



# Failures of Steel Silos for Grain Storage - Fortuity or Underestimated Risk

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## Abstract

The paper describes and investigates several cases of failures of silos made from corrugated thin steel sheets which were delivered and assembled in Bulgaria by foreign companies

Two main patterns of failures which occurred in different times of the year and at different locations in Bulgaria have been analyzed. The first failure pattern is related to collapses of conical roofs made from profiled trapezoidal steel sheetings while the second pattern involves fracture of cylindrical corrugated silo walls. On-site visual investigation of the failed silos and numerical analyses simulating the loading and stress state at the pre-failure situations have been performed.

Based on the lessons drawn from the investigated silo failures recommendations for improved structural design of the corrugated steel silos are proposed with the aim to avoid similar failure situations in the future.

**Keywords:** steel silo; grain storage; shell structures; failure analysis.

## 1 Introduction

The cylindrical steel silos are commonly used worldwide as an optimal structural solution for grain storage (wheat, maize, sunflower seeds, etc.). This structural form allows thin-walled sheets and higher steel grades to be used in combination with fast and easy assembling on site using standardized components. Steel silos are very adaptive to modern technology for grain storage and offer relatively low-cost operation and maintenance due to the reliable corrosion protection (zinc coatings). A general classification of the steel silos for grain storage is proposed on Fig. 1.

In attempt to produce highly competitive and lightweight structures for the silo market, often steel sheets and profiles with very low thickness

are used without previous testing or performance evaluation. The basic fact that the thin-walled steel members do not have essential over-strength and good ductility is often overlooked. In addition, the slender silo walls are very sensitive to initial imperfections and more vulnerable to local (patch) loading.

The most of the steel grain silos are assembled on site using bolted connections. Bolted connections significantly accelerate the installation of the facilities but produce significant reduction of the steel sheeting cross-section areas. Often oversized bolt holes are used in favour of erection operations but this type of bolted connections have lower resistance and exhibit larger slip deformations under loading.