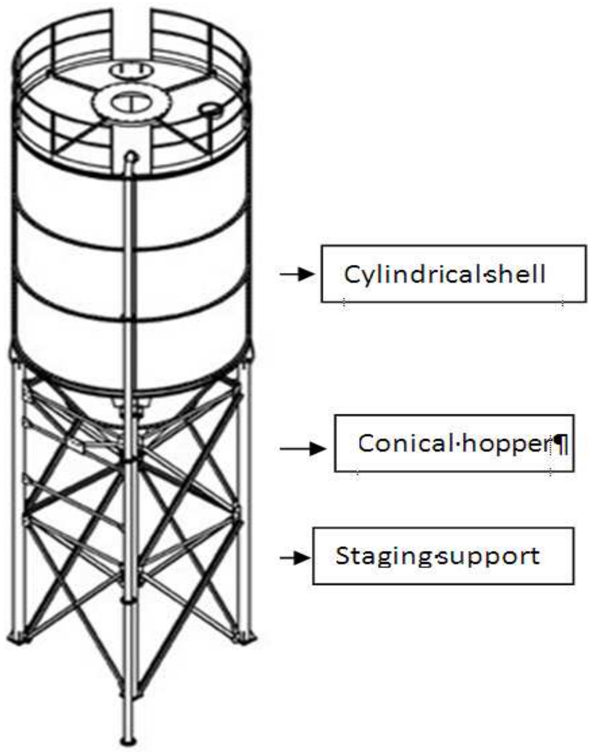


Figure 2: Parts of Silo

Dimension of the Various Parts are Listed Below:

1) Radius of cylindrical portion = 1.75 m
2) Height of cylindrical portion = 12 m
3) Height of bottom hopper = 4.75 m
4) Inlet and Outlet radius = 0.375 m
5) Silo roof has a slope of 60^0 with respect to horizontal
6) Thickness = 6 mm
7) Opening of the circular cutout = 200 mm

Material Properties of the Silo are Given Below:

1) Young's modulus = 210 kN/m^2
2) Poisson's ratio = 0.3

3) Specific weight = 78.5 kN/m^3

Details of Stiffeners Properties Are:

1) For horizontal stiffener: Inverted T section – ISNT 250 250 X 180

2) For vertical stiffener: Inverted T section – ISNT 80 80 X 80

Loads Considered for Analysis

Main loads acts on silo walls are hoop tension due to the pressure exerted by the cement particles on the wall, axial compression due to the friction developed at the interface, and the wall self weight. The magnitude and distribution of both shear and normal pressure over the height of the wall were determined using Janssen’s theory.

Silo, being a tall and slender structure, is also invariably affected by earthquake. The distribution and magnitude of earthquake load on silo structure is calculated in accordance with IS 1893 (Part 1) – 2002.

The behaviour of the silo for the load combination 1.2 (DL+LL+EL) is considered.

SILO MODEL USING ANSYS SOFTWARE

Analysis of Stiffened Steel Model:

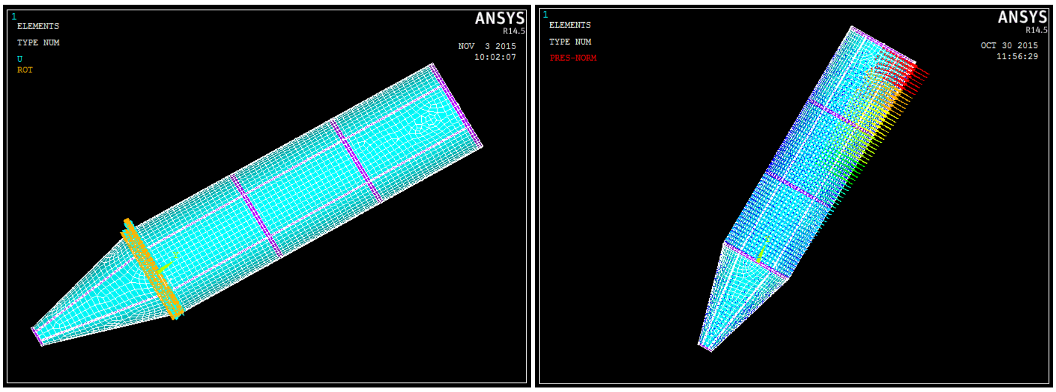


Figure 3, 4: Model with Applied Boundary Conditions and Loading

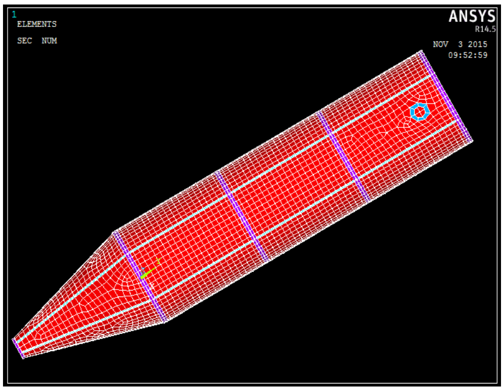
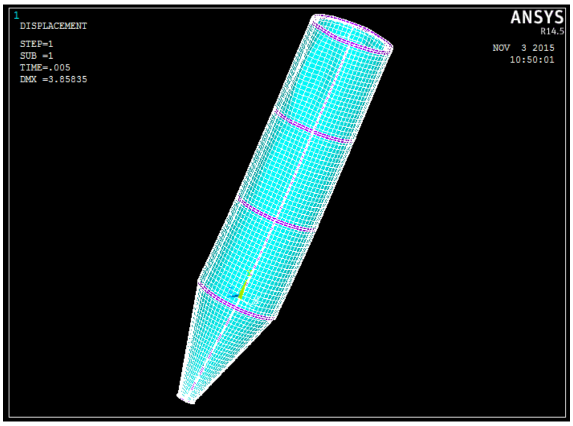


Figure 5: Model with Applied Boundary Conditions and Loading

Following figures shows the deformed shapes for different cutout thickening for 6mm thick shell.

Without Cutout



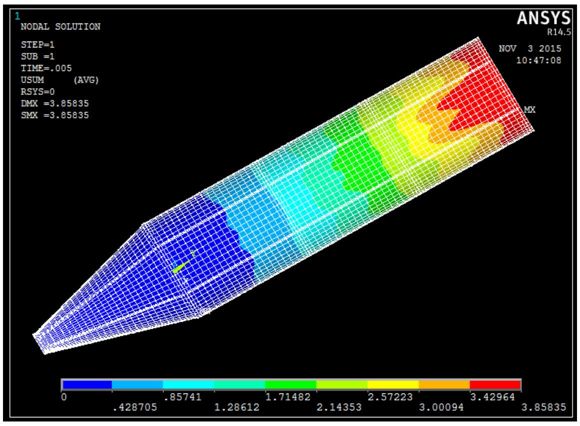
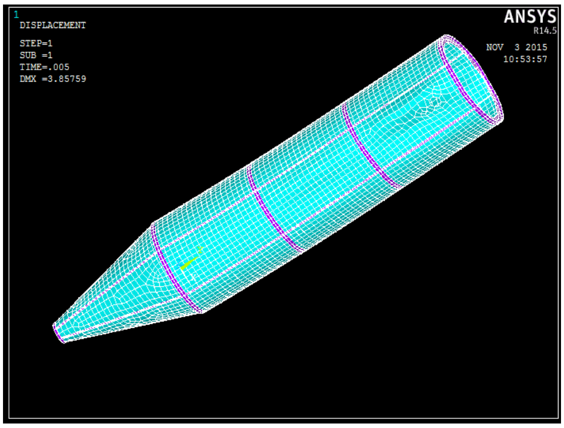


Figure 6: Deformation **Figure 7: Displacement**

With Cutout



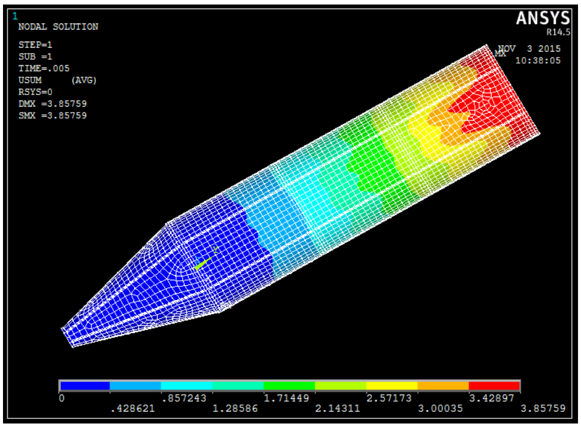
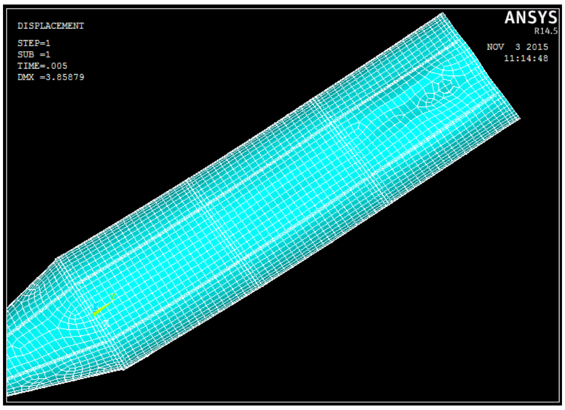


Figure 8: Deformation **Figure 9: Displacement**

5.3.1 Adding Thickness to the Shell- 14mm Thickness



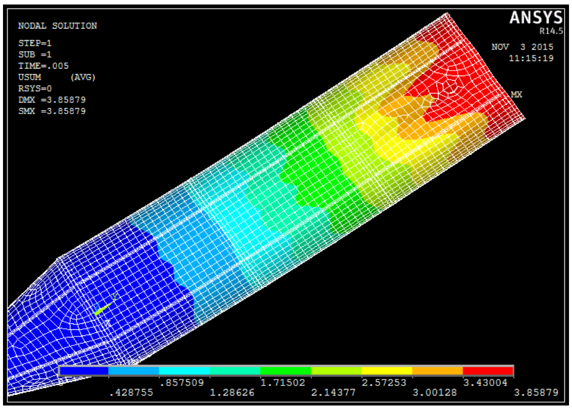


Figure 10: Deformation **Figure 11: Displacement**

SUMMARY AND CONCLUSIONS

The displacement diagrams obtained for different thicknesses around the cutout - with shell thickness 2.5mm are shown below:

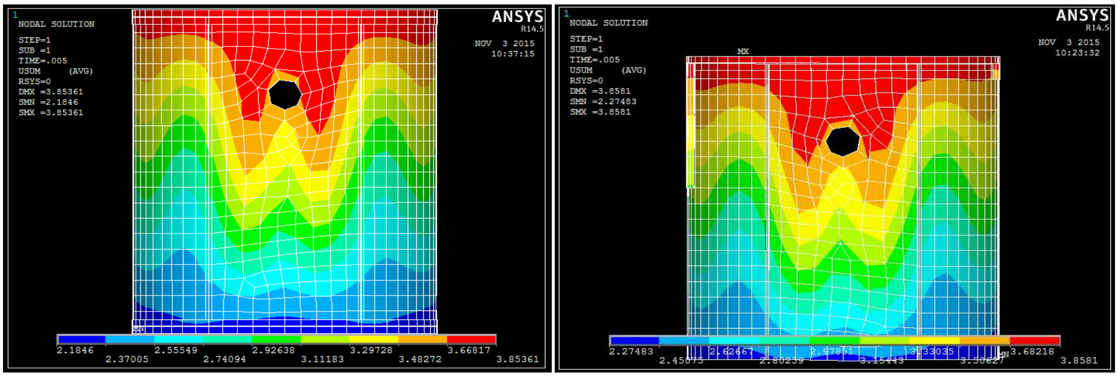


Figure 12, 13: Displacement Diagram without Thickening, with 8mm Thickness around the Cutout

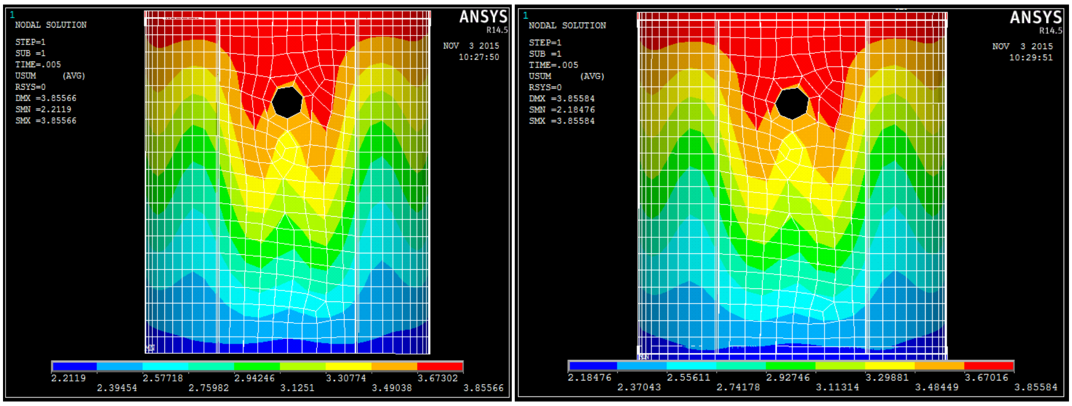


Figure 14, 15: Displacement diagram with 10mm and 12mm Thickness around the Cutout

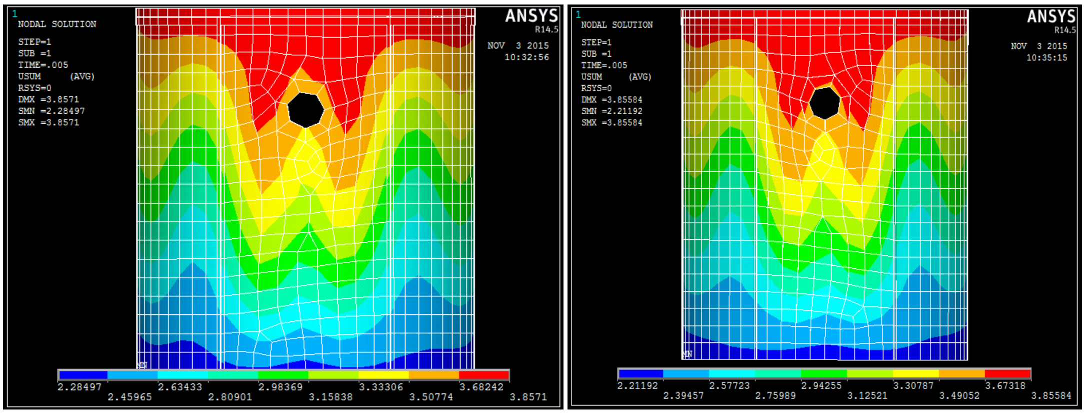


Figure 16, 17: Displacement diagram with 14mm Thickness around the Cutout, 16mm Thickness around the Cutout

The displacement diagrams obtained for different thicknesses around the cutout –with shell thickness 2.5mm are shown below:

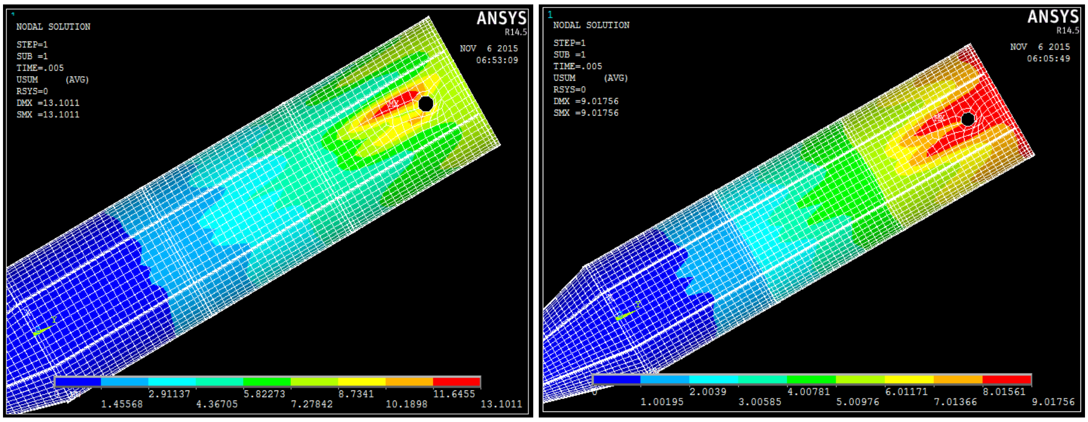


Figure 18, 19: Displacement Diagram without Thickening, with 5mm Thickness around the Cutout

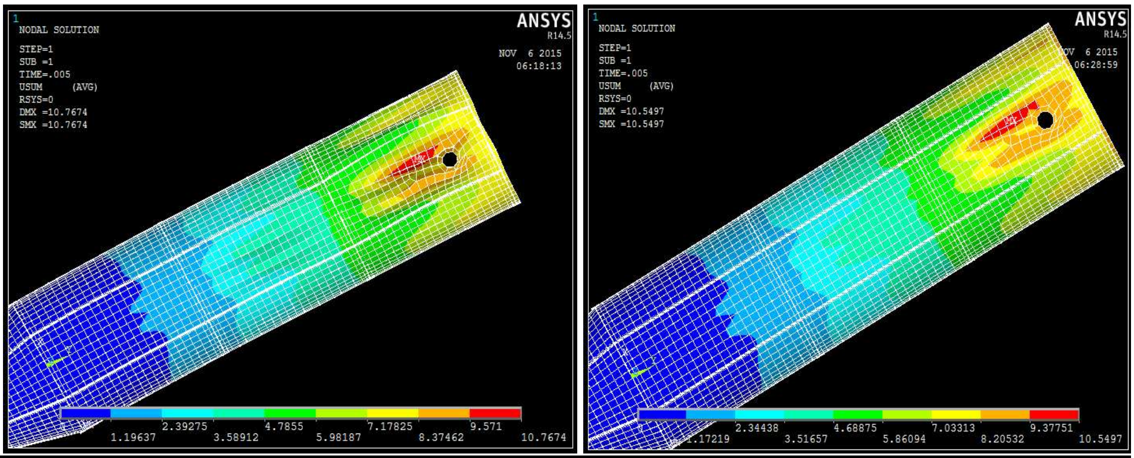


Figure 20, 21: Displacement Diagram with 7.5mm and 10mm Thickness around the Cutout

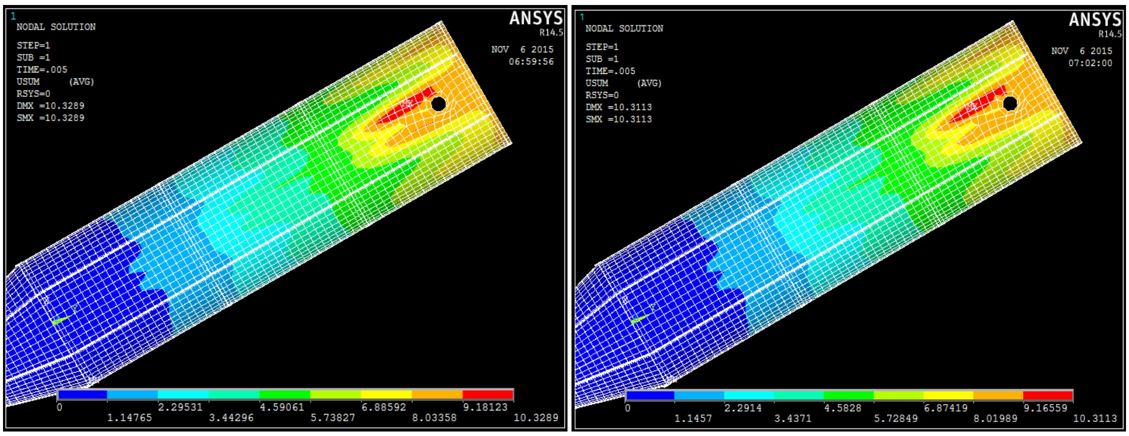


Figure 22, 23. Displacement Diagram with 1.25mm and 15mm Thickness around the Cutout

The displacement is maximum at the top portion of the silo. While considering operational purposes the displacement should be minimum around the cutouts. On comparing the results, it is clear that, on thickening the elements around the cutout leads changes in the behavoiur of steel silo when subjected to loading. This change is different for silos with different shell thickness. On increasing the thickness, the displacement is minimum only at one thickness. In this study the decrease in displacement around the cutout changed only for 14mm thickness when the shell thickness is 6mm. But for 2.5mm thick shell this value changes to 7.5mm.

Nonlinear buckling analysis of stiffened steel silo is carried out and understood the concept of buckling and its failure modes in thin steel silos. Observed the effect of cutout in buckling (variation of displacement, stress intensity etc are studied). From the study it is clear that the variation of thickness around the cutout portion affects the buckling behaviour of the shell structure. There is an optimum thickness around the cutout for which the displacement will be the minimum.

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