CALCULATION STANDARDS

DATA SHEET 7.1
VERSION 2
28/01/2021

PROCEDURE

Symaga makes the calculation of the silos following the next standards:

NORMATIVA	DENSIDAD DEL GRANO	ÁNGULO DE REPOSO
ANSI-ASAE EP 433 2003	834 Kg/m3	27º
EUROCODE EN 1991-4	918 Kg/m3	34º

It is a general consideration that the horizontal pressure is holded by the bodysheets and the vertical forces supported by the stiffeners. Resistances are calculated according to Eurocode.

LOADS CALCULATION

We analize four loads for silo calculation:

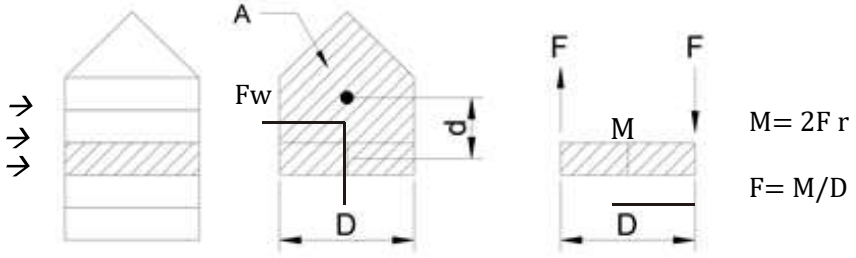
1 GRAIN

Following the equations given by ANSI EP 433 2003 and EUROCODIGO EN 1991-4 standards, to calculate grain pressure loads in the interior of the silo, we obtaine the loads that support the bodysheets and stiffeners.
Basically, grain pressure loads are calculated combining Janssen formula and the specific coefficients corresponding in each case. That way we obtain the horizontal loads held by the bodysheets and the vertical loads to be held by the stiffeners.

2 WIND

Wind force is given by the customer. If it is not the case, Symaga will considers 100 kg/m2 and a exposure coefficient of 0.8.
The wind pressure in the silo walls is converted in an overturning moment in the base of the structure. It is general consideration that the stiffeners absorb this torque. Half of the stiffeners are considered to be compressed by the effect of this torque and half of the stiffeners are stretched. Sizing of the stiffeners is based on those compression forces.

P 100 Kg/m2 x A 10 m2 = F100 Kg $\quad W \rightarrow Fw = W \times A \rightarrow M = F \times d \rightarrow F = M/D$



3 SNOW

Snow loads are given by the customer. If not the case 80 kg/m2.
This load acts directly on the roof and is transferred equitably to the stiffeners.

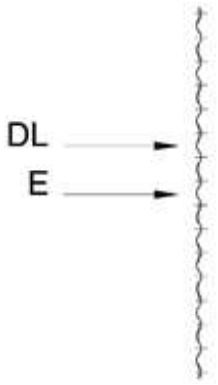
4 EARTHQUAKE

Seismic coefficient is given by the customer. Otherwise, Symaga consideres that seismic coefficient is 0.
Seismic load is considered as a horizontal load, proportional to the silo weight plus grain load. This load is considered in additional hypothesis that combines seism and other loads.
The seismic acceleration is the data that gives the norm regarding the area (location).
The seismic coefficient is the acceleration due to the different coefficients of increase or decrease. This is why we multiply the mass to obtain the seismic force.
When we are given a UBC zone, we use this norm to calculate CS2. $Fs = MxCs$

BODYSHEET CALCULATIONS

We study this three design criteria and size basing in the worst case:

DESIGN CRITERIA	DESCRIPTION	CALCULATIONS
Cross section	Elastic resistance of the bodysheet steel	UNE-EN 1993-1-1:2013
Shear resistance	Shear resistance per shear plane in the bolts.	UNE-EN 1993-1-8:2013
Bearing resistance	Bearing resistance of the sheets surrounding the joint holes when being bended by the loaded bolts.	



This values should be more than these forces:
-Horizontal forces due to grain loads. (DL)
-Seismic force due to load grain and silo weight. (E)
In the bodysheet calculations we always analyze the joint zones, which are the weekest.

STIFFENER CALCULATION

Stiffeners are sized comparing the loads with the cross section resistance.
The calculation of the cold rolled profiles are run according UNE-EN 1993-1-3:2012 Standards. According to this, the load is reduced by a factor. This reduction factor depends on the slenderness of the stiffener.

It can be one of these four types:
1.Plastic
2.Compact
3.Semicompact
4.Slender (Most unfavourable)

LOADS SUMMARY		
LOAD	SHORT DESCRIPTION	DESCRIPTION
Permanent loads	$D_L(1)$	Silo permanent loads. It is considered silo weight and redler weight of 150 kg/m in the area supported by the silo
Permanent loads	$D_L(2)$	Silo permanent loads. It is considered silo weight and redler weight of 150 kg/m in the area supported by the silo
Wind	W	Wind load
Snow	S_N	Snow load
Seism	E	Seism load

COMBINATIONS

According the corresponding standards the following situations are calculated:

LOAD	SILO STATUS	EARTHQUAKE	COMBINATION
1	Silo vacío	No	$1.35D_L(1) + 1.5W + 1.5\ S_N$
2		Si	$D_L(1) + 0.3W + E$
3	Silo lleno	No	$1.35D_L(2) + 1.5W + 1.5\ S_N$
4		Si	$D_L(2) + 0.3W + E$

Status 2 it is not considered because: $DL(1) < DL(2)$

ROOF CALCULATION

Roof calculations are run with a finite elements software called Diamonds.