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## Review

## Oval concrete domes

Sylwester Kobiela<sup>\*</sup>, Zenon Zamiar

Wrocław University of Environmental and Life Science, Faculty of Environmental Engineering and Geodesy, Poland

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## ABSTRACT

The paper presents a review and update of the design and construction of oval concrete domes with a particular emphasis on the rectangular plane, with rounded corners, of the RC dome constructed in Wrocław, Poland, which is one of the few shells of this type realized in the world. The roots of oval domes lie in mediaeval times, when they were made as masonry. The best known dome examples of this period, as well as the development outline of thin oval concrete structures and the data on the geometry of such domes were given. One of the major challenges in the realization of such non-standardized concrete domes is applying novel, cost-effective forming techniques in their construction. A review of innovative low cost aesthetic forming systems of thin concrete shells was made.

Nearly a half of the paper makes a description of the design and construction of Wrocław's oval dome (23.7 m × 18.20 m × 4.70 m) of thickness 80 mm, which covers the rectangular nave of the church building. The RC dome is supported by two longitudinal and two transversal beams (200 mm × 2600 mm), which rest in the four corners of the building's masonry walls. The geometry and equations of the section curves as well as the results of a static analysis with the use of FEM as well as reinforcement drawings of the dome and its support beams were given. The particular phases of the dome construction illustrated by means of drawings were presented.

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## 1. Introduction

Oval concrete domes, which serve primarily as roof structures, are built in rounded forms. In everyday language, “oval” most often means the shape of an ellipse. The golden age of ovality was the Baroque period, in which this form occurred in architectural solutions of buildings as well their supported structures and covers with masonry domes (Fig. 1) [1].

The largest dome of this kind in the world spans the roof of the Sanctuary of Vicoforte in Italy, with an elliptical plane and the dimensions of axes 37.15 m and 24.80 m. The dome in

Vicoforte is the fourth largest in the world, after Saint Peter, S. Maria del Fiore and the Gol Gumbaz Mausoleum in India [7]. The dimensions of the dome are much larger than those of the other elliptical domes in Rome – of Andrea del Quirinale (1658) by Bernini, S. Carlo by Borromini 1638, (Fig. 2), S. Giacomo by Volterra (1592), S. Hermenegildo in Córdoba (1616) and Convento de las Bernardas in Alcalá [5].

The world's first reinforced concrete oval dome on the plan of an ellipse was realized in Wrocław, Poland, in the years 1912–1913, designed by Hans Poelzig, in the object called Four Domes Pavilion [8], nearby the monolithic reinforced concrete ribbed dome of Centennial Hall from 1913 of Max Berg,

\* Corresponding author.

E-mail address: [sylwester.kobiela@up.wroc.pl](mailto:sylwester.kobiela@up.wroc.pl) (S. Kobiela).<http://dx.doi.org/10.1016/j.acme.2016.11.009>

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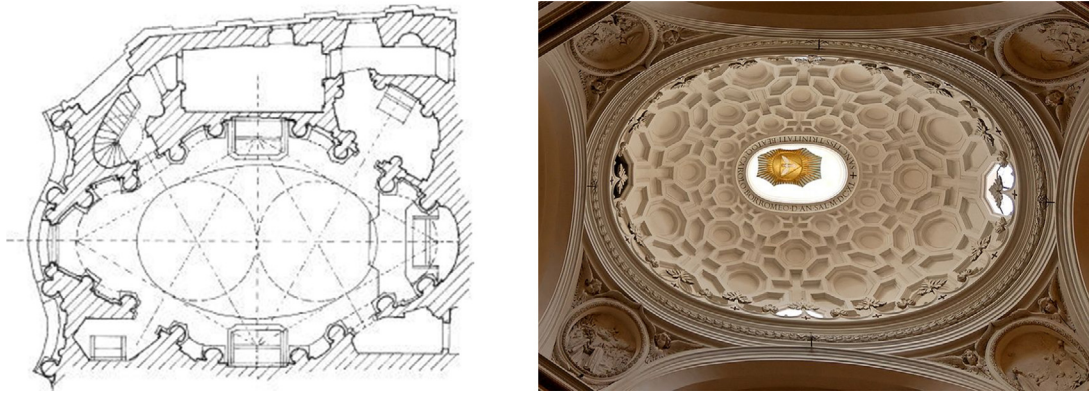


Fig. 1 – Horizontal section of the church building [2] and internal view of the dome [3]: San Carlo alle Quattro Fontane, designed by Francesco Borromini (1638) [4].

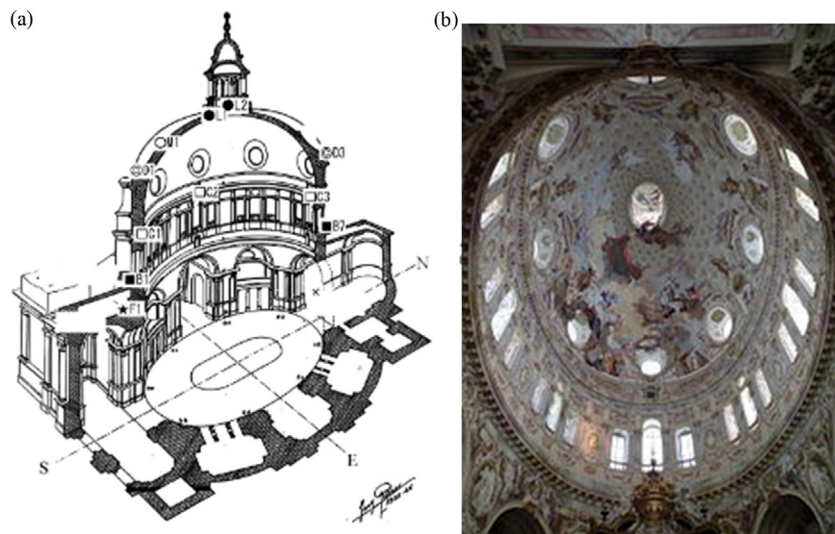


Fig. 2 – The elliptical masonry dome of the sanctuary of Vicoforte, Italy: (a) general view of the Sanctuary [5], (b) internal view of the dome [6].

spanning 65 m, which exceeded the span of the Pantheon in Rome. In 1957, in Jerusalem, a synagogue building shaped like a dome was constructed on a square plan, with rounded corners [9]. Heinz Isler, between 1956 and 1985, at the time of increasing labour costs in Europe, provide in for 749 shells standard sized so called bubble shells on rectangular plan construction in large scale re-use of formwork [10]. The largest spans of Isler's "bubble" shell had the size 54.6 m × 58.8 m [11]. The largest, until that time, solid (without ribs) concrete elongated oval domes in the form of an ellipsoid (93 m × 52 m × 22 m) was constructed in Chiasso, Switzerland [12]. In the city of Wrocław, in 1979, the construction of an oval concrete dome of a rectangular plan with rounded corners above the church nave<sup>1</sup> was started. The construction of the dome was completed in December 1987. This paper describes the design and construction of all the above mentioned domes and, broadly, the dome structure in Wrocław.

<sup>1</sup> Structural design: Sylwester Kobiela. Architecture: Wacław Kamocki.

## 2. Review of oval dome structures

### 2.1. Geometric configuration of oval domes and bases of structural design

An oval dome may be defined as a dome whose plan or profile (or both) has an oval form. The word "oval" comes from the Latin "ovum", i.e. "egg" [13]. Thus, an oval dome is egg-shaped. As the oval takes a curve made up of circular arcs or rounded forms approximate an ellipse of the same axes [13]. The ground plan of oval domes belongs to the family of curves ranging between an ellipse and a rectangle (Fig. 3). Shapes of curves configuration plan are expressed by the equation of the horizontally long super-ellipse.

$$\left(\frac{x}{a}\right)^n + \left(\frac{y}{b}\right)^n = 1 \quad (1)$$

When the  $n=2$  figure is the ordinary ellipse, for values  $n > 2$ , we receive a super-ellipse, in particular, a rectangle for  $n = \infty$ , and a rectangle with rounded corners for  $n = 9.9$ .

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