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THE INFLUENCE OF THE SHAPES OF AN INDIVIDUAL HOUSE MODEL ON THE PRESSURES OF THE AIR CURRENTS IN THE WIND

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ABSTRACT

Wind tunnels have been largely used when numerical methods do not offer satisfying results. Pressure values cannot be obtained using numerical methods in different areas of a model because they are not yielded individually. These values are important in determining the forces that act on different components of a model or structure. By using wind tunnels and by carefully placing transducers (Pitot – Prandtl tubes) in the areas that are of specific interest, we can acquire the exact distribution of pressure values that can be subsequently used in determining the forces that take place around the model. In this article, we are presenting the results obtained through experimental tests done in a wind tunnel owned by the Faculty of Naval Architecture on a scaled down model of an individual house. Using a Pitot – Prandtl tube that was placed in specific areas, we observed and measured the pressures that formed at different wind speeds and incidence angles.

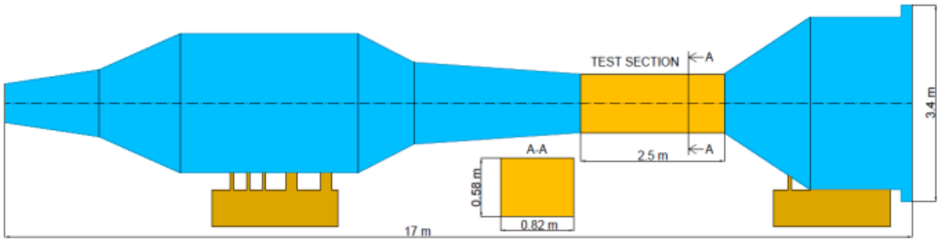
Keywords: wind tunnel, air flow, numerical and experimental simulation.

1. INTRODUCTION

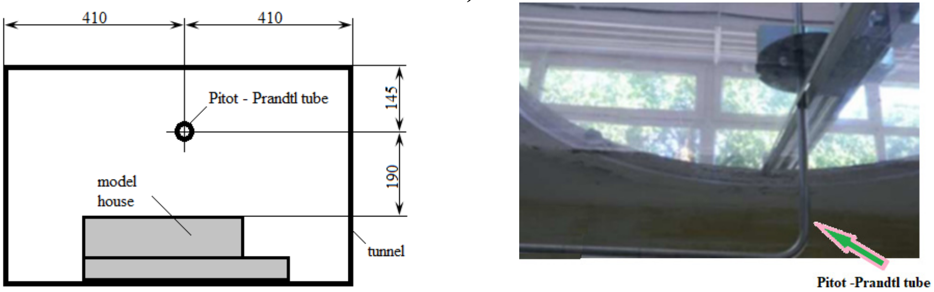
In order to study the forms of various constructions, regardless of their destination, we must take into consideration that they are generally subject to the action of fluids (air, water, etc.), depending on their importance, experimental, numerical modeling or sometimes both are required. The paper presents experimental modeling in a wind tunnel for the model of a residential building. The wind tunnel that was used for the aforementioned experimental tests is presented in figure 1, where:

a) wind tunnel elevation and the measurement section;
b) the positioning of the Pitot – Prandtl tube from the walls of the measurement section;
c) general view of the wind tunnel.

The wind tunnel presented in figure 1 has the following characteristics[1]:
- General dimensions: length 17 m, wind entrance section 3.4 x 3.7 m;
- Measurement section: width 820 mm, height 580 mm;
- Maximum wind speed: 23.5 m/s.



a)



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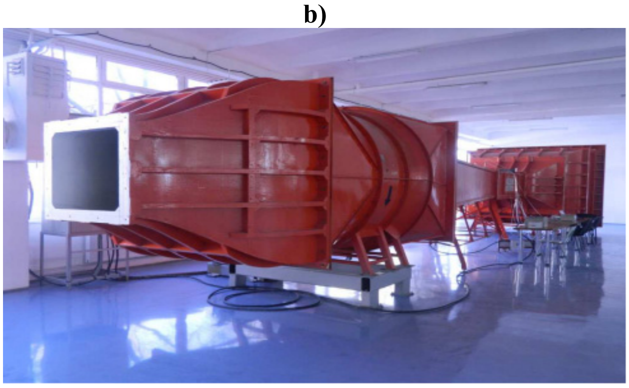


c)

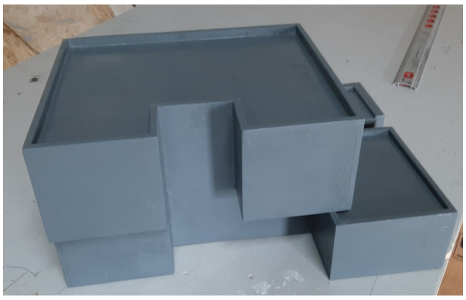
Fig. 1. Wind tunnel

The physical model of the individual house was built out of poplar wood boards with a width of 9 mm. The assembly of the various components was done by gluing with a fast adhesive used in the wood industry. Afterwards, it was painted grey, as seen in figure 2. The actual dimensions of the house were scaled down with a coefficient of 0.033, resulting in the final dimensions of the model: width 570 mm, height 230 mm.

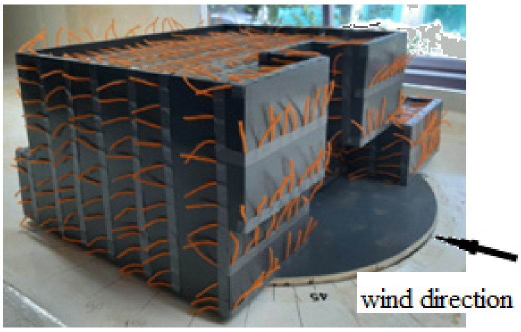
The longitudinal axis of the wind tunnel is the one indicated in figure 2 b). The longitudinal axis of the physical house model was chosen to coincide with that of the wind tunnel.

In order to study the air flow pattern created by the wind tunnel fan around the house at different incidence angles, the model was mounted on a circular wood board with a diameter of 580 mm that can rotate around its axis.

The choice for the downscaling coefficient of the house model takes into consideration the blocking coefficients. These blocking coefficients are determined both for the wind tunnel and for the hydrodynamic naval basins.



a) house model



b) the model placed in the wind tunned

Fig. 2. Individual house model

The first coefficient refers to the proportions of the width of the tunnel and the model, and is given by the specialty literature [4] as the following relation:

$$\alpha = \frac{B_{model}}{B_{tunnel}} \quad 1)$$

where:

- B_{model} - represents the width of the model;
- B_{tunel} - represents the width of the wind tunnel.

The dimensions presented before the blocking coefficient are 0.666>0.5, which is imposed by the specific rules.

Another coefficient that refers to the proportion is given by the following relation:

$$\beta = \frac{S_{frontmodel}}{S_{tunnel}} \quad 2)$$

where:

- $S_{frontmodel}$ - represents the frontal higher area of the model;
- S_{tunnel} - represents the area of the measurement section of the wind tunnel.

The dimensions presented before the blocking coefficient are 0.225<0.5, which is imposed by the specific rules.

Data acquisition was done with the help of a special data computing software installed on a calculation system.

2. METHOD

Before starting the experimental tests, we need to establish both the wind directions in relation to the longitudinal axis of the tunnel and the different wind speeds.

For the city of Galati, according to [2], the main direction of the wind seems to be from the North and North-North-West as presented in figure 3 a). From the Design regulation [2], we extract the local dynamic wind pressure, which in this case is 0.6 kPa, as shown in figure 3 b).

In figure 3 c), we show the chosen incidence angles from which the wind will act on the physical model of the individual house.

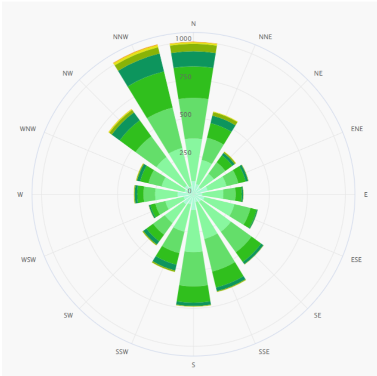
Using the mathematical equation (3), we can determine the wind speed in the wind tunnel based on the dynamic pressures:

$$v_m = \sqrt{\frac{2 \cdot \Delta p}{\rho}} = 1.300 \cdot \sqrt{\Delta p} \quad 3)$$

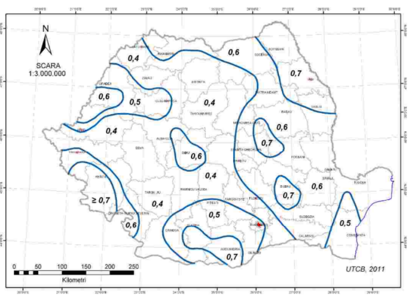
where:

- Δp - represents the measured pressure in the wind tunnel;
- ρ - the air density, which at a standard temperature of $25^0\,C$ is $1.184\,kg/m^3$.

Therefore, we were able to set the speed of the wind tunnel fan to produce an air flow with a speed ranging between 5.25 m/s and 8.9 m/s. This interval was chosen because [1] in the geographical area of Galati the maximum wind speed used in engineering and construction is 31 km/h (corresponding to a wind tunnel speed of 8.6 m/s).



a)



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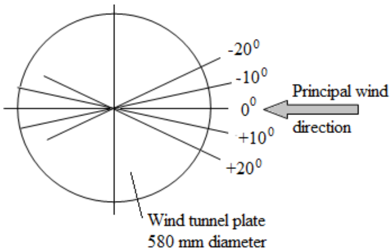
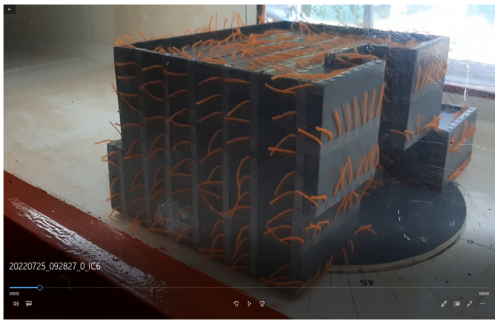


c)

Fig. 3. Main wind direction for the City of Galati according to CR 1-1-4/2012 [2]

The model was tested as following:
- model without vegetation (figure 4 a));
- model with tree (figure 4 b));
- model with low and high vegetation (figure 4 c)).

The pressure values were recorded, stored and processed.



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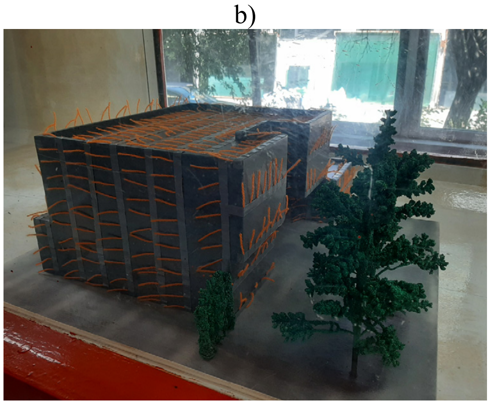

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Fig.4

3. CONCLUSIONS

3.1 General conclusions

Air currents through the pressures that are formed can act differently on distinct elements of construction or structure. Furthermore, they can produce forces and moments that are destructive to these components. Therefore, determining these forces and moments from the design stage of a project seems to be imperative for the safety of the occupants.

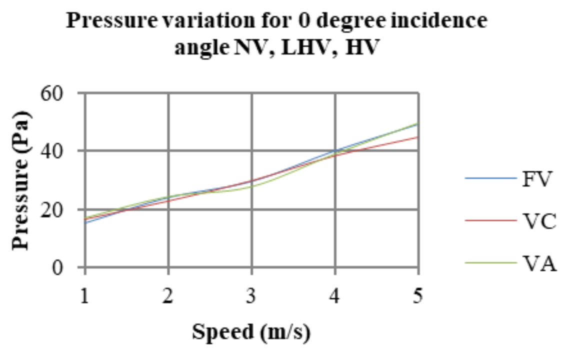
Analyzing the pressure values of the air currents that act on the individual house model result in the variations presented in table 1 and in the graphics from figure 5.

In these tables, the data acquired and presented are at the level where the Pitot-Prandtl tube is installed in the wind tunnel. In some situations, it is necessary to determine the pressures in various areas of the model. In this case, several tubes must be installed to determine a more detailed pressure map.

Table 1

Curent direction rotation	Incidence angle /Wind speed	Model without vegetation	Model with tree	Model with low and high vegetation
Clockwise (CW)	0^0	*Pressure* (Pa)		
	IC6	15.452	16.455	17.134
	IC7	24.110	22.765	24.392
	IC8	29.587	29.774	27.788
	IC9	39.978	38.420	38.927
	IC10	48.930	44.848	49.429
	10^0			
	IC6	17.548	15.035	17.824
	IC7	24.257	23.037	23.482
	IC8	29.791	29.463	30.703
	IC9	39.092	36.584	39.093
	IC10	47.317	44.864	48.248
	20^0			
	IC6	14.945	15.014	15.109
	IC7	20.635	21.036	21.473
	IC8	28.096	29.010	28.015
	IC9	32.466	36.791	34.189
	IC10	45.161	44.196	42.398
Counterclockwise (CCW)	-20^0			
	IC6	15.565	13.424	14.608
	IC7	20.070	17.474	20.387
	IC8	25.422	27.301	25.433
	IC9	34.257	32.936	33.242
	IC10	43.273	40.029	39.639

	-10^0			
	IC6	15.796	14.620	14.514
	IC7	22.049	20.843	21.281
	IC8	29.129	26.265	27.527
	IC9	36.220	34.644	34.395
	IC10	47.967	42.687	42.607
	0^0			
	IC6	14.931	16.544	17.070
	IC7	23.589	22.854	24.328
	IC8	29.086	29.838	27.739
	IC9	39.477	38.484	38.878
	IC10	48.429	44.912	49.380



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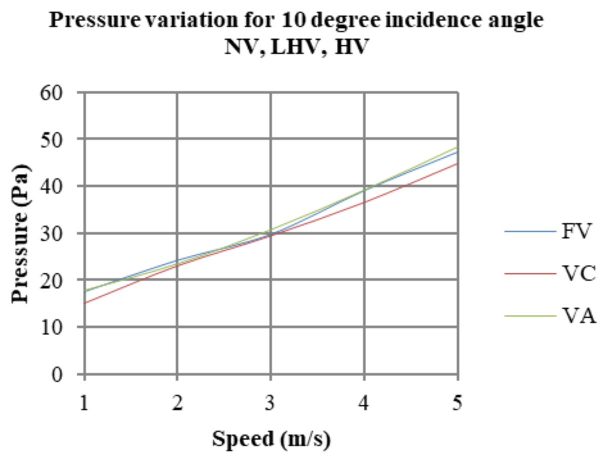

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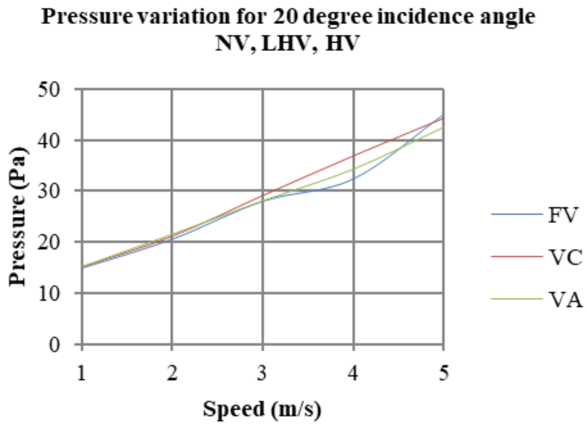
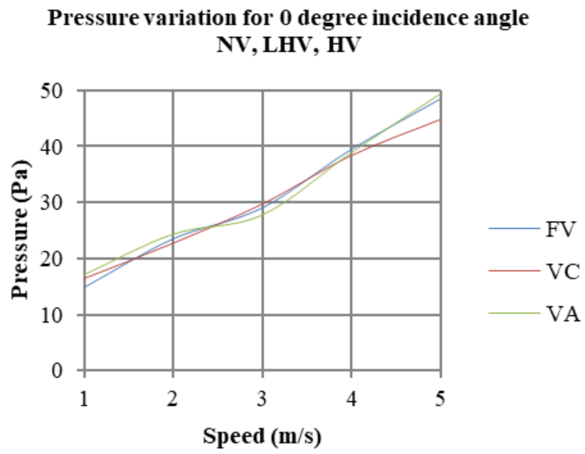
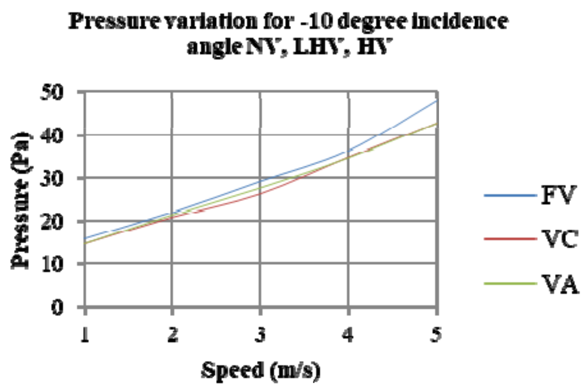

Pressure variation for 20 degree incidence angle NV, LHV, HV
Pressure (Pa)
Speed (m/s)
FV
VC
VA
0
10
20
30
40
50
1
2
3
4
5

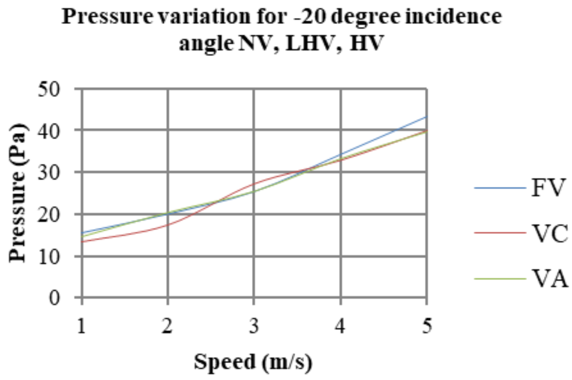
c)


Pressure variation for 0 degree incidence angle NV, LHV, HV
Pressure (Pa)
Speed (m/s)
FV
VC
VA
0
10
20
30
40
50
1
2
3
4
5

d)


Pressure variation for -10 degree incidence angle NV, LHV, HV
Pressure (Pa)
Speed (m/s)
FV
VC
VA
0
10
20
30
40
50
1
2
3
4
5

e)



f)

Fig. 5. Pressure variation according to wind speed in the wind tunnel

3.2 Particular conclusions

As we can observe from figures 5 a, b, c) for the clockwise incidence angles, the presence of vegetation leads to lower pressures for different wind speeds. These differences of 1,…., 2 Pa are significant given large surface industrial buildings.

For counterclockwise incidence angles, we also obtain a decline in wind pressures, especially for high wind speeds.

Taking into consideration that the individual house is currently under construction in the city of Galati, the results of this research paper will be implemented after the construction is done for the landscaping process. Furthermore, they can be used in detailing the house accessories fixtures for the North elevation (incidence angle 0^0 figure 2 b)), to provide better integration with the house structure and higher wind resilience.

Lastly, it needs to be mentioned that the careful placement of vegetation around an individual house has the potential to lower or even completely eliminate unwanted air currents that can produce vibrations to different parts of the building.

Acknowledgements

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