Construction of Concrete Shells Using Inflated Forms

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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

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CHAPTER 1—GENERAL

1.1—Introduction (Fig. 1.1)

For centuries, arched and dome-shaped structures have efficiently enclosed large clear-span volumes. The strength of compound-curved surfaces allowed early builders to construct self-supporting thin-shell buildings from a variety of materials. Due to the tremendous amount of time and effort needed to create the desired shapes, construction of these thin-shelled structures sometimes spanned several decades.

Knowledge of the design and construction of thin-shell concrete structures has greatly increased over the past 100 years, both from research and practical experience. In the past 40 to 50 years, the use of inflated forms has allowed shells to be constructed more economically (South 1990). This new type of construction process presents new challenges and concerns. Safety measures and construction tolerances are addressed in this report for many types of systems using inflatable forms.

1.2—Scope (Fig. 1.2)

This report contains the lessons learned in the construction of thin-shell concrete dome structures using inflated forms. As this method of construction continues to gain popularity, additional research is needed to increase understanding of the behavior of this type of shell so that inflated-form structures continue to meet adequate levels of safety and serviceability. Included are construction procedures, tolerances, and design checks to ensure that the finished structure meets adequate safety and serviceability levels. This document focuses primarily on inflated form thin shells using polyurethane foam as part of the construction process. Many structures are built using fabric forms where the concrete is applied directly to the form either from the outside or the inside. These general guidelines apply to all methods.

1.3—History (Fig. 1.3)

Since the early 1940s, several methods of construction using inflatable forms have been used. These methods include shotcrete applied to the form exterior, and foam and shotcrete applied to the form interior.

Fig. 1.1—Faith Chapel Christian Center, Birmingham, Ala.: 280 ft (85.35 m) diameter and 72 ft (22 m) tall that includes a 3200-seat sanctuary, classrooms, and an administration building.

Fig. 1.2—Price City Works Complex, Price, Utah. 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 90 x 40 ft (27 x 12.2 m) office and administration building.

Fig. 1.3—U.S. Borax and Chemical Co., Boron, Calif.: two 20,000 ton (18,000 tonne) borax storage domes, 150 x 79 ft (45.7 x 24.1 m).

In 1942, Wallace Neff received a patent on a system where the form was inflated to the shape of the structure, and then the reinforcing bar and shotcrete were placed on the exterior of the form (Neff 1942). Dante Bini later developed and received a patent on a system where the reinforcement and concrete were placed on the exterior of the form before it was inflated. It was then raised by air pressure to form the dome (Fig. 1.4) (Bini 1986).

In 1972, Lloyd Turner received a patent on a process in which the inflated form was sprayed with foam on the inside to a desired thickness creating a self-supporting foam dome