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RATIONAL CONSTRUCTIVE FORM OF FRAMELESS THIN-WALLED DOMES MADE OF MONOLITHIC POLYCARBONATE

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Анотація

У науковій роботі узагальнено науково-практичні результати з пошуку раціональної конструктивної форми та оптимальних співвідношень між основними габаритами полікарбонатного куполу діаметром екватору до 5 м. Як ключові параметри проаналізовано критерій ергономічності (функціональності), архітектурної виразності та економічної доцільності. Розраховані конкретні конструктивні рекомендації щодо раціонального проектування куполів. Рекомендовані раціональні товщини монолітного полікарбонату для луски сферичних куполів які рекомендовано встановлювати у 1 …4 сніговому, 1 … 3 ожеледному та 1 … 3 вітровому районах.

Ключові слова: сферична тонкостінна оболонка, куполи, монолітний полікарбонат, габаритні розміри, конструктивна форма

Abstract

The scientific work summarizes the scientific and practical results of finding a rational structural form and optimal ratios between the main dimensions of a polycarbonate dome with an equatorial diameter of up to 5 m. Have been analyzed the criteria of ergonomics (functionality), architectural expressiveness and economic feasibility as key parameters. Specific constructive recommendations for the rational design of domes are calculated. Have been recommended rational thickness of the monolithic polycarbonate of the domes plates, which are recommended to be installed in 1 ... 4 snowy, 1 ... 3 icing and 1 ... 3 windy areas.

Key words: spherical thin walled shell, domes, monolithic polycarbonate, main dimensions, structural form.

Introduction

This scientific work is a logical continuation of the research carried out in [1] and [2] and devoted to the search for rational structural forms of polycarbonate thin-walled domes. Have been known from [1] and [2] that sheets monolithic polycarbonate is advisable to be used in individual buildings as a self-supporting material. As an example of such structures are frameless thin-walled domes of various shapes as opposed to frame systems [3]. In these regards, an important scientific tasks arises to find the optimal geometric forms of polycarbonate domes and find the optimal ratios between the main geometric parameters of the elements of such structures.

Research results

One of the most important issues in terms of optimal design of polycarbonate frameless thin-walled domes is the issue of a rational constructive form (outline) of the shell. This issue should be considered in terms of functional purpose (visitors standing at full height should feel comfortable).

Ergonomic requirements, which are decisive for domes of a small diameter, dictate requirements for overall dimensions. It is clear that for domes of a standard average diameter (from 3 m to 5 m), the optimal shape is a sphere truncated at the base. For example, take a dome, the height of which is determined in advance and is equal to ~2.4 m. Graphic schemes in the fig. 1 and fig. 2 illustrates various options of forms of domes and selected the most rational domes dimensions.

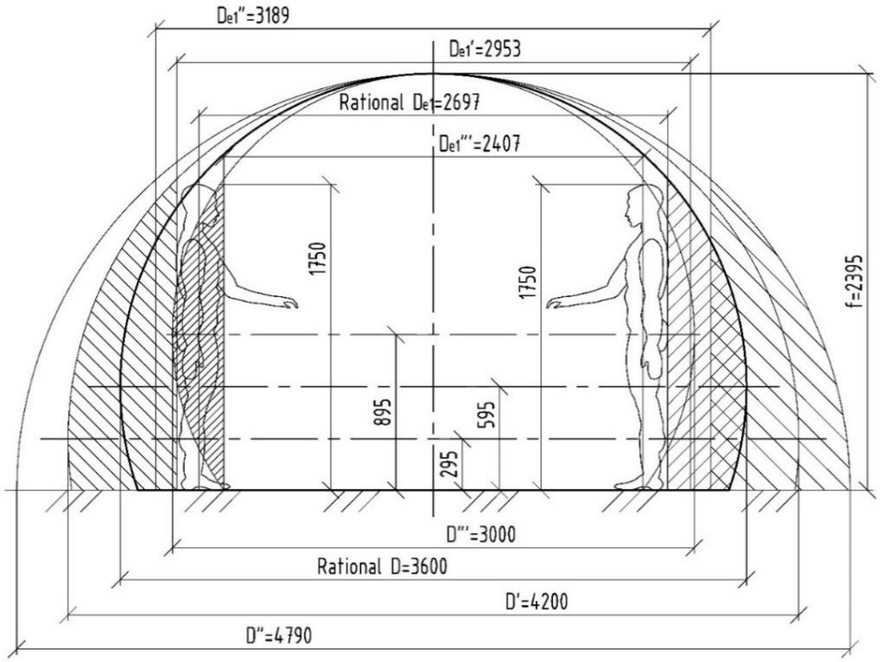

Fig. 1. The methodology for selecting the rational diameter of a spherical dome made of polycarbonate by given height ~2,4 m by the factor of minimum of "dead zones" which are shaded

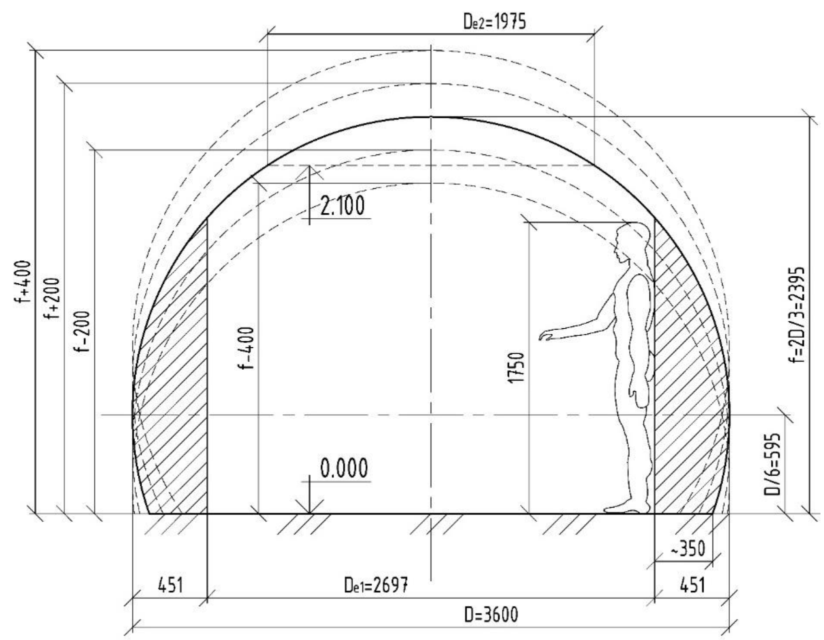

Fig. 2. The methodology for selecting the rational height of a spherical dome made of polycarbonate by given diameter of equator of shell (on the example of a dome with an equatorial diameter of 3.6 m). Shaded dead zones

At fig. 1 have been shown that the classic semi-spherical dome is clearly not optimal when using the dome as an independent small architectural form due to the significant amount of "dead zones" on the example of a dome with an given height ~2,4 m. Surface area of the hemisphere of equatorial diameter D'' = 4.79 m: $A'' = \pi \cdot D''^2/4 = \pi \cdot D'' \cdot f$ = 36.04 m^2.

Surface area of sphere segment of optimal diameter D = 3.6 m with similar height: $A = \pi \cdot D \cdot f$ = 27.14 m^2.

Material saving is proportional to the surface area. The ratio between which, with the same height *f* of dome structures, is proportional to the ratio of diameters. It is advisable to calculate the savings coefficient according to the proposed formula:

$$\alpha = \frac{A}{A''} = \frac{\pi \cdot D \cdot f}{\pi \cdot D'' \cdot f} = \frac{D}{D''}. \quad (1)$$

For the depicted version of the dome savings the polycarbonate material when moving from a standard hemispherical dome to an elongated dome in the optimal form of a segmented sphere with a height of more than half the diameter the savings coefficient is α = 0,75 (i.e. 25% savings).

At the same time, the operational factor of minimum dead zones is important, which are shown for a person of average height of 1.75 m and, accordingly, the maximum diameter of the exploited medium, limited by a cylindroid of rotation with a diameter of D_{e1}.

By sorting through possible geometric ratios, it was established that within the limits of the dimensions of domes with an equatorial diameter *D* of 3 to 5 m, the rational height f_{opt} of dome is: $f_{opt} \approx 2 \cdot D/3$.

The table 1 shows the recommended heights of domes with an equatorial diameter of 3 to 5 m.

Based on economical criterion for domes with equators diameter of more than 5 m, it is advisable to use a geometric shape in the form of a truncated ellipsoid of rotation, flattened in height, instead of a spherical shape with a limitation of the maximum dome height of 3.3 m (fig. 3).

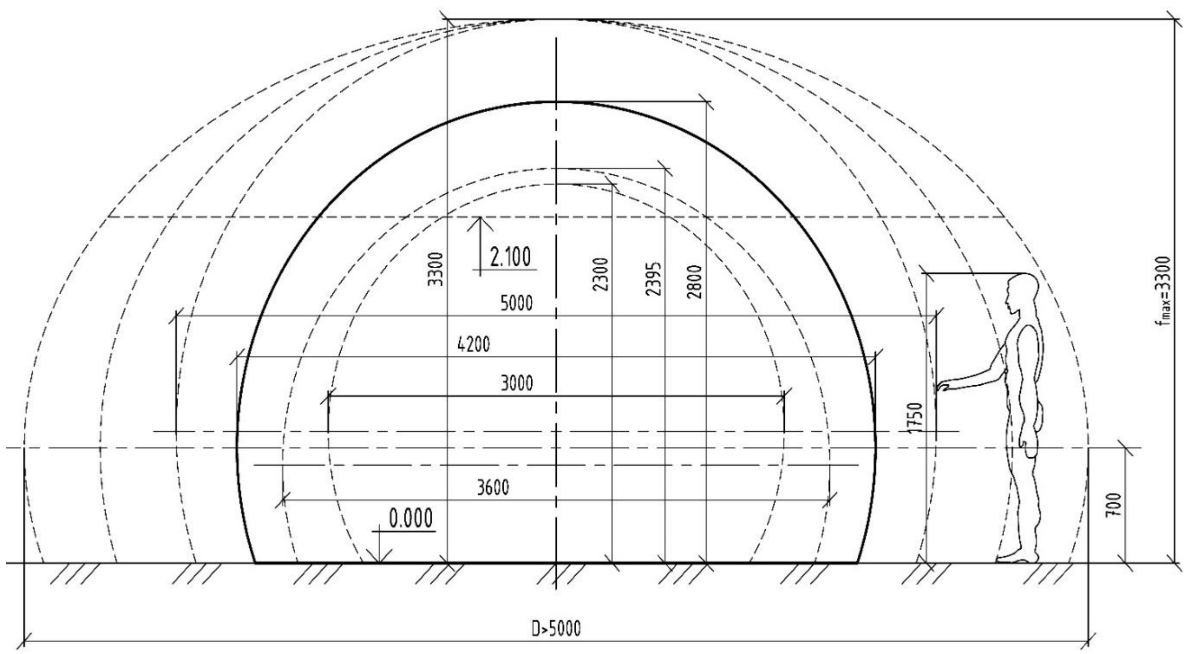

Fig. 3 Rational form of large polycarbonate domes

However, for domes with an equatorial diameter of more than 5 m, additional fundamental research should be conducted.

When designing polycarbonate domes, the engineer, in general, must determine the rational form and two key parameters – the height of the dome and the thickness of the polycarbonate sheets.

At the first stage, it is necessary to determine the main dimensions of the dome, based on its purpose (the diameter of the equator and the index of the boom (height) by the data of table 1.

Table 1 – Recommended levels height parameters for inside installing domes

The domes diameter of the equator, *D*, m	3.0	3.6	4.2	4.8	5.0
Approximate height of the dome, *f*, m	2.3	2.4	2.8	3.2	3.3
The recommended distance between the floor and the suspended ceiling inside installation of the dome, m	2.5	2.6	3.0	3.3	3.4

The recommended thickness of the material (monolithic polycarbonate) of the domes polycarbonate plates, which are recommended to be installed in 1 ... 4 snowy, 1 ... 3 icing and 1 ... 3 windy areas:

for domes with a diameter of the equator up to 3.2 m – 2 mm;

for domes with a diameter of the equator from 3.2 to 3.8 m – 2,5 mm;

for domes with a diameter of the equator from 3.8 to 4.5 m – 3 mm;

for domes with a diameter of the equator from 4.5 to 5 m – 3.5 mm.

The rational dimensions of the cross-section of the metal elements of the support ring and the door frame are checked according to the limit states by the method of finite elements on software complexes. Have been recommended the support ring elements section as rectangular tube with a section made of stainless steel ANSI 304 [1, 2].

Conclusions

1. Based on the ergonomic criterion of the maximum effective area and, accordingly, the minimum volume of dead zones and economical feasibility have been proven that the standard hemispherical shape of domes, which is most often used in small architectural forms, is not optimal. The most rational is the spherical shape of the domes, with the height of the segment more than half the diameter.

2. By sorting through possible geometric ratios, it was established that within the limits of the dimensions of domes with an equatorial diameter D = 3…5 m, the rational height of domes is: $f_{opt} \approx 2 \cdot D/3$ (fig. 2).

3. Have been proven that the maximum rational height of polycarbonate thin-walled domes is 3.3 m for domes with a diameter of more than 5 m (fig. 3).

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