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# Determination of wind pressure coefficients on spherical domes called onion domes (defined in standard 400)

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**ABSTRACT:** Wind force is one of the lateral loads in the design of structures. One of the parameters for calculating wind force on structures is called pressure coefficient (CP), which is related to the geometry of the building. The design codes provide the pressure coefficient of conventional buildings. In the absence of these coefficients in the design codes, wind tunnel testing or numerical modeling should be used. Numerical method based on computational fluid dynamics (CFD) has been used in modeling to simulate wind flow. The model used in computational fluid dynamics in this research is the K-ε (Standard) model. The sphere is modeled with a diameter of 50 cm and the results of numerical modeling are compared with the results of the wind tunnel test presented in reference [2]. The dome is made with different height to span ratio, with increasing height-to-span ratio to maximum The negative pressure (suction) obtained at an angle of 90o increases as this value reaches –2.24 in dome 122, and it is also observed that at an angle of 150o to 180 o the pressure coefficient is constant for all domes. Finally, the equation the wind pressure coefficients of this type of dome is presented.

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## 1- Introduction

The use of dome structures to cover all types of roofs is very common, especially for covering stadiums and meeting halls. One of the common types of domes is the onion dome (according to standard 400). Figure 1 shows the exterior of two onion domes. For a long time, spherical domes have been built all over the world with construction materials such as brick and stone. In determining the wind pressure coefficients on these domes, considering that the geometry of these domes is close to the spherical dome, usually the wind pressure coefficients of spherical domes are used in determining the coefficients. Wind pressure is used in the design of these domes, due to the absence of wind pressure coefficients for this type of dome in the regulations, in this article, wind pressure coefficients are used using fluid dynamic analysis and modeling in ANSYS software. Examples of this type of dome are presented in the regulation of Iran's space structures (publication number 400 of the country's planning and budget organization).

Many researches have been done on the effect of wind load on domes, two examples of these studies are: The research that Sadeghi et al.(2017) presented using numerical modeling of wind pressure coefficients on scallop domes[1], also in this research the equation of wind pressure coefficients in spherical domes and scallop domes has been presented as well as in another research (2018) considering Taking the effect of the group of spherical domes, wind pressure coefficients on spherical domes have been presented[2], Blocken [4] outline the past, present and future of wind engineering and give a comprehensive account of the wind engineering.

The pressure coefficient (Cp) depends on the geometry of the building, and the values of this coefficient are available in various codes. This coefficient is obtained by dynamic analysis of wind flow behavior. According to the codes, the pressure or suction caused by the wind on a component or the entire surface of a structure or building is obtained from equation (1).

$$P = I_W q C_e C_g C_p \tag{1}$$

The dimensionless pressure coefficient Cp is defined as equation (2).

$$C_p \frac{p - p_0}{\frac{1}{2}\rho\mu^2} \tag{2}$$

## 2- Verification of numerical modeling

In this section, with the aim of verifying the results of numerical modeling, the results of the wind tunnel test on the spherical dome reported in reference [2] have been examined

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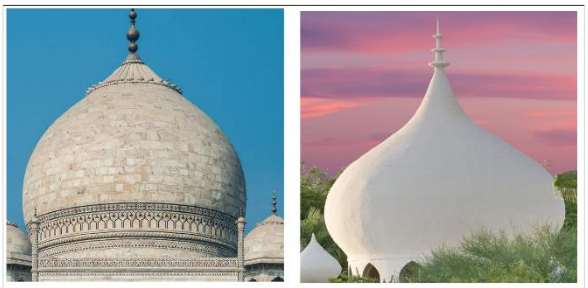

**Fig. 1. Two examples of spherical domes known as onion domes**

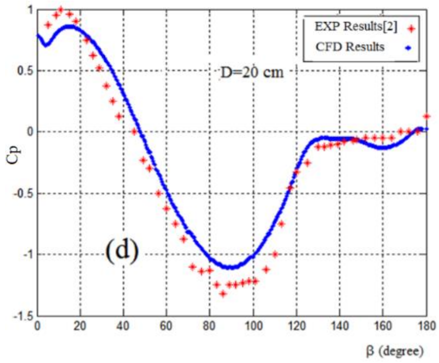


**Fig. 2. Comparing the results of numerical modeling using ANSYS software with the results of wind tunnel testing [3]**

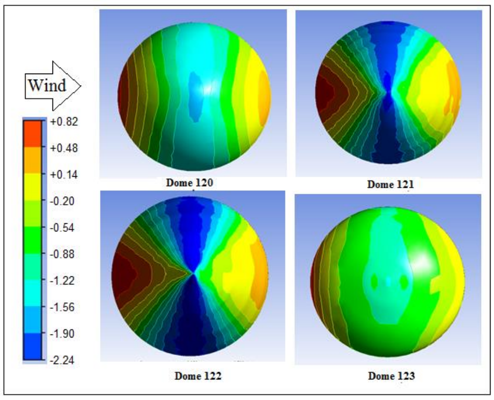


**Fig. 3. Contour of wind pressure coefficients on domes with different height to span ratio (view from above)**

and the results of numerical modeling have been compared with the results of the mentioned reference. The mentioned structure has a diameter equal to 200 mm.

## 3- Investigating wind pressure coefficients on domes with different height-to-span ratios

In this section, the pressure coefficients on the mentioned domes with 4 height-to-span ratios are evaluated, In Figure 3, the contour of the pressure coefficients on the domes can be seen.

Figure 4, shows the changes in the wind pressure coefficients on domes 120 and 121 at different height levels, the symmetry in the pressure coefficients is evident due to the symmetry of the dome, with the increase in the ratio of the height to the span of the dome, the negative pressure coefficient increases at an angle of 90 degrees.

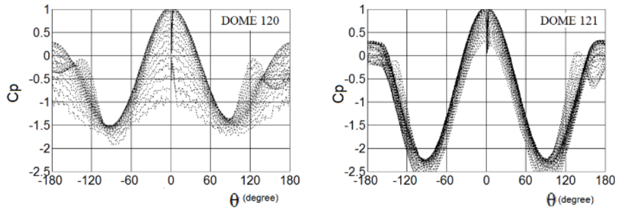


**Fig. 4. Variation of Cp on domes 120 and 121 at different height levels**

**Table 1. The amount of parameters used in Eq.3**

| Dome | 120 | 121 | 122 | 123 |
|---|---|---|---|---|
| K=H/D | 0.72 | 1.45 | 2.23 | 6.78 |
| A | –0.078 | –0.095 | –0.24 | –0.266 |
| B | –0.27 | –0.26 | –0.17 | –0.037 |
| C | +0.26 | +0.37 | +1.01 | +1.019 |
| D | –0.13 | –0.15 | –0.11 | –0.366 |
| E | –0.27 | –0.25 | –0.19 | –0.159 |
| F | –0.46 | –0.92 | –1.01 | –1.031 |

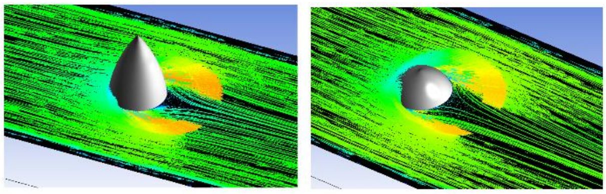

**Fig. 5. Wind velocity vectors in the vicinity of domes 120 and 121**

In Figure 5, the streamline is drawn in the vicinity of domes 120 and 121, the decrease in the distance of the flow lines indicates the increase in speed, in some parts of the models, a vortex flow is observed, which occurs due to the separation of the flow from the surface of the dome.

## 4- The equation of wind pressure coefficients on the studied domes

Due to the absence of pressure coefficients on this type of domes in the codes, in this study, using different models of these domes, we present sinusoidal equations with the same general form for all models to determine the pressure coefficients for all types of this type of structure. The presented values can be easily calculated for each point. This equation was obtained using MATLAB software with pressure coefficients on the domes.

$$
\begin{aligned}
&Cp = f \times \cos(2.6\theta) + g \times \sin(\theta) \\
&f = Ah^2 + Bh + C \\
&g = Dh^2 + Eh + F \qquad (3) \\
&H = \frac{z}{H}
\end{aligned}
$$

## 5- Conclusions

In this article, the wind flow was validated using the computational fluid dynamics method and using the standard turbulence model in a computational model, and in the following, the mentioned model was used to investigate the airflow and its dynamic parameters around onion domes. The aim is to find the governing equation of the wind pressure coefficients on this type of domes, the following results are obtained from the research.

a) By increasing the ratio of height to span, the maximum negative pressure (suction) that is obtained at the angle β=90 increases, so that in dome 122 this value reaches -2.24.

b) By changing the ratio of height to opening, the maximum value of positive pressure that occurs on the face facing the wind is constant and equal to 0.8.

c) By observing the contours of the pressure coefficient, it can be seen that the pressure coefficient is constant for all domes at an angle of approximately 150 degrees to an angle of 180 degrees.

d) In the values of the ratio of the height to the opening of the domes that have not been investigated in the research, it is possible to obtain wind pressure coefficients for the dome with a different ratio of height to the opening by using interpolation.

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