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An ACI Standard

Refrigerated Liquefied Gas Containment for Concrete Structures—Code Requirements and Commentary

Reported by ACI Committee 376

ACI CODE-376-23

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ACI CODE-376-23 (SI Units) supersedes ACI 376M-11, and was approved by the ACI Standards Board for publication in March 2023 and published July 2023.

INTRODUCTION

ACI CODE-376, "Refrigerated Liquefied Gas Containment for Concrete Structures—Code Requirements and Commentary," hereinafter called the Code or the 2023 Code and Commentary, are presented in a side by-side column format. These are two separate but coordinated documents, with Code text placed in the left column and the corresponding Commentary text aligned in the right column. Commentary section numbers are preceded by an "R" to further distinguish them from Code section numbers. The two documents are bound together solely for the user's convenience. Each document carries a separate enforceable and distinct copyright.

ACI Committee 376 was formed and subsequently ACI 376-11 was drafted in response to a request from the National Fire Protection Association (NFPA) Technical Committee 59A on liquefied natural gas (LNG). That committee is responsible for NFPA 59A, which is an internationally recognized standard governing the production, storage, and handling of LNG at an operating temperature of –168°C.

NFPA 59A contains provisions for the use of reinforced concrete and prestressed concrete for two principal applications: 1) impoundment—secondary containment in conjunction with a metallic primary container; and 2) storage—primary containment. NFPA 59A is somewhat limited; it does not provide guidelines specifically tailored to concrete use at cryogenic temperatures. This limitation was the impetus for Committee 59A's request. Although the request was related specifically to containment of LNG, this Code addresses concrete use for other refrigerated liquefied gas (RLG) as well, ranging in operating temperatures from +4 to –198°C. This makes the Code and commentary analogous to the American Petroleum Institute's API 620, which governs design and construction of steel and aluminum RLG storage tanks to –198°C.

The most common use of reinforced concrete and prestressed concrete in cryogenic storage applications is for secondary containment around metal primary storage tanks. Prestressed concrete primary containment tanks were built in North America and Europe from the 1960s through the 1980s. Renewed interest in the use of concrete for primary containment and the need for a code that addressed secondary concrete containment led to the development of this Code, which includes pertinent excerpts from ACI 318-19 and ACI 350-20. The commentary includes considerations by the committee in developing the Code.

The commentary is not intended to provide a complete historical background concerning development of the Code, nor is it intended to provide a detailed summary of the studies and research data reviewed by the committee in formulating its provisions. References to specific research data are provided for more in-depth study of the background materials.

ACI CODE-376 may be used as a part of a legally adopted code and, as such, must differ in form and substance from documents that provide detailed specifications, recommended practice, complete design procedures, or design aids.

Requirements more stringent than the Code provisions are desirable for unusual structures. This Code and commentary cannot replace sound engineering knowledge, experience, and judgment. A code for design and construction states the minimum requirements necessary to provide for public health and safety. ACI CODE-376 is based on this principle. For any structure, the owner and engineer may require the quality of materials and construction to be higher than the minimum requirements necessary to provide serviceability and to protect the public as stated in the Code. Lower standards, however, are not permitted.

ACI CODE-376 has no legal status unless it is adopted by regulatory bodies. Where the Code has not been adopted, it may serve as a reference to good practice. The Code provides a means of establishing minimum standards for acceptance of design and construction by a legally appointed official or designated representative. The Code and commentary are not intended for use in settling disputes between the owner, engineer, contractor, or their agents, subcontractors, material suppliers, or testing agencies. Therefore, the Code cannot define the contract responsibility of each of the parties in typical construction. General references requiring compliance with ACI CODE-376 in the job specifications should be avoided because the contractor is rarely in a position to accept responsibility for design details or construction requirements that depend on a detailed knowledge of the design. The contract documents should contain all the necessary requirements to ensure compliance with the Code, except in cases where the contractor acts as a specialty engineer that is responsible for all or part of the design and construction details. In this case, inclusion of the Code, in whole or in part, by reference in the project documents is acceptable. Other ACI publications, such as ACI 301, are written specifically for use as contract documents for construction and can be included in the project documents by reference.

CODE

CHAPTER 1—GENERAL REQUIREMENTS

1.1—Scope

1.1.1 This Code provides minimum requirements for design and construction of reinforced concrete and prestressed concrete structures for the storage and containment of refrigerated liquefied gases (RLGs) with service temperatures between +4 and –198°C.

1.1.2 Container design shall include the design of the container wall, its foundation (footing and floor slab), the concrete portions of its roof, and the bund wall, if applicable.

COMMENTARY

R1.1—Scope

R1.1.1 Typically, reinforced concrete and prestresssed concrete structures for the containment of RLGs are classified into two main categories:

(a) Secondary containment, which represents the most widespread use of such structures

(b) Primary containment

In this Code, the term "concrete" is used to denote both concrete reinforced with nonprestressed reinforcement and prestressed concrete.

Appendix D has been added in this version of the Code that includes design and detailing requirements for membrane tanks. A membrane tank has a non-self-supporting thin layer (membrane) that is supported through insulation by an outer concrete tank that structurally is the primary container and secondary container.

This Code does not address the materials, design, or construction of steel primary or secondary tanks. Such information is further described in API 620.

R1.1.2 This Code has been developed with the lowest operating temperature of –198°C. Lower product temperatures could also be used, however, provided appropriate additional engineering analysis and justification is performed for each proposed application. Single-containment, double-containment, and full-containment concepts are covered by this Code.

A concrete bund wall is an open-top cylindrical wall serving as the outer boundary of an impounding area surrounding a single-containment RLG storage tank.

In a double-containment tank system, the primary container is normally a single-containment RLG storage tank with a vapor-tight shell and roof designed to contain both refrigerated liquid and the associated vapors under normal operating conditions. In this system, the secondary container is often an open-top concrete wall that serves two basic functions:

1. Provides protection to the primary container from external loads under normal operating conditions.
2. Contains the leakage from the primary container (but not the vapor generated from such leakage) under accidental-spill conditions.

In a full-containment tank system, the primary container is designed to contain the refrigerated liquid under normal operating conditions. In this system, the secondary container is a vapor-tight wall with a vapor-tight roof that spans over the inner tank. The roof may be constructed of metal, concrete, or a composite of the two materials.

Under normal operating conditions, the secondary container provides protection to the primary container from external loads. Under accidental-spill conditions, the secondary container also contains the leakage from the primary container and contains or controls the vapor generated from such leakage.