

THE EFFECT OF PATCH LOAD ON CORRUGATED SILO WALLS

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1. Introduction

Silos are special structures widely used in industries to store all kind of agricultural products. Loads exerted by the stored material over the silo walls are critical in the silo design. Eurocode [1] specifies how to calculate the pressures due to the stored material depending on different characteristics of the silo: shape, slenderness or capacity. If filling is centric, a symmetric flow is expected and, therefore, horizontal pressures acting on the silo wall will have a constant value for the circumferential position at any height. In addition, pressures are greater for higher silo depths.

However, filling is sometimes eccentric and non-symmetric behaviours may also appear during filling and emptying. In those cases, asymmetric flow might appear and this can lead to non-symmetric pressures over the silo wall. Eurocode defines the patch-load to reproduce these non-symmetric pressures. The patch-load is an asymmetric pattern of lateral pressures applied over a part of the silo wall (Figure 1) and added to the symmetric pressures. The patch-load can be applied at any height of the silo but in a reduced length of the walls. In consequence, the design of the silo must satisfy structural safety with independence of the patch-load localisation.

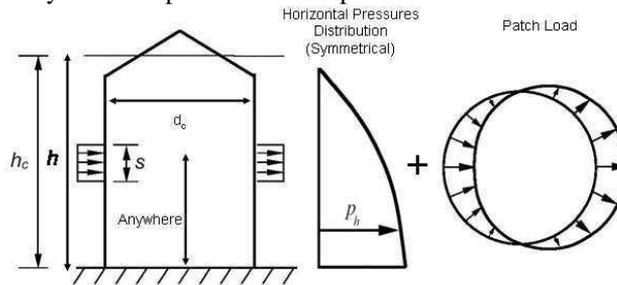


Figure 1. Requirements of patch-load according to Eurocode (EN 1991-4 2003)

For low silo capacities, Eurocode allows replacing the patch-load with a uniform increment in lateral pressures. However, this simplification is not possible for silos with large capacities. In this case, the calculation of the wall stress states due to the patch-load is more complex than for symmetric loads.

2. Methodology.

A three dimensional Finite Elements Model with ANSYS software was developed to simulate the cylindrical corrugated silo walls with flat bottoms (Figure 2). The application of unsymmetrical pressures in silo walls has been considered in some research [2] but simulating smooth walls. The possible influence of different factors in the stress state of the silo wall after the application of the patch-load was considered: the slenderness of the silo ($\lambda=h_c/d_c$), the flexibility of the wall ($t/0.5 \cdot d_c$) and the silo height, h_h , at which the patch-load is applied. By varying the silo height, h_c , the silo diameter, d_c , and the wall thickness, t , forty eight finite element models were developed as a result of considering four slenderness values ($\lambda=1.35$, $\lambda=1.62$, $\lambda=1.90$ and $\lambda=2.17$), three thicknesses of the wall ($t=2$ mm, $t=6$ mm and $t=9$ mm) and four positions for the patch-load ($h_i=0.2 \cdot h_c$, $h_i=0.4 \cdot h_c$, $h_i=0.6 \cdot h_c$, and $h_i=0.8 \cdot h_c$). Results were also obtained for different circumferential positions (0° , 45° , 90° , 135° and 180°) in the silo wall in order to detect the stresses asymmetries produced by the non-symmetric condition of the patch-load.

The purpose was the comparison of the stress states resulting after applying the patch-load and the lateral pressures due to the stored material. Firstly, lateral pressures due to the stored material were applied to the silo wall and the wall stresses in the circumferential positions were obtained. After that, the patch-load was applied to the silo wall, and the new stress state of the silo wall was obtained for the same circumferential positions. Finally both sets of results are compared, and the increment ratio of stresses, k , is obtained at every part of the silo wall.

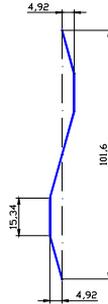


Figure 2. Geometry on an elemental undulation of the corrugated wall (Dimensions in mm).

3. Results.

The patch-load makes the silo wall suffer an inward deformation in the pressure zone and an outward deformation in the opposite part (Figure 3a). It can be clearly seen in Figure 3b that an overstress in the silo wall is detected where the patch-load is applied ($k > 1$). The patch-load does not produce any change in the stress state above the silo height where the patch-load is applied. A linear increase in k is detected for the silo wall placed below h_h . These results may be used to simplify the procedure defined in Eurocode, even for the higher capacity silos.

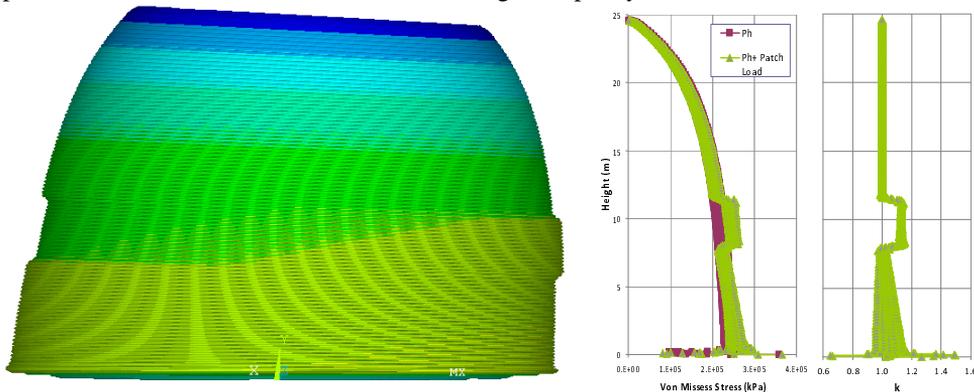


Figure 3. a) Deformation of the silo wall b) Increment ratio of stresses, k , over the silo wall.

4. References.

- [1] EN 1991:4 (2003). *Eurocode 1. Basis of design and actions on structures. Part 4: actions in silos and tanks*, CEN, Brussels.
- [2] D. Briassoulis (2000). Finite Element Analysis of a cylindrical silo shell under unsymmetrical pressure distributions, *Computers & Structures*, **78**, 271-281.