FLASH ARIA
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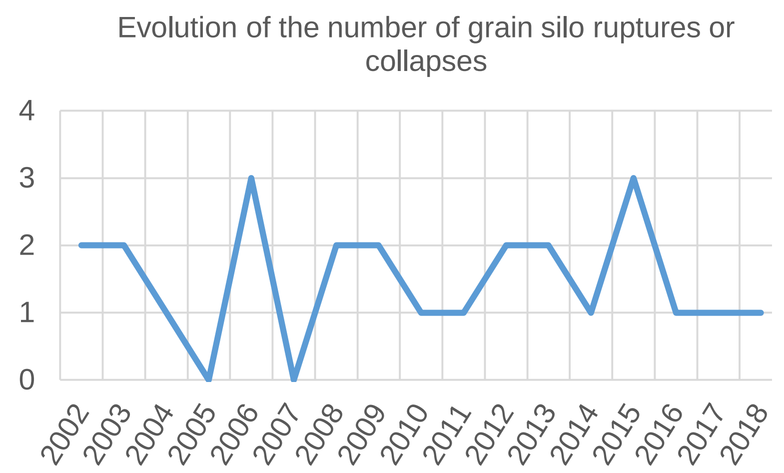
Are visual diagnostics enough to anticipate concrete cell ruptures?

In 30 years, the BARPI has recorded 30 ruptures or collapses of silo in France. These accidents mainly affect metal storage cells, although concrete cells were also involved in 9 accidents recorded in the ARIA database.



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Silo rupture - ARIA 41682

A variety of causes have been identified in various concrete cell ruptures:

- ✓ **corrosion of the steel hoops by water infiltration from the flat roof into the voids of jack rods: non-visible corrosion (ARIA 52062);**
- ✓ **lack of reinforcement (ARIA 25044), insufficient concrete cover, and excessive spacing of silo hoops (ARIA 41682);**
- ✓ **corrosion of the reinforced concrete reinforcement bars (ARIA 35043, 26862);**
- ✓ **significant lack of horizontal tie bars (ARIA 26862);**
- ✓ **decrease in the cross-section of the steel structures by stretching in the failure zones (ARIA 26862);**
- ✓ **the presence of numerous voids around steel structures and the presence of vertical cracks along the jack rods on the inner wall of the cell (ARIA 26862);**
- ✓ **the addition of a lateral emptying system after construction (ARIA 23182).**

ARIA 41682 – 30/01/2012 – SEINE-MARITIME

In a 45,000-tonne port-based grain silo, the cylindrical wall of a 60-m tall concrete cell (capacity: 3,500 t) ruptured transversely at a height of 15 m. The resulting breach allowed the stock of wheat to flow onto the quay through the damaged 4 m² zone. The silo, built in 1983, consisted of a 75-m tower and 18 cells grouped into blocks of 4 or 6 cells. In this case, the block consisted of 4 cells. The operator set up a 150 m safety perimeter and began emptying the damaged cell and the other 3 cells forming the block in order to limit the pressure on the walls.

In 2008, a specialised company had diagnosed steel corrosion problems and concrete defects of varying significance on the 4 silos located in the port area. A causal analysis of the accident highlighted a failure to comply with constructive data, particularly a lack of reinforcement, insufficient concrete cover and excessive spacing of the silo hoops.

A few questions for operators

- ✓ *Are the current discharge rates compatible with those defined when the cells were designed?*
- ✓ *If structural modifications have been made (side discharge, increased flow rates, etc.), has a new design note been compiled by an expert?*
- ✓ *What control procedures are in place (visual inspections, non-destructive testing, radiographic examinations, etc.) to monitor the ageing of silo structures?*
- ✓ *Have any disorders been observed?*
- ✓ *What type of monitoring has been implemented (work performed, shutdown or modification of operations, etc.)?*

The profession and the administration have taken this problem of structural failure and collapse into account, in particular by producing guides that define the observable failures and the techniques to be implemented to further develop a diagnosis:

- **"Guide inspection et maintenance des installations de stockage de céréales" [Guide for the inspection and maintenance of grain storage facilities], published by Coop de France;**
- **note on the ageing of concrete silo structures, compiled by the DREAL Normandy.**

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Collapsed concrete wall - ARIA 52062

Visual inspections are not sufficient to prevent accidents. Additional diagnoses by specialised bodies must be performed since the initial signs of a collapse are not always visible. The silo collapse of August 2018 (ARIA 52062) is a good example of this.

ARIA 52062 – 10/08/2018 – PAS-DE-CALAIS
During a grain delivery operation, the upper half of a silo collapsed. A problem with the sloping flat roof, dating from when the structure was built, allowed water to accumulate and infiltrate into the voids of poorly plugged jack rods. This infiltration then led to the corrosion of the steel hoops under the flat roof over the long term. Owing to the thrust created by the grain during the filling operation, these steel elements failed, causing the non-corroded hoops to break in a cascading manner.
A visual diagnosis had been performed a year earlier. Disorders had been identified but not those resulting in the collapse. These visual diagnoses are unable to detect highly localised corrosion such as that which led to this accident. A corrosion potential measurement could have highlighted this, but this rather expensive technique is proposed only for structures exhibiting chipping with visible steel elements. This was not the case for the corroded steel elements that failed on this silo.
In order to mitigate this accident, the expert report recommended a generalised operation to detect the corrosion of the steel reinforcement in the concrete by compiling potential maps, combined with targeted spot surveys on the results of the potential map established.

Complementary techniques to conduct in-depth diagnostics,
to be carried out by specialised firms:

- ✓ *Detection of the position, diameter and continuity of the reinforcement rods.*
- ✓ *Checking of the resistance, homogeneity, carbonatation and composition of the concrete.*
- ✓ *Mapping of the corrosion potential of concrete silo reinforcement rods associated with punctual destructive sampling to ensure that other parameters do not interfere with the observed potential differences.*
- ✓ *Redo the design notes concerning the structure's resistance according to the Eurocodes.*