Budownictwo o Zoptymalizowanym Potencjale Energetycznym **Vol. 7, Nr 1/2018, s. 37-42**
DOI: 10.17512/bozpe.2018.1.05

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THE INVESTIGATION OF EXTERNAL AERODYNAMICS OF BUILDING OF UNUSUAL ARCHITECTURAL FORM

The issues of buildings aerodynamics have always been considered rather important, and in some cases, crucial for the design of natural ventilation of buildings and smoke extraction systems. The applicable guidelines contain recommendations for regarding the nature of air can flow only along the sides of the building and on the roof. If the structure of the building differs from the rectangular, the nature of the distribution of excessive static and negative pressure zones is different. On the roofs of individual sections of buildings of an unusual configuration, excessive static pressure zone can be formed, which creates unfavorable conditions for the operation of natural ventilation and smoke exhaust systems. This paper presents the results of aerodynamic tests on a geometric model similar to a real residential complex of an unusual architectural form.

Keywords: **exhaust ventilation system, wind pressure, back draft, aerodynamic tube, aerodynamic coefficient**

INTRODUCTION

The rapprochement of the Ukraine with the countries of the European Union takes place in the most diverse directions. One of them is harmonizing the building design documentation in force in the Ukraine with the norms in force in the countries of the European Union. In particular, in 2011, DSTU B EN 13384-1: 2010 and DSTU B EN 13384-2: 2010 were enacted, which comply with European norms EN 13384-1: 2002 + A2: 2008 and EN 13384-2: 2003 + A1: 2009. In 2012, DSTU B EN 15251: 2011 was enacted, which complies with EN 15251: 2007; it sets requirements for the microclimate of the premises, the significance of which influences decisions on engineering networks.

These international building standards, as well as the Ukrainian national regulations [1-3], require the mandatory design of an exhaust ventilation system and the design, if necessary, of a smoke removal system from domestic gas equipment. One of the important issues when designing the natural ventilation of buildings and smoke extraction systems is the aerodynamics of buildings. In particular, in the construction of multi-storey buildings of complex architectural forms, there is a problem to determine the real limits of the wind pressure zones - zones with excessive static pressure in conditions of strong winds. In such cases, a multistory building of an unusual configuration is the reason for the formation of dangerous meteorological conditions for the functioning of natural ventilation systems of lower residential sections. Existing regulatory documents regulate the allocation of the wind pressure zone to a separate building, taking into account the fact that the wind flow extends along the surface of the earth as along a solid impermeable boundary. In this case, the air can flow around the building only on the sides and over the roof. Under the influence of the wind flow in front of the building air is accumulated and a zone of high static pressure is formed, creating unfavorable conditions for the operation of natural ventilation systems. In conditions where the wind flow extends over buildings of unusual architectural forms, the conditions for the formation of wind pressure zones are different.

The aim of the study is to determine the aerodynamic coefficients on the roofs of residential sections of a building of an unusual architectural form.

1. ANALYSIS OF EXISTING RESEARCH

In accordance with construction standards, all residential buildings should be equipped with a natural ventilation system. Moreover, the inflow of air in the volume of a single-air exchange should be fed through the windows, and air removal should be carried out by individual vertical exhaust channels from the kitchen and sanitary facilities [1, 2]. In addition, in residential buildings with household gas appliances that require the removal of combustion products, each appliance should have a separate chimney [3].

The installation of airtight windows, insufficient height of the exhaust duct, and the construction of houses of different height can cause back draft in ventilation and smoke channels. The presence of back draft can contribute to the accumulation of combustible gases and their combustion products in the premises, lowering of the temperature of apartment ventilation unit surfaces below the dew point, the formation of condensation and the appearance of mold in individual sections of ventilation ducts, external walls and window slopes. Therefore, when selecting and planning a construction area, it is necessary to take into account the influence of aerodynamic parameters (velocity and direction of wind streams, turbulence zones, wind pressure, dilution zones, etc.) on the functioning of the natural inflow and exhaust ventilation system as well as the smoke exhaust system [1].

It is technically possible to determine the conditions forming back draft in real time on concrete construction objects under conditions of the functioning of currently existing ventilation systems. However, due to the low probability of the occurrence of corresponding wind conditions in all existing directions, this type of examination is expensive and uncertain over the duration of conducting the research. In addition, it should be borne in mind that each geographic space has its own probability of direction and duration of strong winds. The expertise of projected (unbuilt) construction objects by means of such an option is in principle not possible.

The required information on the distribution of wind loads on buildings of an unusual configuration can be obtained using methods of physical (in aerodynamic tubes) or mathematical (computer) simulations.

At present, the most accurate method is to determine the wind pressure zone by means of mathematical modeling. The developed software ANSYS, Cosmos FloWorks and FlowVision allow one to create high resolution 3D models of static and dynamic pressures when wind interacts with the projected house [4-6].

Physical modeling of the wind load on the house can be done by investigating building models in an aerodynamic tube. Air flow with the given characteristics is formed in the working part of the pipe, where the model under investigation is placed. However, this simulation has certain disadvantages: the experimental data is difficult to generalize, given the different configuration of buildings and their location in the residential district.

In existing engineering techniques [7], the influence of changing the wind speed with height above ground level is taken into account by specifying the corresponding wind load factors. The main indicator used in calculating the wind load on the building and in determining the pressure at certain points of its outer surface is aerodynamic coefficient c. The aerodynamic coefficient shows the ratio of excess static pressure at one of the points on the outer surface of the building P to the dynamic wind pressure $\frac{\rho \cdot v^2}{2}$.

$$\pm c = \frac{P}{\frac{\rho \cdot v^2}{2}} \tag{1}$$

Aerodynamic coefficients are usually determined experimentally in aerodynamic tubes on building models. The value and sign of the aerodynamic coefficient are influenced by the location of the point on the surface of the building, the shape of the building and the direction of the wind, the presence of closely spaced buildings and terrain. The value of the aerodynamic coefficient is also affected by the opening of windows in the building and the organization of cross ventilation.

2. MAIN MATERIAL

In this paper, the influence of wind on the functioning of exhaust ventilation channels and chimneys was investigated for a residential complex constructed in Lviv. The investigated complex consists of 9 residential sections, in which sections 1, 7-8, and 9 have 15 floors, sections 2-3, 4, 5-6, have 9 floors. For the experimental investigation a geometric-like model of a residential complex was created, the study of which was carried out in an aerodynamic tube with an open working part in Lviv Polytechnic. In this case, the model of the building was located in the working area of the aerodynamic tube (Fig. 1), where, with the help of a specialized measurement system, all the necessary characteristics were identified to determine the aerodynamic coefficients on the roofs of the residential sections and the possibility of back draft in the natural ventilation systems of the specified complex.

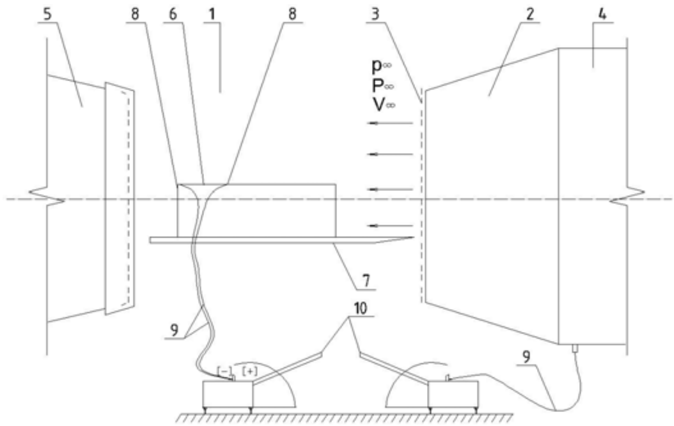

Fig. 1. Diagram of experimental installation of residential complex model in aerodynamic tube: 1 - working part of aerodynamic tube, 2 - nozzle, 3 - alignment grid, 4 - fire chamber, 5 - diffuser, 6 - residential complex model, 7 - model substrate surface, 8 - selected static pressure points, 9 - flexible tubes, 10 - micromanometer

The research was carried out at different speeds and angles of attack of the wind air flow on the house model (Fig. 2).

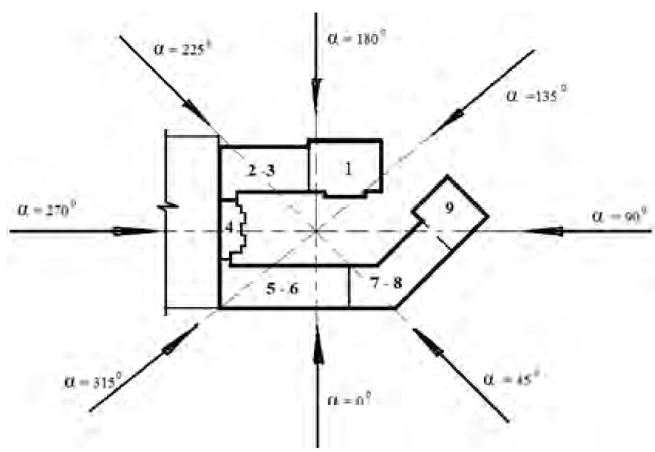

Fig. 2. Angles of attack on residential complex model

As the experimental studies have shown, all the sections except Section 4 at certain angles of attack have a zone with excessive static pressure on the roof, which is characterized by positive values of the aerodynamic coefficient. Thus, at an angle of attack, $\alpha = 45°$, a positive aerodynamic coefficient value was on the roof sections of Section 9, with $\alpha = 135°$ - Sections 1, 2-3, with $\alpha = 270°$ - Sections 2-3, with $\alpha = 315°$ - Sections 5-6, 7-8. Excess static pressure zones arise when the angle of attack relative to the facade of the relevant section of the residential complex is 45°. Since the studied complex has an unusual architectural form, this phenomenon is observed for virtually all sections, except Section 4.

In particular, in the work devoted to the study of aerodynamics of high-rise buildings [8], if the wind direction with the building facade is 45°, then there are strong wind streams along the windward edges of the roof (Fig. 3a). The high velocity of the air flow in these vortices leads to a rather significant negative pressure at the edges of the roof. On the other hand, there is a wind pressure zone over the rest of the roof surface.

In article [9] the picture of the flow around cube at the angle of attack of 45° is shown and it is shown that despite the general features of the flows, there are a number of differences. As can be seen from the visualized studies (Fig. 3b), on the upper face of the cube there are two cone-shaped vortices that rotate. The peaks of these vortices are directed toward the flow direction.

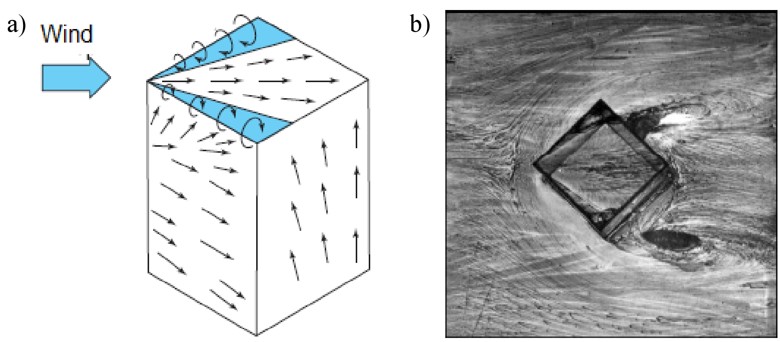

Fig. 3. Distribution of air flows that arise at a wind load directed at angle of 45°to building facade: a) scheme of air flows [8], b) results of soot-oil visualization [9]

From Figure 3 it is seen that when the wind direction relative to the facade of the house is 45°, there are strong vortical streams near the edges of the roof. The high velocities of air flow in these vortex flows cause a fairly strong formation of negative pressure around the edges of the roof, which in the case of a strong wind can be dangerous to the engineering equipment located in this part of roof.

CONCLUSIONS

On the basis of experimental investigation of a residential complex model in an aerodynamic tube, the distribution of aerodynamic coefficients along the roof surface of residential sections was determined. Zones of excessive static and negative pressure are determined. As the results of the research have shown, all the sections, except Section 4, at certain angles of attack are in the wind pressure zone. In the zone of excessive static pressures with aerodynamic coefficients, which have values greater than zero, conditions unfavorable for the operation of natural exhaust ventilation and smoke exhaust systems occur. In this case, there is a threat of back draft in both ventilation and smoke channels. Further research should be devoted to experimental and field studies of houses of other architectural forms and geometric ratios of their sizes to generalize the results of the study.

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BADANIE AERODYNAMIKI POWŁOKI ZEWNĘTRZNEJ NIETYPOWYCH FORM ARCHITEKTONICZNYCH

Kwestie aerodynamiki budynków zawsze były uważane za dość ważne, a w niektórych przypadkach kluczowe w projektowaniu wentylacji grawitacyjnej budynków i systemów odprowadzania spalin. Obowiązujące wytyczne zawierają zalecenia odnośnie do charakteru przepływu strumienia powietrza tylko wzdłuż bocznych ścian i na dachu budynku. W przypadku kiedy forma budynków różni się od prostopadłościanu, charakter rozkładu stref z nadciśnieniem statycznym i podciśnieniem jest inny. Na dachach poszczególnych odcinków budynków o złożonej formie tworzą się strefy nadciśnienia statycznego, co stwarza niekorzystne warunki dla działania wentylacji naturalnej i odprowadzania spalin lub dymu. W artykule przedstawiono wyniki eksperymentalnych badań aerodynamicznych modelu geometrycznego zbliżonego do rzeczywistego kompleksu budynków mieszkalnych o złożonej formie.

Słowa kluczowe: **system wentylacji wywiewnej, ciąg wsteczny w kanałach wentylacyjnych, tunel aerodynamiczny, współczynnik aerodynamiczny**