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EXPERIMENTAL RESEARCH ON THE MECHANICAL SOLICITATIONS OF THE GREENHOUSES OF VEGETABLES AND FLOWERS LOCATED ON ROOFTOPS

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***Abstract**: This paper presents work algorithm and experimental research results related to the solicitations of the greenhouses for vegetables and flowers placed on rooftops in urban built environment. For research was designed and developed five models of possible forms of greenhouses, which were introduced in HM170 wind tunnel [8]. Air flow speeds to which they were exposed to the front and side surfaces, as well as the roofs of the layouts were 20, 25, 27.5, and 30 m/s. Were measured the pressures in 12 - 16 points on each of the surfaces specified, the data are necessary to design structures of greenhouses resistance of various shapes [2] .All the layouts had the same height and length, but were differentiated by the shapes of roofs and their inclination angles [1].*
***Keywords**: Greenhouses for vegetables and flowers, mechanical solicitations, experimental researches.*

1. INTRODUCTION

Resisting movement of an object relative to the air is proportional to the air density ρ, the front surface of the body S and the square of the velocity relative to the air v_a.
Aerodynamic drag force is defined by the formula:

$$F_a = \frac{1}{2} \cdot \circ \cdot c_x \cdot S \cdot v_a^2 \tag{1}$$

where c_x is called the coefficient of aerodynamic resistance.
Ţhe coefficient of aerodynamic resistance c_x represents of the body form influence on the resistance to the force of the air and determined experimentally [3]. This factor is not a constant, but varies depending on the speed, air flow direction, the position and size of the object, density and viscosity of air. Speed, kinematics viscosity and a characteristic length scale of the object are incorporated into non dimensional coefficient called Reynolds number (Re). In compressible mediums is relevant and the speed of sound, and c_x depends on also on the Mach number (Ma). To some form of body drag coefficient of only depend on the number Re, Ma number and direction of the current. At low speeds is no longer dependent coefficient of Mach number (Ma) [4]. Also, the variation with Reynolds number is typically small for most areas of interest. For this reason the air current has the same direction relative to the examined body, it is considered to be constant coefficient c_x [5].
Aerodynamic drag coefficient determined experimentally for a spherical body is 0.47 [6]. Direction of the airflow in the case of a spherical body is not important, the body profile is the same in any direction. It should be noted that a building with the same floor area as a spherical body, but rectangular form, would have a drag coefficient of about 1, and the exposed surface would also significantly higher, so that the force of the wind presses on such construction would be higher (estimated 4 - 5 times higher).

2. MATERIALS AND METHOD

For experimental research on the influence of wind on roofs type greenhouse buildings from urban areas were built five models of greenhouses, which differ in shapes and angles of roofs (Figure 1) .In all frontal and lateral walls as well and the roof surfaces have been made holes with diameters of 3 mm, in which were introduced and were sealed heads gauge hoses connecting with tubes of multitube manometer by the equipment for measuring the pressure exerted at different wind speeds.

Figure 1. Greenhouse layouts built for experimental research

Wind tunnel HM170 used in experimental research (Figure 2) [7] is the type subsonic (air speed up to Mach 0.1), open circuit, outside air is taken in and expelled all outside, with increased speed.

Figure 2. HM 170 Educational Wind Tunnel manufactured by GUNT Gerätebau GmbH, Barsbütte, Germany.

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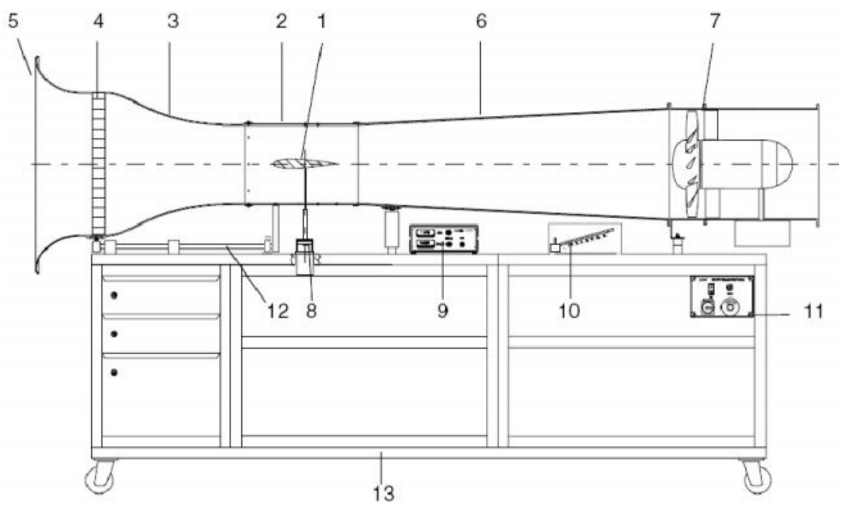
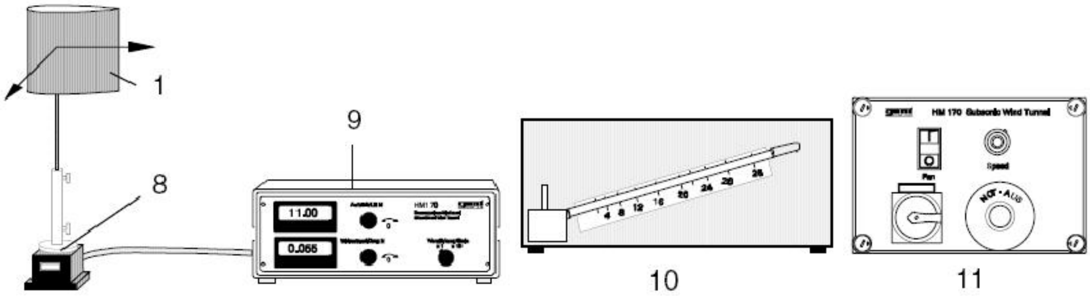


Figure 3. The components of wind tunnel HM170 [8]

The model 1, that is experimental investigated is fixed in the measurement section 2 (Figure3). Air is drawn into tunnel through the feeding hopper 5, and laminar flow is ensured by section 4 (possible cross components of the

air flow is reduced to zero). The flowing of laminar air is accelerated by approximately 3.3 times in section 3 and in area 6 of the tunnel is made slower air speed that is pushed out through the fan 7.
Measurement of forces is achieved by means of the force transducer 8 which is integral with the experimental model 1 (Figure 4.a). This transducer inside the tunnel can perform measurements (after 2 directions - driving and port) on: strength, speed, pressure, aerodynamics coefficient to drive (drag) and lift (elevator). The measurements values of forces can be displayed on the screen the amplifier 9.



a b c

Figure 4. The measurement system (a), the manometer tube (b) and control panel (c) of the wind tunnel

Air speed in section for measurements 2 can be read on the manometer tube inclined 10 (Figure 4.b). The control panel 11 (Figure 4.c) contains a main switch ON / OFF power supply, emergency stop button, a button for adjusting the air speed (frequency converter) and an ON / OFF main switch for fan. Rail 12 allows the translation of wall to the measuring section and access inside section. System is placed within section 13 provided to the frame with rollers.
The air speed is measured with a thermal anemometer shown in Figure 5.

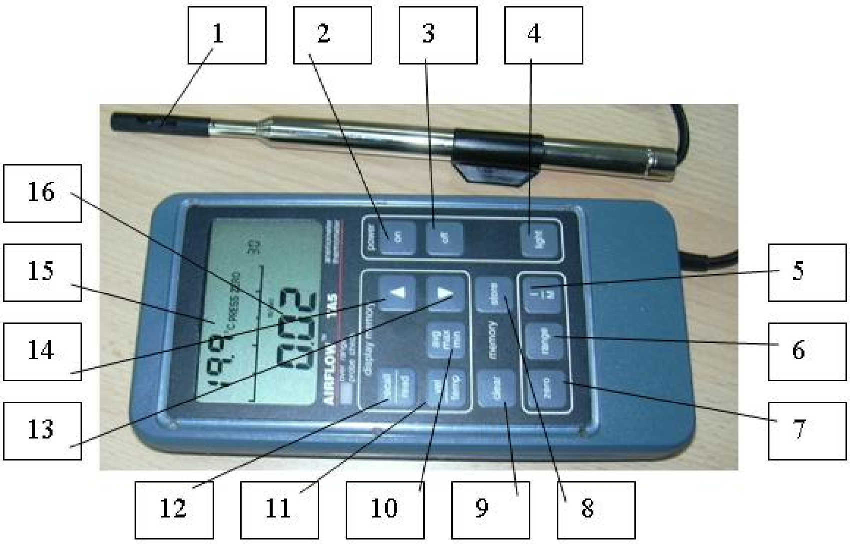


Figure 5. Thermal anemometer of the wind tunnel structure

Thermal anemometer (Figure 5) has the following features: 1 - type strain gauge sensor; 2 - button on; 3 - off button; 4 - light button of the screen; 5 - button for calculating the average measured; 6 - setting the unit of measurement; 7 - button calibration; 8 - Memory button; 9 - button to delete the stored value; 10 - button to display the minimum, maximum, average measured the activation button "on"; 11 - button measured temperature display; 12 - button display wind speed measured; 13 - down scroll button; 14 - scroll up button; 15 - display measured temperature value; 16 - display wind speed measured.
To experimental researches made in this paper was measured the pressure with which pushed the wind wich different speeds, using the multitube manometer presented in Figure 6.
Multitub manometer (Figure 6) [4] containing the 16 tubes of the type manometer with graduated scale 2, mounted on a hinged panel 1. Each tube is provided at the upper parts with connection nozzle 3. Water supply is achieved by means of tank 4, connected to link tube 5. The multitub manometer offers the possibility of measuring absolute or relative air pressure, static or dynamic pressure of the air in the flowing. The panel can tilt in 3 positions through lever 6, enabling the possibility to measurement of very low pressures. The angle can be

read on the indicator panel 7: 1: 2 (63,4^{o}), 1: 5 (78,7^{o}) 1:10 (84,3^{o}). Fixing the vertical direction of the panel is achieved by means of screws 8 taking account of the indicator 10. Panel fixing on stand 11 is achieved by tightening bolts 9.

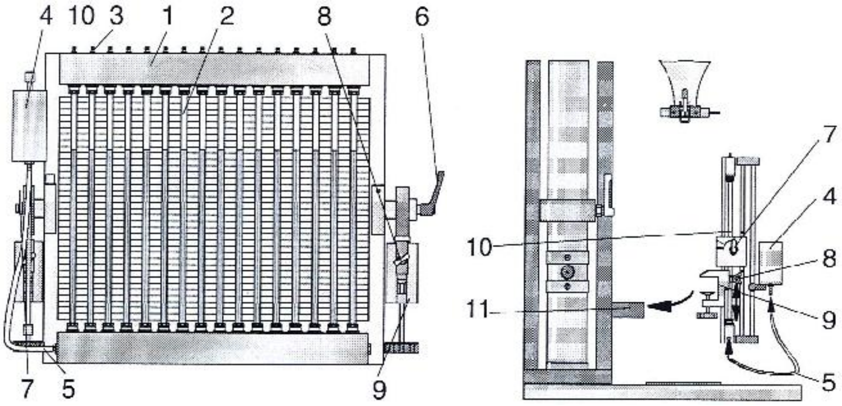
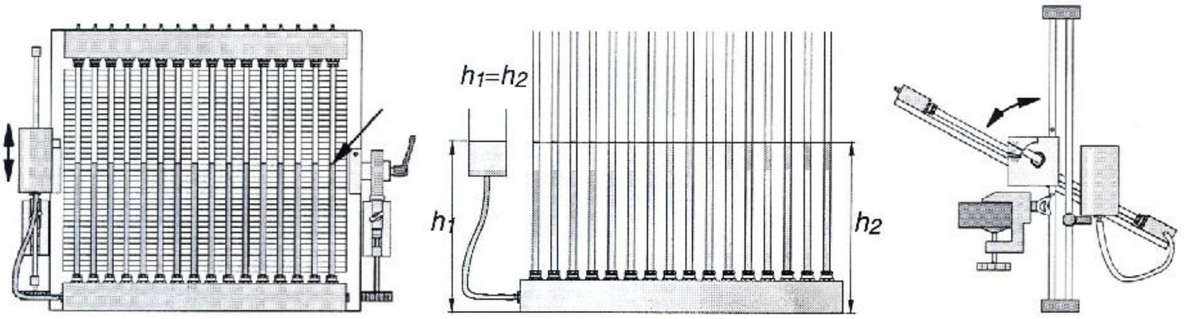


Figure 6. The mmultitub manometer of wind tunnel [4]

Multitub manometer (Figure 6) [4] containing the 16 tubes of the type manometer with graduated scale 2, mounted on a hinged panel 1. Each tube is provided at the upper parts with connection nozzle 3. Water supply is achieved by means of tank 4, connected to link tube 5. The multitub manometer offers the possibility of measuring absolute or relative air pressure, static or dynamic pressure of the air in the flowing. The panel can tilt in 3 positions through lever 6, enabling the possibility to measurement of very low pressures. The angle can be read on the indicator panel 7: 1: 2 (63,4^{o}), 1: 5 (78,7^{o}) 1:10 (84,3^{o}). Fixing the vertical direction of the panel is achieved by means of screws 8 taking account of the indicator 10. Panel fixing on stand 11 is achieved by tightening bolts 9.

For water supply, the tank is fixed in the middle of manometers tubes and fed with water up to half the height of the tank (Figure 7 a).

At water supply, the nozzles upper of the manometers tubes are off, and on the principle of communicating vessels, the water level in the tank is the same in all tubes (Figure 7, b), taking into account atmospheric pressure.



a. b. c.

Figure 7. Water supply (a), the water level (b) and adjusting the inclination (c) at the multitube manometer

For accurate measurements it is possible to adjust the inclination of the panel (Fig. 7 c) to 1: 2 (63,4^{o}), 1: 5 (78,7^{o}), 1:10 (84,3^{o}) by operating the lever 6 (fig.17.10) and reading the indicator 7.

The models of greenhouses have been specially prepared to be subjected to experimental research in wind tunnel. In this respect they were performed on the frontal and lateral surfaces and on the roof the holes with diameters of 3 mm (Figure 8), which are inserted from the model inside the tubes connecting to the multitube manometer for measuring the pressure of the stream of air different speeds.

For entering the tubes was performed on the base plates of the models by a 30mm diameter hole. This hole served subsequently and to layouts fixing on the bottom wind tunnel. The motherboards of layouts is detaches to model corps for introducing these tubes and fastening to the floor tunnel, after being mounted around the template, ready for experimental researches. The holes that have not participated in the current samples were coated with adhesive foil (Figure 9). For accurate recording of all results were numbered holes which participated in a particular sample.

Figure 8. Preparing the greenhouses models for experimental researches

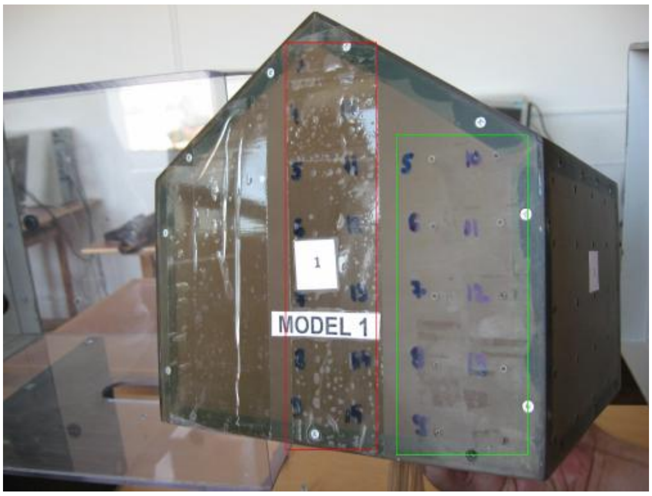


Figure 9 The numbering to Holes on the layouts surfaces and cover those who do not participate in a particular sample

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Figure 10. The wind tunnel with a greenhouse model located in a position of the airflow direction

Figure 10 is present the wind tunnel prepared for experimental research at a model of greenhouse, fixed by one of the airflow direction.
Figure 11 present the entire installation of greenhouse Prepared for an experimental research model and the a sequence of conducting experimental researches


Figure 11 Moment of conducting to experimental researches

The wind speeds considered for experimental research had values of 20 m/s, 25m/s, 27.5/s and 30/s. For all the models were measured the airflow pressures on greenhouse surfaces where the frontal or lateral surfaces have been on the airflow direction.

3. RESULTS AND DISCUSSION

The force with the wind acting on greenhouse pending roofs of buildings in this research is assessed by pressures on their surfaces when blowing in different directions and at different speeds. Since lower wind speeds of 20 m/s is considered not dangerous to the stability of these greenhouses were investigated experimentally only the influences of winds with speeds of 20-30 m/s. Wind tunnel used in experimental research can not generate airflow speeds greater than 30m / s. For each greenhouse model were retained the pressures measured in the 12 to 16 holes on different surfaces when airflow direction has been frontal or lateral. The Gradation with the value 30 on the multitub manometer was considered the benchmark, so that higher values recorded for pressures means pushing forces and lower values are depressed forces.
In Tables 1, 2, 3 and 4 is illustrated the results of experimental research to model No 1 of greenhouse, where the roof slope was 30^0 from the horizontal

The pressure values on the front wall, the front direction of the air flow **Table 1**

MODEL: 1 FRONTAL ■ LATERAL: □ WALL: ■ROOF: □

	30 m/s	27,5 m/s	25 m/s	20 m/s
3	31,5	31,3	31	30,7
4	30,6	30,5	30,4	30,2
5	30,3	30,2	30,1	30
6	30	30	30	29,9
7	29,9	29,9	30	29,9
8	29,8	29,8	29,9	29,9
9	29,9	29,8	29,9	29,9
10	30,7	30,6	30,6	30,3
11	30,2	30	30	30,1
12	30	29,9	29,9	29,9
13	29,9	29,8	29,8	29,9
14	29,8	29,8	29,8	29,8
15	29,9	29,8	29,8	29,9

The pressure values on the lateral wall, the frontal direction of the air flow **Table 2**

MODEL: 1 FRONTAL ■ LATERAL: ■□ WALL□ ROOF: □

	30 m/s	27,5 m/s	25 m/s	20 m/s
3	-	-	-	-
4	-	-	-	-
5	30,3	30,4	30,4	30,2
6	30,1	30,2	30,1	30
7	30	30,1	30	30
8	29,9	30	30	30
9	30	30	30	30
10	30,9	30,8	30,8	30,5
11	30,5	30,7	30,5	30,3
12	33	33	32,5	31,5
13	30,4	30,4	30,4	30,2
14	30,7	30,6	30,6	30,4
15	-	-	-	-

The pressure values on the roof, the lateral direction of the air flow **Table 3**

MODEL: 1 FRONTAL □ LATERAL: ■ WALL: □ ROOF: ■

	30 m/s	27,5 m/s	25 m/s	20 m/s
3	35,9	35	33,9	32,5
4	33,9	33,5	32,7	31,8
5	33,1	32,9	32,3	31,5
6	34,4	33,8	32,9	31,9
7	36,2	35,3	34,1	32,8
8	35,7	34,8	33,8	32,5
9	32,9	32,6	32	31,4
10	34,7	34,1	33,1	32,2
11	35,8	34,9	33,9	32,5
12	33,6	33,2	32,4	31,6
13	32,9	32,6	32	31,2
14	29	29,2	29,8	29,5
15	-	-	-	-

The pressure values on the lateral wall, the lateral direction of the air flow **Table 4**

MODEL: 1 FRONTAL □ LATERAL: ■ WALL: ■ ROOF: □

	30 m/s	27,5 m/s	25 m/s	20 m/s
3	32,2	32	31,7	31
4	33	33	32,5	31,6
5	31	31	31	30,6
6	31	31	30,2	30,5
7	30,8	30,7	30,7	30,4
8	30,1	30,1	30,1	30
9	30	30	29,9	29,9
10	29,8	29,9	29,8	29,9
11	30,8	30,7	30,6	30,4
12	29,7	29,7	29,7	29,8
13	29,9	29,8	29,8	29,9
14	29,8	29,8	29,8	29,9
15	30,3	30,2	30,1	30

Similarly is presented the results of experimental research for the other four models of greenhouses. It highlights that at the same level of greenhouses the exposed surfaces to winds are even greater, as are smaller inclinations of roofs . It also the pressures on researched surfaces increased with the square of velocity of the air stream.

4. CONCLUSIONS

1. For the experimental research of the strength of greenhouses located on rooftops have produced five models, which have the same heights, but they differ in angles with that are inclined roofs. In this way, the exposed surfaces of pressing force on wind would be higher or lower depending on these angles.
2. The experimental investigations were conducted in an aerodynamic tunnel type HM170 manufactured by GUNT Educational Wind Tunnel Gerätebau GmbH, Barsbüttel, Germany. Air flow speeds to which they were exposed to the front and side surfaces, as well as the roofs of the models were 20, 25, 27.5, and 30 m / s
3 On the basis of experimental research may be completed formula (1), so as to establish the value of the pressing force of the air flow on an inclined surface with an angle to the direction of the current, respectively. Also these investigations are necessary to validate the simulation modeling software with finite element method for calculation of thrust and lift forces and overturning moment of the greenhouse by air currents.

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