IN-LB	Inch-Pound Units
SI	International System of Units

Concrete Shell Structures—Guide

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This guide discusses the practical aspects of shell design, including recommendations for designers of thin concrete shells. General guidance based on current practice is given on analysis, proportioning, reinforcing, and construction. A selected bibliography on analytical methods, featuring design tables and aids, is included to assist the engineer.

Keywords: buckling; design; double-curvature shell; edge beam; folded plate; formwork; model; prestressing; reinforcement; shell; single-curvature shell; splice; stiffening member; supporting member; thickness; thin shell.

CONTENTS

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CHAPTER 1—INTRODUCTION AND SCOPE

1.1—Introduction

The design and construction of thin shell structures continues to evolve as building techniques and technology advances. Thin shells are appealing because of their efficient use of materials. Historically, however, shells have often required labor-intensive formwork. Innovations in forming and placing concrete have reduced labor, thus increasing the use of thin shells. Labor-reducing processes include the use of shotcrete, frequently used in concert with the use of inflatable forms. For more information on inflated forms, refer to ACI 334.3R.

While thin shells have been formed in many geometric shapes, historically the geometry has been limited to shapes that are relatively simple to design, such as domes, folded plates, and barrel roofs. Computer modeling has allowed architects and engineers to explore more complex geometries and to perform more precise calculations, leading to increased efficiency. Further, advances in concrete material technology to increase workability without losing strength have enabled more efficiency in placement of concrete. Advances in three-dimensional (3-D) printing provide an opportunity to improve the forming of complex shapes. Further into the future, there is speculation that cementitious materials will be found on the surface of Mars (McKay and Allen 1996) and perhaps other destinations in space, allowing shell structures to be built in place with available materials.

The analysis, design, and construction of thin shell structures require a thorough knowledge of shells. While finite element methods are commonly used for the analysis and design of shell structures, the following classical references are recommended to professionals interested in shells to complement the understanding gained using finite element methods: Billington (1981), Candela (1950), Flügge (1973), Timoshenko and Gere (1961), Tsui (1968), Wilson (2005), and Yitzhaki (1958).

1.2—Scope

Design recommendations in this guide are for thin shell portions of concrete structures, unless otherwise stated. ACI 318.2 and all applicable sections of ACI 318 or ACI 350 should be followed in the design of shell structures.

CHAPTER 2—DEFINITIONS

2.1—Definitions

ACI provides a comprehensive list of definitions through an online resource, "ACI Concrete Terminology." Definitions provided herein complement that resource.

air form—fabric membrane that is inflated to form the shell's shape.

closed form solution—a solution calculated from a set of equations that are derived from the theory of elasticity.

member, edge—structural element along the edge of a thin shell that does not form part of the main supporting structure but serves to stiffen and act compositely with the thin shell to carry loads to the supporting member.

member, stiffening—structural element that serves to stiffen the thin shell or to control local deformations, such as ribs.

radius of curvature—the radius of an idealized arc that approximates the shell curvature. Due to varying geometry, the value may change over the surface of the shell.

thin shell—a three-dimensional spatial structure made up of one or more flat or curved slabs whose thickness is small compared to its other dimensions.