An ACI Standard

Design Specification for Concrete Silos and Stacking Tubes for Storing Granular Materials (ACI 313-16) and Commentary

Reported by ACI Committee 313

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This Design Specification provides material, design, and construction requirements for concrete silos, stave silos, and stacking tubes for storing granular materials, including design and construction requirements for cast-in-place or precast and conventionally reinforced or post-tensioned silos.

Silos and stacking tubes require design considerations not encountered in building structures. While this Design Specification refers to ACI 318 for several requirements, static and dynamic loading from funnel, mass, concentric, and asymmetric flow in silos; special loadings on stacking tubes; and seismic and hopper bottom design are also included.

Keywords: asymmetric flow; bins; funnel flow; granular materials; hoppers; mass flow; silos.

ACI 313-16 supersedes ACI 313-97, was adopted May 24, 2016, and was published August 2016.

CONTENTS

SPECIFICATION

COMMENTARY

Introduction

This commentary presents considerations and assumptions in developing provisions of the Design Specification. Initial filling (static) pressures are exerted by the stored material at rest. Flow pressures differ from initial filling pressures, and are exerted by the stored material during flow.

Comments on specific provisions of the Design Specification are made using corresponding chapter and section numbers of the Design Specification. References cited in the commentary are listed in Chapter R10.

SPECIFICATION

CHAPTER 1—GENERAL

1.1—Scope

This Design Specification covers the design and construction of concrete silos, stave silos, and stacking tubes for storing granular materials.

For the design of these structures, initial filling and flow loading shall be considered. This Design Specification is supplemental to ACI 318-11 for design and ACI 301-10 for construction, where indicated.

1.1.1 *Specific inclusions*—Industrial stave silos for storage of granular materials are included in these specifications. The application to precast concrete is limited to industrial stave silos. Effect of hot stored material is included in this Design Specification.

1.1.2 *Specific exclusions*—Silos for storing silage are not included in this Design Specification. This Design Specification does not consider any chemical reaction between the silo reinforced concrete and the stored granular material. Three-dimensional dome structures are not included in this Design Specification.

1.1.3 *Hierarchy of standards*—Whenever the requirements of this Design Specification are more stringent than the requirements of ACI 318-11, the requirements of this Design Specification shall govern.

1.2—Documentation

1.2.1 Project drawings and specifications for silos shall be prepared under the direct supervision of and bear the seal of the licensed design professional.

1.2.2 Contract documents shall show all features of the work, naming the stored materials assumed in the design and stating their properties, including the size and position of all structural components, connections, and reinforcing steel; the specified concrete strength; and the specified strength or grade of reinforcement and structural steel.

COMMENTARY

CHAPTER R1—GENERAL

R1.1—Scope

Silo failures have alerted licensed design professionals to the inadequacy of designing silos for only static pressures due to stored material at rest. Those failures motivated researchers to study the variations of pressures and flow of materials. Research has established that pressures during withdrawal can be significantly higher (Turitzin 1963; Pieper and Wenzel 1964; Reimbert and Reimbert 1980, 1987) or significantly lower than those present when the material is at rest. The excess (above static pressure) is called overpressure, and the shortfall is called underpressure. One of the causes of overpressure is the switch from active to passive conditions that occurs during material withdrawal (Jenike et al. 1972). Underpressures can occur at a flow channel, and overpressures can occur away from the flow channel at the same level (Colijn and Peschl 1981; Homes 1972; Bernache 1968). Underpressures concurrent with overpressures cause circumferential bending in the silo wall. Impact during filling can cause the total pressure to exceed the static pressure. Whereas overpressures and underpressures are generally important in deeper silos, impact loading is usually significant for shallow bins (bunkers) in which large volumes of material are dumped suddenly. Some stored granular materials have sufficient cohesion and unconfined compressive strength to form large arches or cavities during discharge. The collapse of these arches and cavities can develop significant impact loads when the material above strikes the wall or floor. This document does not provide methods for calculation of such loads. The probability of forming arches and cavities can be reduced by using hopper and discharge equipment designs that reflect results from flowability testing of the stored material.

Overpressure, underpressure, or impact should be considered in the structural design of silos if present. Initial filling (static) pressures are exerted by the stored material at rest. Flow pressures differ from initial filling pressures, and are exerted by the stored material during flow.

R1.2—Documentation

Silos and stacking tubes are unusual structures. Many licensed design professionals are unfamiliar with computation of their design loads and with their design and detail requirements. Design computations and the preparation of project drawings and project specifications for silos, bunkers, and stacking tubes should be done under the supervision of a licensed design professional experienced in the design of such structures.

If possible, the properties of the stored materials to be used in the design should be obtained from tests of the actual materials to be stored or from records of tests of similar materials previously stored. Properties assumed in the design should be stated in the contract documents.