ÉPÜLETMODELL VIZSGÁLATA SZÉLCSATORNÁBAN

BUILDING MODEL TEST IN WIND TUNNEL

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ABSTRACT

The primary objective of the research is to test a building model in a wind tunnel. Given the potential for technological development, different building models will be tested using simulation, but real measurements are also required. The priority is to be able to provide architects with adequate baseline data and to verify the environmental impact of different buildings. This paper presents the construction of a building model for the study, the measurement setup in an experimental wind tunnel and the evaluation of the results. The paper presents the evaluation of the results and the experiments carried out on the basis of different test cases. The results in turn provide an opportunity for further improvement and adaptation of the building for a more cost-effective operation.

1. INTRODUCTION

As early as the 18th century, experiments were being carried out to model wind-driven currents, the main tool being the so-called vortex arm. Until the 19th century, this method was used to obtain aerodynamic information, but its application continued to reveal flaws and shortcomings. In the case of high turbulence, the measurement results did not reflect reality and something better was needed. This was the advent of wind tunnel modelling. The first wind tunnel was built by the English engineer Francis Herbert Wenham in 1871. Osborne Reynolds was the first to demonstrate at the University of Manchester that measurements on small samples could be extrapolated to large installations. The foundations of the current measurement technique were developed in Göttingen, Germany, in the 1930s. This, and experiments carried out at the same time, were performed in low turbulence and without boundary layers. Later, in order to be able to model atmospheric turbulence properly, it led to the design of so-called Atmospheric Boundary Layer Wind Tunnels. The first of these was recorded in the 1950s. In these wind tunnels, already relatively long working spaces have been developed. Since the 1960s, wind load experiments have been carried out in these facilities or installations. Wind tunnels built during this period are still in use today. The development of computer technology has also brought progress in this field, because it has made it possible to handle large amounts of data. Modern wind tunnel studies for wind loads on buildings use the method of static analysis for measurement to determine the design loads.

Thanks to the wind tunnel, the model placed in the flowing air needs to be tested for various physical properties, which can be determined by measurement. These can be velocity components of the flowing air, absolute and relative pressure, temperature, forces, gas concentration, etc.

In today's practice, the testing of buildings in wind tunnels is also of great importance, because, using the results of these tests, the cost of the building can be significantly reduced and the various loads on the building can be calculated, thus preventing possible disasters [1-7].

An important pillar of testing is to ensure that the right external conditions are in place during the tests to ensure that the results are correct. Wind speeds are zero immediately along the ground, increasing intensively at first and then moderately as it moves upwards. Records of instrumental measurements show that the wind speed and direction are not constant in most cases, but constantly changing. Forests, contiguous building complexes and other obstructions can severely slow down the flow of air. Therefore, in the lower layers in front of obstacles, the velocity is strongly reduced. This reduction in velocity is noticeable at a considerable distance in front of the obstacle. Above the barrier, the velocity increases rapidly. Behind the barrier it is also small and only regains its original magnitude at a considerable distance from the barrier.

So, it is not only the wind that affects the buildings, but of course the buildings also affect the wind. Behind the building, the flow direction behind the building is called a trail with a steadily increasing cross-sectional area, where the flow velocity is lower than in front of the building, the turbulence is higher and detachment bubbles are generated in this area, which are responsible for the backflow.

Turbulent flow is a range of flow where the physical characteristics of the flowing medium (e.g. pressure, velocity) change rapidly in a chaotic manner. Its opposite is laminar flow.

The impact on buildings is manifested by overpressure on the windward side and pressure drop on the leeward side, and boundary layer separation on the windward side and roof edges. If this boundary layer separation has a significant effect on the flow, we speak of a blunt body. The majority of buildings behave as a blunt body. A body can be either blunt or streamlined, which can be influenced by the direction of blowing. In streamlined bodies,

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there is very little or no perceptible boundary layer separation, or in a perfectly streamlined body, no boundary layer separation at all. At the building face, the wind is braked and its kinetic energy is converted into pressure energy. The windward side pressure drop can be interpreted as a positive pressure and the windward side pressure drop as a negative pressure relative to the absolute pressure [7].

2. BUILDING MODEL

In general, the model describes the operation of some structure. It does not have to be reduced or even enlarged, nor does it have to be a faithful copy of the original.

A model can be made of several different materials. This can be wood, cardboard, plexiglass, plastic or paper. So, our first task is to make a model of the building we have chosen, which is the University of Miskolc's Uni sports hall (Figure 1.). After choosing the building, we had to decide what material to use and what scale to use for the building model.

The model material: wood, plywood, scale of the model: $\lambda g = L_{WT}/L_{FS} = 0.01$, where the index *WT* is the model size and *FS* is the original size of the building. When building a model to scale, the choice of scale should take into account that the strength of the wind on a model is greatly influenced by the size of the model itself. The ratio of the surface of a plane perpendicular to the air flow in the measurement space to the surface of the same plane of your model should not be greater than a certain ratio. This effect is referred to simply as the "blockage effect" [2].

To avoid this error, the following ratio should be observed: $A_m/A_{mt} \leq 0.1$, where: A_m: surface of the model perpendicular to the flow; A_{mt}: surface of the measuring field perpendicular to the flow. In our case, the value of this quotient is, roughly: $0.0625/(1.2x0.8)=0.065 < 0.1$, so the size of the model will not have a negative influence on the test.

In order to make the mock-up accurately, we needed a blueprint of the building, which was provided to us, so we could start working with the exact dimensions.

Figure 1. University sports hall [own picture].

The finished model is shown in the figure below (Figure 2.). Its total height is 15.3 cm and its base is a regular 24-angles with a radius of 49.33 cm. The side walls of the building are perpendicular to the ground up to a height of 3.7 cm, and then continue at a 70° angle of inclination up to a height of 12.5 cm. The roof of the building is not completely horizontal either, as seen from the side walls it first has a gently sloping design which continues in a horizontal section, then in the middle of the roof of the building rises a cylinder 13.5 cm in diameter, 4.8 cm high, the engine house, which gives a total height of 15.3 cm. On the side of the building, at each of its 24 angles, there is a column connected to the side walls of the building with a 70° inclination, and 10 lamellas are placed between the columns. The only major difference between the model and the original building is the thickness of the slats, because they are so thin in real life that scaling them down to 1:100 would have been impractical.

There is a small hill near the building under study, as well as the tall building E/7, which affects the wind flow when the wind direction is such that it blows from it, but we will not be able to include this in the wind tunnel study because the measuring space is not large enough for it, and so we would have to scale down the building, which would make the model very difficult to build. For these particular tall buildings, like the E/7 building We mentioned, the effect on the flow depends on the height. If the distance between the two buildings is five times the height of the building in the path of the wind, or less, then the building is in the wind shadow. If the distance between the two buildings and the height of the building is twelve times or less, then the windward side of the second building may be subject to both positive and negative pressures. If the distance between the buildings is greater than this, there is no effect on the flow around the second building [7].

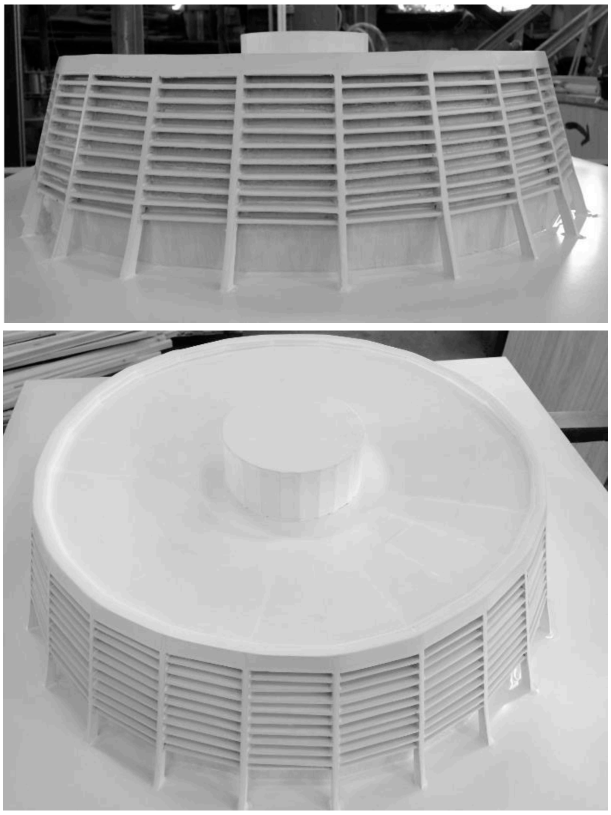


Figure 2. The completed building model [own pictures]

A wind tunnel test is often performed twice, once when the various surface constraints are taken into account, and often performed afterwards without the surface constraints, without any obstructions, just placing the building under test in the wind tunnel itself.

Basic conditions for the applicability of wind tunnel models:

- Identity of main dimensionless constants between model and reality, such as Jensen, Reynolds, Strouhal number,
- undistorted geometry,
- similar surface boundary conditions,
- similar flow theory approach,
- assessment and consideration of the building's boundary environment.

The models may be tested for:

- the air forces acting on the body in the flow (buoyancy, drag or momentum of the air forces),
- pressure distribution around the body in the flow,
- study of the boundary layer behaviour,
- the shape of the flow lines,
- study of air flow induced vibration and noise,
- heat transfer in a flowing body.

3. MEASUREMENT TASK

To carry out the necessary tests on the model I have built, I will need a wind tunnel to provide us with steady-state flow. A wind tunnel, as the name suggests, is a closed channel in which air at a given velocity is produced by a fan or other artificial propulsion system. The main part of the wind tunnel is the working section, where a scale replica of the real building is exposed to the airflow we set [1-7].

The biggest advantage of a return-flow wind tunnel is its economy, as the fan does not have to accelerate the still air, but only make up for losses. It is constructed from the same components as the two types of ducts described earlier. Furthermore, since the flow field is closed, the measurement is not affected by the external environment and the operation of the wind tunnel does not affect the environment. However, one major disadvantage of its enclosure is the need for baffles, as the air has to be deflected by 90° to four points in the turning chambers.

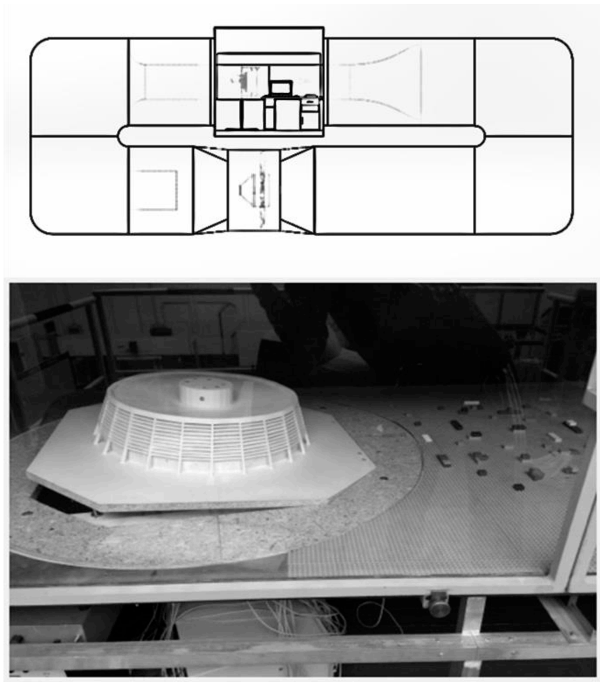


Figure 3. Experimental wind tunnel [own pictures]

Figure 3 shows the wind tunnel used for the tests, which is shown as a Göttingen type closed wind tunnel. The axial fan is located in the lower part of the wind tunnel, which can produce a maximum wind speed of 72 km/h in the measurement section located in the upper part of the wind tunnel.

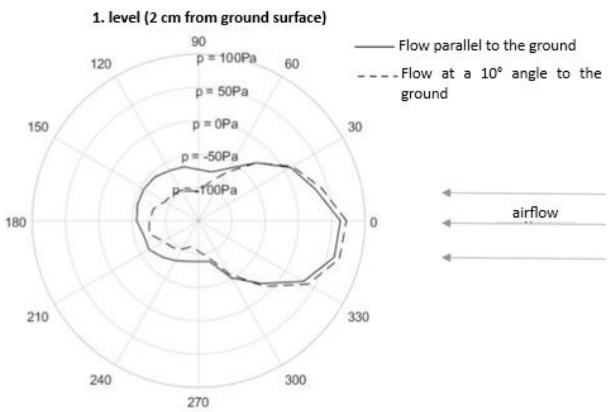
A 90 cm diameter circular section of the wind tunnel can be used to accommodate the measuring field without modifying the wind tunnel. It is also circular in order to easily rotate the test body when testing it at different wind directions, but since the model I made is cylindrically symmetric, this will not be necessary in my case, instead, we will take the measurement with a different wind angle. When tilting the building model, care should be taken that the tilt is not too large, as this would affect the flow in the wind tunnel in such a way that it could affect the measurement, thinking of the "blockage effect" discussed earlier, which could be too large in the case of a possible larger angle tilt (maximum 10°).

4. RESULTS

Pressure measurements were taken in two cases, one perpendicular to the building and the other at an angle of 10° to the parallel flow. Furthermore, the measurement was carried out at a wind speed of 20 km/h in both cases (examined on the basis of meteorological data for the area - Hungarian Meteorological Service Nonprofit Ltd.).

To perform the measurement, we designed the measurement on the available 64 channel pressure measurement system - Single Scanivalve System (SSS-64C) MK4 - 64 channel pressure measurement system (max. 3.45 bar, measurement accuracy 0.1%). We measured uniformly on 3 levels on the building model, level 1 (2 cm), level 2 (6.5 cm), level 3 (9 cm) was measured in relation to the theoretical ground surface. This allowed us to measure all 3 levels simultaneously with the 64-channel pressure measurement system. At each pressure measurement point, measurements were taken for 10-12 seconds, during which time roughly 300-350 measurements were obtained and averaged and entered into the data system. The measurement results were then plotted in polar coordinate system in the figures below (Figure 4). Each side is assigned a direction angle, and the distance from a marked point on the plane represents the pressure value, in our case.

The pressure distribution plots clearly show the effect of wind direction and the lower pressure values at points closer to the ground. These data allow to design different modifications of the building.



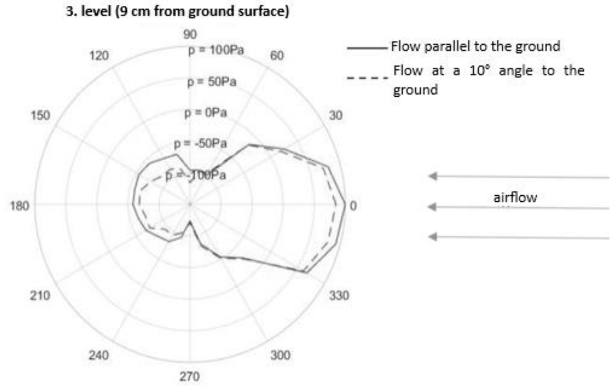


Figure 4. Pressure distributions.

5. SUMMARY

The pressures on the walls of the building model have been measured in different cases, and the results show that the angle at which the wind hits the building affects the measured values, if not significantly, but that this should be taken into account in any structural analysis of the building, which will cover wind loads. Finally, the measured values were plotted using the MATLAB® program, using a polar coordinate system, in order to make the measurement results more transparent and to illustrate the difference between the two cases with transparent plots. Based on the results, it can be said that the investigated building has sufficient stability (typically due to the building design) even considering the typical wind loads.

6. REFERENCES

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