INVESTIGATION REPORT

Date: 21st November 2017

Location: Agrar Logistik Hafen Hamm
Speicherstrasse 1
59067 Hamm
Germany

Reference: S01472 Ottevanger / Hamm Project

Silos: 2 smooth silos 12m diameter with 21 rings

Storage product: Rapsschrot

GENERAL COMMENTS

The case we have in Hamm, is not one of the scenarios describes in the Eurocode. There is not a particular section in the Eurocode that describes such a load case and cover the design of silos equipped with an unloader like the one in Hamm. So, there is not an official and recognized method to take care of it officially.

This kind of silo (with Hydrascrew) have traditionally been designed based on the loads provided by the manufacturer of the unloader. In this particular case, they use a former French code (P22-630) and they assume that a silo equipped with an Hydrascrew is equivalent to one of the load cases described in P22-630. This load case is known as “full eccentric discharge” and based on it higher pressures are considered to be applied on the silo wall (these pressures are perpendicular pressures and vertical pressures, but they do not feature a torsion effect).

In the Eurocode there is also a “full eccentric discharge”, which is an analogous load case to that in P22-630. Again, this load case doesn’t describe the exact situation of a silo + Hydrascrew and there is no torsion.

In the calculations of silos in Hamm, the maximum pressures and vertical loads from the “full eccentric discharge” load case given in the Eurocode was considered to be supported by the silo structure. Also the loads provided by the manufacturer (and based on P22-630) were checked and considered in the BRSS silo calculation.

Morillon recommends the calculation and design of the silo where the Hydrascrew is installed is complying with NF P22-630 (French code) and EN 1991-4 (Eurocodes), both are based on free flowing materials.

Silos were calculated and designed for the worst case of all possible scenarios considering standard calculation with free flowing material and centre calculation and the highest loads and pressures in case of full eccentric unloading.

There are clear evidences of torsion forces in the silo like the twist of the bottom hip ring, inclined of anchor bolts, sheared bolts of horizontal joints between wall sheet rings and silo wall deformations 45 degrees. The silos were not designed to take any rotational force. There is no mention in Eurocode neither in NF P22-630 or in the Hydrascrew manufacturer documentation that gave BRSS any reference about these forces.

COMMENTS TO HHW REPORT

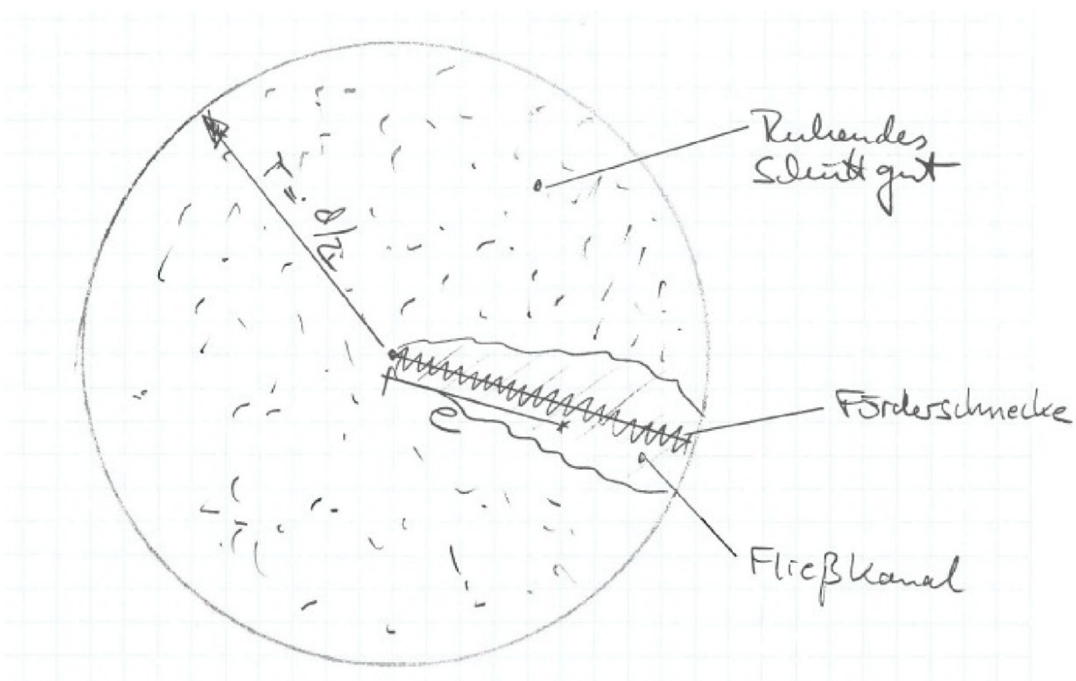
Silos were designed and calculated for soymeal, using the material parameters for flour listed in Eurocode EN 1991-4 (2006) ANNEX E. Density used in the silo calculation (650 – 700 kg/m3) is higher than the ones in our order confirmation (650 kg/m3).

Sojaschrot has never been mentioned before.

Rapsschrot has different material properties than the ones used in silo calculation and described in BRSS order. This product produce higher vertical loads on the silo and lower pressures.

The difference between results of the products tested by Schwedes and Schulze are smaller than the strength of the silo design. The product test results suggests the material used isn't the reason for the issues at Hamm however moisture content and oil content are not reported, both have significant effect on the characteristics of the material inside the silo and friction coefficients.

Eccentricity is the distance from the centre of the outlet to the centre of the silo. In this case because the Hydrascrew takes product all along the radius length, the e_0 = 3m.



This image comes from HHW report (Figure 4: Situation with the discharge auger during the discharge). The consultant engineer also use e_0 = 3m.

The silo is in Action Assessment Class 2 for all products (e_0<= 0.25 dc). Here below the table 2.1 from EN 1991-4 / 2.5.

Table 2.1: Recommended classification of silos for action assessments

Action Assessment Class	Description
Action Assessment Class 3	Silos with capacity in excess of 10 000 tonnes Silos with capacity in excess of 1000 tonnes in which any of the following design situations occur: a) eccentric discharge with e_o/d_c > 0,25 (see figure 1.1b) b) squat silos with top surface eccentricity with e_t/d_c > 0,25
Action Assessment Class 2	All silos covered by this standard and not placed in another class
Action Assessment Class 1	Silos with capacity below 100 tonnes

In the BRSS silo calculation, the special calculation case for large eccentricity unloading was considered as an extra calculation, also knowing that it's not strictly required by Eurocode.

Pressures values from the special calculation are always bigger than those from the standard calculation (e_0=0m or e_0=3m). And the silo was calculated and designed for the worst case of every scenario, again assuming that this procedure isn't required by Eurocode for this scenario where e_0<= 0.25 dc.

Torsional effects on the silo is mentioned in the HHW report but the theoretical approach by the consultant doesn't explain these effects. The consultant calculation doesn't give any torsional loads.

In case of the stresses given by the FEA done by the consultant, are higher than 4 times the ultimate strength of the wall sheets steel. This would have meant the collapse of the silos starting from the vertical seams of the wall sheets, which didn't happen. Also this would have meant plastic deformations which remained after the silo discharge. However, based on pictures and visits on site, it was appreciated the wall deformations disappeared after the silos were emptied.

Based on the above considerations, we believe the conclusions shown in the HHW report do not explain the failures seen on site. In our opinion, the failures seen on site are more likely to do with torsional effects.

The only equipment that can cause these torsion forces are the Hydrascrew installed inside the silos because it's the only moving equipment installed and it turn in the same direction of issues appeared in the silos.

It's very important to understand the reasons for these effects and confirm if they are common scenario due the normal use of this equipment under the site conditions and storage product, and in case they are, evaluate the value of these forces to defend a solution for.

In case it's an unusual effect, it should be important to review it and find the origin of these to be solve and avoided and reduce these effects as much as possible.

OTHER COMMENTS

The reported irregular top boundary mark of dust, inside of the silo 102, on the top of the silo wall shows issues during the unloading of the product that need to be analysed.

RECOMMENDATIONS

It is our understanding the issues at Hamm relate to the torsion forces. Bentall Rowlands are a an engineering company as such once we are made aware or can determine the torsion forces caused by material handling and product then we can engineer the solution.

Last week we met with several unloader manufacturers and material handling specialist, including Morillon, to gather further information and understanding. Some have suggested they are aware of torsion forces existing but surprisingly non are aware of a known theory or norm providing a basis on how to calculate them. Also from our discussions with them we believe operational settings on rotation speed and planetary movement of the unloading equipment, and circulation cycles can have bearings.

Whilst we appreciate the urgency of the situation we believe it is in the end users interest to get the final solution right, for that further time is needed to formulate how to proceed.

- We recommend affording Bentall Rowlands engineering authorisation and time to communicate directly with the client's engineer.
- We recommend setting up and attending a meeting with Mr Morillon at Hamm who will confirm comments and understandings we have heard last week during our investigative discussions and consider how to establish the torsion forces in action.
- Given our understanding of this torsion force thus far we recommend a material handling specialist perform testing on the existing silos with the actual product being stored. This test will then allow monitoring of the forces from which a designed engineering solution can be concluded.

END