

IN-LB

Inch-Pound Units

SI

International System of Units

Construction of Concrete Shells Using Inflatable Forms—Report

Reported by Joint ACI-ASCE Committee 334

ACI PRC 334.3-24



American Concrete Institute
Always advancing



Construction of Concrete Shells Using Inflatable Forms—Report

Copyright by the American Concrete Institute, Farmington Hills, MI. All rights reserved. This material may not be reproduced or copied, in whole or part, in any printed, mechanical, electronic, film, or other distribution and storage media, without the written consent of ACI.

The technical committees responsible for ACI committee reports and standards strive to avoid ambiguities, omissions, and errors in these documents. Despite these efforts, the users of ACI documents occasionally find information or requirements that may be subject to more than one interpretation or may be incomplete or incorrect. Users who have suggestions for the improvement of ACI documents are requested to contact ACI via the errata website at <http://concrete.org/Publications/DocumentErrata.aspx>. Proper use of this document includes periodically checking for errata for the most up-to-date revisions.

ACI committee documents are intended for the use of individuals who are competent to evaluate the significance and limitations of its content and recommendations and who will accept responsibility for the application of the material it contains. Individuals who use this publication in any way assume all risk and accept total responsibility for the application and use of this information.

All information in this publication is provided “as is” without warranty of any kind, either express or implied, including but not limited to, the implied warranties of merchantability, fitness for a particular purpose or non-infringement.

ACI and its members disclaim liability for damages of any kind, including any special, indirect, incidental, or consequential damages, including without limitation, lost revenues or lost profits, which may result from the use of this publication.

It is the responsibility of the user of this document to establish health and safety practices appropriate to the specific circumstances involved with its use. ACI does not make any representations regarding health and safety issues and the use of this document. The user must determine the applicability of all regulatory limitations before applying the document and must comply with all applicable laws and regulations, including but not limited to, United States Occupational Safety and Health Administration (OSHA) health and safety standards.

Participation by governmental representatives in the work of the American Concrete Institute and in the development of Institute standards does not constitute governmental endorsement of ACI or the standards that it develops.

ACI documents are written via a consensus-based process. The characteristics of ACI technical committee operations include:

- (a) Open committee membership
- (b) Balance/lack of dominance
- (c) Coordination and harmonization of information
- (d) Transparency of committee activities to public
- (e) Consideration of views and objections
- (f) Resolution through consensus process

The technical committee documents of the American Concrete Institute represent the consensus of the committee and ACI. Technical committee members are individuals who volunteer their services to ACI and special technical committees.

American Concrete Institute
8800 Country Club Drive
Farmington Hills, MI 48331
Phone: +1.248.848.3700
Fax: +1.248.848.3701

Construction of Concrete Shells Using Inflatable Forms—Report

Reported by Joint ACI-ASCE Committee 334

Robert B. Esplin, Chair

Bryan S. Butikofer
Charles S. Hanskat
Takashi Hara
Brent K. Hardy
Michael D. Hunter
Samaan Ladkany
Ryan Partridge

Ryan E. Poole
Theodore J. Smolinski
Andrew J. South
Jason P. South
Mark E. Williams
Chris Zverifel

Consulting Members

John F. Abel
Arthur J. Boyt Jr.
James L. Byrne
Frederick L. Crandall
Charles W. Dolan
Phillip L. Gould

Ajaya Kumar Gupta
Mark Allen Ketchum
Lei Lou
John C. Miller
Thomas E. Nelson Jr.
John M. Rotter

William C. Schnobrich
Barry South
Bing-Yuan Ting
Arnold Wilson

This report provides information on the construction of structural concrete shells using an inflated form. Major facets of the construction process are covered, including foundations, inflation, monitoring, and backup systems. Other aspects, such as the geometric variations of inflated forms, thickness of polyurethane foam, and mixture proportions for shotcrete, are also considered.

Keywords: dome; fabric; inflation; polyurethane foam; reinforcement; shotcrete; thin shell.

CONTENTS

CHAPTER 1—GENERAL, p. 2

- 1.1—Introduction, p. 2
- 1.2—Scope, p. 2
- 1.3—History, p. 2
- 1.4—Methods, p. 3
- 1.5—Preconstruction, p. 4
- 1.6—Work schedule, p. 4

CHAPTER 2—DEFINITIONS, p. 4

CHAPTER 3—FOUNDATIONS, p. 4

- 3.1—General, p. 4
- 3.2—Concrete, p. 4
- 3.3—Soil conditions, p. 4
- 3.4—Reinforcement material, p. 4
- 3.5—Placement of reinforcement, p. 5
- 3.6—Placement of anchors, p. 5
- 3.7—Concrete placement, p. 5
- 3.8—Foundation dowels, p. 5
- 3.9—Uplift prevention, p. 6

ACI Committee Reports and Guides are intended for guidance in planning, designing, executing, and inspecting construction. This document is intended for the use of individuals who are competent to evaluate the significance and limitations of its content and recommendations and who will accept responsibility for the application of the information it contains. ACI disclaims any and all responsibility for the stated principles. The Institute shall not be liable for any loss or damage arising therefrom. Reference to this document shall not be made in contract documents. If items found in this document are desired by the Architect/Engineer to be a part of the contract documents, they shall be restated in mandatory language for incorporation by the Architect/Engineer.

ACI PRC-334.3-24 supersedes ACI 334.3R-05(20) and was published December 2024. This report was first published in 2005 and revised in 2024.

Copyright © 2024, American Concrete Institute.

All rights reserved including rights of reproduction and use in any form or by any means, including the making of copies by any photo process, or by electronic or mechanical device, printed, written, or oral, or recording for sound or visual reproduction or for use in any knowledge or retrieval system or device, unless permission in writing is obtained from the copyright proprietors.

CHAPTER 4—INFLATED FORMS, p. 6

- 4.1—General, p. 6
- 4.2—Inflated form material and manufacturing, p. 6
- 4.3—Field layout, p. 7
- 4.4—Form protection, p. 7
- 4.5—Initial stretching, p. 7
- 4.6—Inflation, p. 7
- 4.7—Construction tolerances, p. 8
- 4.8—Air pressure maintenance, p. 8
- 4.9—Collapse prevention, p. 8
- 4.10—Miscellaneous connections, p. 8
- 4.11—Fabric form repair, p. 9
- 4.12—Polyurethane foam (when used), p. 9
- 4.13—Preparation, p. 9
- 4.14—Foam application, p. 9
- 4.15—Construction hazards, p. 9

CHAPTER 5—SHOTCRETE DOME, p. 9

- 5.1—General, p. 9
- 5.2—Reinforcement material and size, p. 9
- 5.3—Clear spacing between bars, p. 10
- 5.4—Splices, p. 10
- 5.5—Cover, p. 10
- 5.6—Preliminary reinforcement mat (premat), p. 10
- 5.7—Shell reinforcement, p. 10
- 5.8—Preconstruction shotcrete tests, p. 10
- 5.9—Shotcrete compression tests, p. 10
- 5.10—Proportions and materials, p. 10
- 5.11—Field practice, p. 11
- 5.12—Shotcreter qualifications, p. 11
- 5.13—Shotcrete operation, p. 11
- 5.14—Discharge time, p. 12
- 5.15—Joints, p. 12
- 5.16—Multi-pass technique, p. 12
- 5.17—Curing, p. 12
- 5.18—Shotcrete placement tolerance, p. 12
- 5.19—Shotcrete damage, p. 12
- 5.20—Completion, p. 12

CHAPTER 6—REFERENCES, p. 13

- 6.1—Referenced standards and reports, p. 12
- Authored documents, p. 13

CHAPTER 1—GENERAL**1.1—Introduction**

For centuries, concrete shells (predominantly arched and dome-shaped structures) have efficiently enclosed large clear-space volumes. The strength of compound-curved surfaces allowed early builders to construct self-supporting thin-shell buildings from a variety of materials, especially concrete. In the past, it took a tremendous amount of time and effort to create the desired shapes; construction of these thin-shell structures sometimes spanned several decades.

Knowledge of design and construction approaches for thin-shell concrete structures has greatly increased over the past 100 years, both from research and practical experience. The use of inflated forms has allowed shells to be constructed more economically (South 1990). Inflated



Fig. 1.1—Faith Chapel Christian Center, Birmingham, AL. 280 ft (85.4 m) diameter and 72 ft (22 m) tall, which includes a 3200-seat sanctuary, classrooms, and an administration building.



Fig. 1.2—Price City Works Complex, Price, UT. Four domes: 130 x 43 ft (40 x 13.1 m) fire station; 130 x 43 ft (40 x 13.1 m) storage facility; 130 x 43 ft (40 x 13.1 m) maintenance shop; and 50 x 40 ft (27 x 12.2 m) office and administration building.

forms (or air-supported forms) use air pressure to expand and hold a prefabricated flexible membrane in a predesigned shape. This type of process has become a primary mode for constructing thin-shell concrete structures in recent decades and presents unique challenges and concerns. This report contains lessons learned in the construction of thin-shell concrete dome structures using inflated forms. One example of a thin-shell concrete structure constructed using an air-inflated form is Faith Chapel Christian Center, shown in Fig. 1.1.

1.2—Scope

As inflatable forms continue to gain popularity, additional research is needed to increase understanding of the behavior of this type of concrete shell construction process. Included in this report are construction procedures, tolerances, and design checks to ensure that the finished structure meets adequate safety and serviceability levels. This report focuses primarily on inflated forms for concrete thin-shell domes (and structures of similar geometry), which also incorporate a spray polyurethane foam (SPF) layer as part of the construction process. The addition of SPF layers to a flexible inflated form aids in the safe construction of concrete thin shells and contributes to the overall thermal efficiency and longevity of the concrete shell. While a large percentage of concrete shells are designed and constructed with an SPF layer, many structures are built using fabric forms where the concrete is applied directly to the form, either from the outside or the inside. The guidelines in this report apply generally to all methods of concrete shell construction with inflated forms. One example of a dome using SPF as part