Charles S. Hanskat, P.E, FASCE, FACI is Managing Principal at Concrete Engineering Group, LLC, a consulting firm he founded in 2008 located in Northbrook, Illinois. He is a licensed professional engineer in twenty-two states. Hanskat has been involved the design, construction and evaluation of environmental concrete and shotcrete structures for nearly 35 years. He is an active voting member of many ACI technical and Board committees. He is also a Board member on the American Shotcrete Association (ASA) and chair of the ASA Sustainability Committee. He has served on AWWA technical committees developing standards for prestressed concrete for over 25 years. Hanskat has been active in professional and technical engineering societies since engineering school. He served as state president of Florida Engineering Society and a national director of NSPE. He served as a District Director for Tau Beta Pi for 25 years. He is a fellow member of ACI, ASCE and FES, and an active member of ACI, ASA, ASTM, AWWA, and NFPA. He holds a Bachelor’s and Master’s degree in Civil Engineering from the University of Florida.

Overview

- History of concrete structures in RLG
- Why Code is required
- Committee membership
- Document outline
- Current status

ACI 376 Code

“Code Requirements for Design and Construction of Concrete Structures for Containment of Refrigerated Liquefied Gases (ACI 376-10) and Commentary”
- Complete standalone Code and Commentary
- Liquefied Natural Gas is the predominate refrigerated liquefied gas (RLG)

Liquefied Natural Gas (LNG)

- Cold colorless liquid
- Lighter than water
- Boils at approx. -260°F (at atmospheric pressure)
- When liquefied shrinks approx. 620 times
- Essentially all methane - CH4 (liquefaction process strips most higher freezing-point products)

LNG Tanks

- Offshore Platform
- Liquefaction Plant
- Power Station
- LNG Storage
- Jetties
LNG Tanks

- First Prestressed Concrete RLG Tank
- 950 m³ Liquid Oxygen Tank (250,000-gallons) East Chicago, IN
- 1953 – Preload Inc. Jack Closner Nicholas Legatos

Full-Containment LNG Tank

- 9% Ni Steel or Prestressed Concrete

Market for LNG Tanks

- LNG tanks containments are predominantly 9% nickel steel – 5083 aluminum (not currently used)
- Both these metals are extremely tough at service temperatures of -260°F.
- Outer vessels are usually carbon steels.
- Diking or product spillage containment has been mounded earth to form dikes

LNG Tank Types

- Single containment
- Double-containment
- Full-containment

Current Practice
Concrete LNG Tanks

- Unlined concrete tanks → liquid oxygen 1992

- Precast (lined) concrete tanks:
  - Barcelona 1969
  - Philadelphia 1974
  - Staten Island 1974
  - Cumberland, RI (81) 1975
  - Barcelona (82) 1981

1 m³ = 6.23 Bbl = 264 US gallons
80,000 m³ = 21,000,000 Gallons

Concrete Advantages

- Concrete construction produces inherently robust structures
- Concrete provides corrosion and fire protection to the embedded reinforcement
- Concrete structures are the most resistant to fires, explosions and terrorist actions.

Metal Shell Considerations

- Thin metal shells are efficient liquid containment structures.
- Cost requirements mandate that these structures be made as thin as possible.
- Corrosion protection is a concern with environmental exposures
- With “thinness”, additional protection needed for fire protection and resistance to terrorism or explosion.

Governing Documents

- DOT 49CFR193 - Rules for LNG facilities connected to pipelines (pipelines are governed by 49CFR192)
- NFPA 59A (2009) – current standard which governs the LNG industry

Regulatory Structure

Department of Transportation (DOT)
Pipeline and Hazardous Materials Safety Administration

49CFR193

NFPA 59A: Structure

NFPA 59A

- Covers
  - Plant Siting and Layout
  - Process Equipment
  - Stationary LNG Storage Containers
- Also referenced by FERC & other agencies
- Use as “last word” on siting, design, construction & fire protection

Stationary LNG Storage Containers

- Piping Systems and Components
- Instrumentation and Electrical Services
- Transfer of LNG and Refrigerant
- Fire Protection, Safety, and Security
- Operating, Maintenance, and Personnel Training
- Systems Design of LNG Plants
- Security
NFPA 59A: Current

For Steel Tanks:
API Standard 620
“Design and Construction of Large, Welded, Low-Pressure Storage Tanks”

• ACI 318
• ACI 372
• ACI 373

NFPA 59A: Future

For Steel Tanks:
API Standard 620
API Standard 625
Tank Systems for RLG Storage

For R.C. & PSC Tanks:
ACI 376

Primary Reasons for ACI 376

- Give the LNG industry a comprehensive, mandatory document for use of concrete in LNG tanks
- Allows NFPA 59A to make direct reference to the Code for Concrete LNG tanks
- Concrete in LNG tanks produces a system that is inherently fire and terrorist resistant.

ACI 376: Objectives & Scope

- OBJECTIVE: Use of reinforced and prestressed concrete tanks for primary and secondary containment.
- SCOPE: Encompasses all members that are a physical part of these two types of containers

ACI 376 Membership

<table>
<thead>
<tr>
<th>Major International Companies Represented on ACI 376</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arup</td>
</tr>
<tr>
<td>Baker Concrete Construction</td>
</tr>
<tr>
<td>Bechtel Corp</td>
</tr>
<tr>
<td>Ben C Gerwick Inc</td>
</tr>
<tr>
<td>BERGER/ABAM Engineers</td>
</tr>
<tr>
<td>BP America</td>
</tr>
<tr>
<td>Chevron Energy Technology</td>
</tr>
<tr>
<td>Chicago Bridge &amp; Iron</td>
</tr>
</tbody>
</table>
ACI 376: Content

A. Materials and Tests
B. Design Loads
C. Minimum Performance Criteria
   - Primary Concrete Container
   - Secondary Concrete Container
   - Roof Performance Criteria
   - Other Performance Criteria

D. Load Factors and Strength Reduction Factors
E. Analysis and Design
   - Design Basis
   - Foundation Design
   - Roof Design
F. Detailing
   - Reinforcement
   - Prestressing systems
   - Concrete containment wall
   - Anchorage to concrete
   - Liners and coatings

G. Foundations
   - Geotechnical Investigation
   - Design Requirements for Shallow & Deep Foundations
   - Ground Improvement
   - Inspection and Testing

H. Construction Requirements
   - Mockups
   - Tolerances
   - Shotcrete
   - Prestressing
   - Forming
   - Joints, Embeds and Coatings

I. Commissioning/Decommissioning
   - Hydrostatic Testing
   - Pressure and Vacuum Testing
   - Purging into Service
   - Cooldown
   - Settlement and movement monitoring
   - LNG tank fill methods
   - Decommissioning: Purging out of service and warm up

J. Tank Details (Appendix A)
K. Offshore Concrete Terminals (Appendix B)
L. Fatigue Performance (Appendix C)
Resources

- World’s LNG Plants & Terminals
  - www.globallnginfo.com
- LNG Terminals-status of proposed and existing facilities
  - www.intelligencepress.com/features/lng
- Introduction to LNG* (Good “primer”)
  - www.beg.utexas.edu/energycon/lng

Thank You