INFLUENCE OF GREENHOUSES FORMS, LOCATED ON THE ROOFS OF BUILDINGS ON THE RESISTANCE TO WIND ACTION

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Abstract: *The paper highlights the importance that the current trend is manifested in the developed countries of Western Europe, USA, Japan etc., regarding the location of greenhouses for vegetables and flowers on the roofs of buildings, and the need they satisfy all the requirements imposed by Crops grown on ensuring environmental factors, those required by architects planners, but also those on the mechanical safety of the wind and bad weather they perform them at all times. Theoretical and experimental research conducted on 5 models of greenhouses showed the influence of the number of pitches roofs and angles they form these slopes over the forces of pressure / suction the wind at different speeds and directions exerts upon the strength structures of greenhouses, specifying in all cases of aerodynamic drag coefficient values of the respective forms of roofing.*

Keywords: *Greenhouses on the roof, mechanical strain, aerodynamic drag coefficient.*

1. Introduction

In the current period the construction of greenhouses located on the ground has become an attractive and highly competitive market, characterized by a high normalization and standardization. The general trend of making structures as safe in terms of resistance to mechanical stresses, overlaps with the need to reduce manufacturing costs, installation and equipping of greenhouses [7], but also with the rigorous selection of vegetables or flowers to cultivate so that the final product quality to live up to the highest level, and total spending to a minimum. Theoretical research and the practice have validated some constructive forms of greenhouses that have proven most effective. At the same time, free movement of products on the European market put before the committee specialized in Brussels circulation problems produced vegetables and flowers in greenhouses and construction of greenhouses question.

The first notable achievement in terms of building greenhouses unification is the minimization of distances between the rows of pillars, ie width sections, establishing the European Standard EN 13031-1 Greenhouse shape and construction. Part I: Commercial production greenhouses, CEN European Comittee for Standardization (2001) Brussels, be 6.40 m, 9.60 m, 12.80 m and produce a typology of greenhouses for each of the intervals.For greenhouse manufacturers is essential the existence of normative calculation and design through to optimize its structural capacity / cost. The methodologies provided for in the national regulations of the member countries in the European Union must respect the framework methodologies from Brussels, taking account of local conditions related to levels requests posed to those greenhouses. In Romania is used to design buildings with different shapes of roofs, and other structures with different uses Code Design Assessment of Wind on Buildings Indicative 1-1-4 CR / 2012. This bill is in turn placed permanently in line with European legislation and other standards that designers and builders of greenhouses on roofs must follow. The same applies to other countries, where construction standards are continuously updated, so as to make buildings more secure environmental factors, especially wind [3].

Like any law or standard nor code CR-1-1-4 / 2012 could not take into consideration all circumstances that could occur in practice. For this reason, in paragraph 1.4 aided design attempts to make the following clarifications:

1. For the evaluation the effect of wind on the building and its response may be used in the wind tunnel test results and / or numerical methods, using appropriate models and construction of the wind;
2. To conducting experimental attempts in the wind tunnel, wind action should be designed in a

manner that (i) the average wind velocity profile and turbulence characteristics in the construction site.

The greenhouses located on the roofs of buildings can not be confused with normal roofs, even though in some cases their shapes are close to them. The requirements that requires these greenhouse grown plants, on the materials to be used for the side walls and roofs, the existence of the necessary equipment and facilities to ensure growth factors, etc., makes these vulnerable construction elements to requests due to wind, snow formations earthquakes or their combined actions [5]. For the design and proper execution of these greenhouses, conducting further research it is not only useful, but even necessary.

The theoretical researches by simulation with finite element method and experimental research in the wind tunnel, models of greenhouses with shapes similar to those considered buildings with roofs typical respectively two and four slopes and angles between the limits in the Code were intended to pressure values available to designers / wind suction acting on rigid surfaces external forces such as pushing and overturning moments of drag coefficient of pressure / suction and force roof greenhouses with two four slopes. The speeds and wind drive directions were identical to theoretical and experimental research, and the similarities and differences between models of greenhouses offers designers the possibility of comparison and choice of the optimal solution for a given situation. On the other hand, comparing the results of theoretical and experimental research among themselves but also with the code entered in the CR-1-1-4 / 2012 aims to validate the research method adopted in this paper.

2. Material and Method

2.1 The aerodynamics resistance to wind action

A body moving from ambient air opposes a drag force F_d, proportional to air density ρ, with the front surface A of the body and the square of velocity relative to the body and air respectively.

F_d force called aerodynamic drag force and is calculated by equation (1): Following the evolution of the population in Romania, it can show that it follows the European trend as seen in Table 1 [27].

$$F_d = \frac{1}{2} \cdot \rho \cdot c_d \cdot A \cdot v_a^2 \qquad (1)$$

where c_d is called coefficient of aerodynamic drag.

The drag coefficient c_d represent the influence body shape is the force exerted on the resistance to air and is determined experimentally [6].

This coefficient 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, kinematic viscosity and a characteristic length scale of the object are incorporated into a coefficient called dimensionless Reynolds number (Re). The compressible media, it is important to speed of sound, and the c_d is also dependent of the Mach number (Ma). For some form of body drag coefficient of cd depends only on the number Re, Ma number and direction of the current. At low speeds coefficient of aerodynamic drag is no longer dependent on the Mach number. Also, for most areas of practical interest, the variation in Reynolds number is relatively small, so that for a flow of air having the same direction relative to the body examined, the coefficient cd can be considered constant [11].

The aerodynamic forces on a body come mainly from differences in pressure and viscous shear stress. Thus, the aerodynamic drag force exerted on a body can be divided into two components, namely resistance due to friction (slip viscous) due to pressure and resistance (drag). In these cases, the coefficient of aerodynamic drag of a body placed in a flow of air is variable in its speed. [10] having a specific value for a given speed of the air stream [2].

The wind velocity is the main factor which determines and influences the aerodynamic drag force and can be measured accurately using anemometers. Visual estimation of wind speed can be done using the Beaufort scale (defined by Admiral Francis Beaufort in 1805), which has 12 degrees (0 ... 12), the latter being the hurricane, the wind speeds exceed 33m / s.

Air density is approximated in this paper to 1.225 kg / m^3, its real value is influenced by temperature, humidity and air pressure.

2.2 Calculation and design of greenhouses located on the roofs of buildings using Code CR 1-1-4 / 2012

In accordance with the Code CR-1-1-4 / 2012 the buildings are divided into classes of importance-exposure, according to the human and economic consequences that may be caused by a natural hazard and / or major anthropogenic and role their post-hazard response activities of the company. For the evaluation the effect of wind on buildings, each class of importance-exposure (I-IV) is associated with an exposure factor importanţă-, g_{Iw} applied to its characteristic value. Values important factor - exposure, wind g_{Iw} actions are: g_{Iw} = 1.15 for the construction of important classes I and II-exposure; g_{Iw} = 1.00 for building class-important exposure III and IV.

The buildings equipped with greenhouses on roofs is better to be included in the class of importance-exposure immediately above normal building since the destruction of greenhouses under the action of winds can cause significant damage, including serious injury population.

The resulting pressure (total) of wind on a building component (eg a greenhouse built on a roof) is the difference between the pressures (oriented surface) and suction (targeted near surface) on both sides of the element; to be taken with their signs. Pressures are considered the sign (+) and suction sign (-) as shown in Figure 1, which is a diagram exemplifying the building roof greenhouses studied similar models in theoretical and experimental work.

The force of the wind acting on a building / structure or of a structural element (for example, a greenhouse built on the roof) can be determined in two ways:

- as a global force, using aerodynamic coefficients of force;
- by adding pressure / suction acting on surfaces (rigid) of the building / structure, aerodynamic coefficients using pressure / suction.

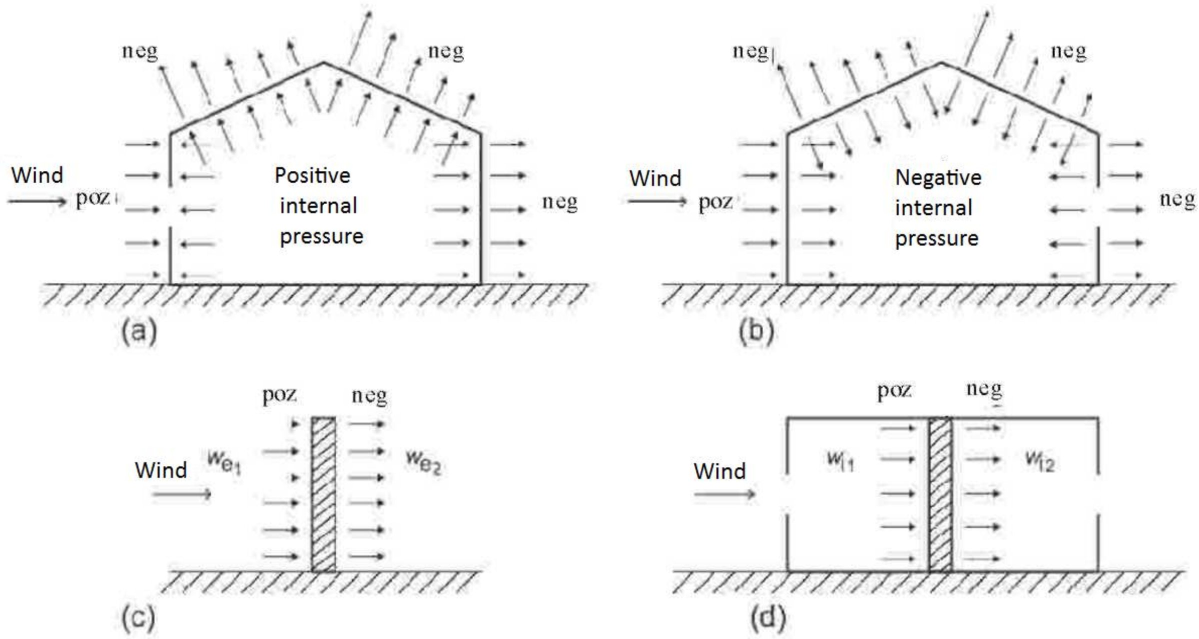


Fig.1. *Representation of the pressure / suction on surfaces in the Code CR-1-1-4 / 2012*

The first version was used in this paper, that was determined experimentally global force with which the greenhouses of different shapes are pushed by air currents at different speeds and using the relation (1) were calculated coefficients aerodynamic force that characterizes a greenhouse of a some form.

To the theoretical and experimental investigations have included two strands wind to models of greenhouses, namely a front direction and lateral direction, as shown in the examples of code situation and CR-1-1-4 / 2012. Experimental investigations led forces push Fd emissions for each model and knowing the reference area A in each case were calculated aerodynamic drag coefficient of cd force.

The effects of air friction on surfaces will not be neglected to check the state of static equilibrium limit construction in question [12].

2.3 The aerodynamic coefficients of pressure / suction and force

The aerodynamic force coefficients are used to determine the overall strength of the wind on the structure (for example, a greenhouse), structural element or component, including this effect and friction.

- ***The aerodynamic coefficients of pressure / suction and force for roof with two slopes***

Four of greenhouses researched theoretical simulation and FEM three experimental models studied in the wind tunnel roofs with two slopes are symmetrical, as shown in Figure 2. Between notations and values of tilt angles of roofs in Figure 2 and Tables 2-a and 2-b angles and scoring models researched correlation is as follows (Table 1).

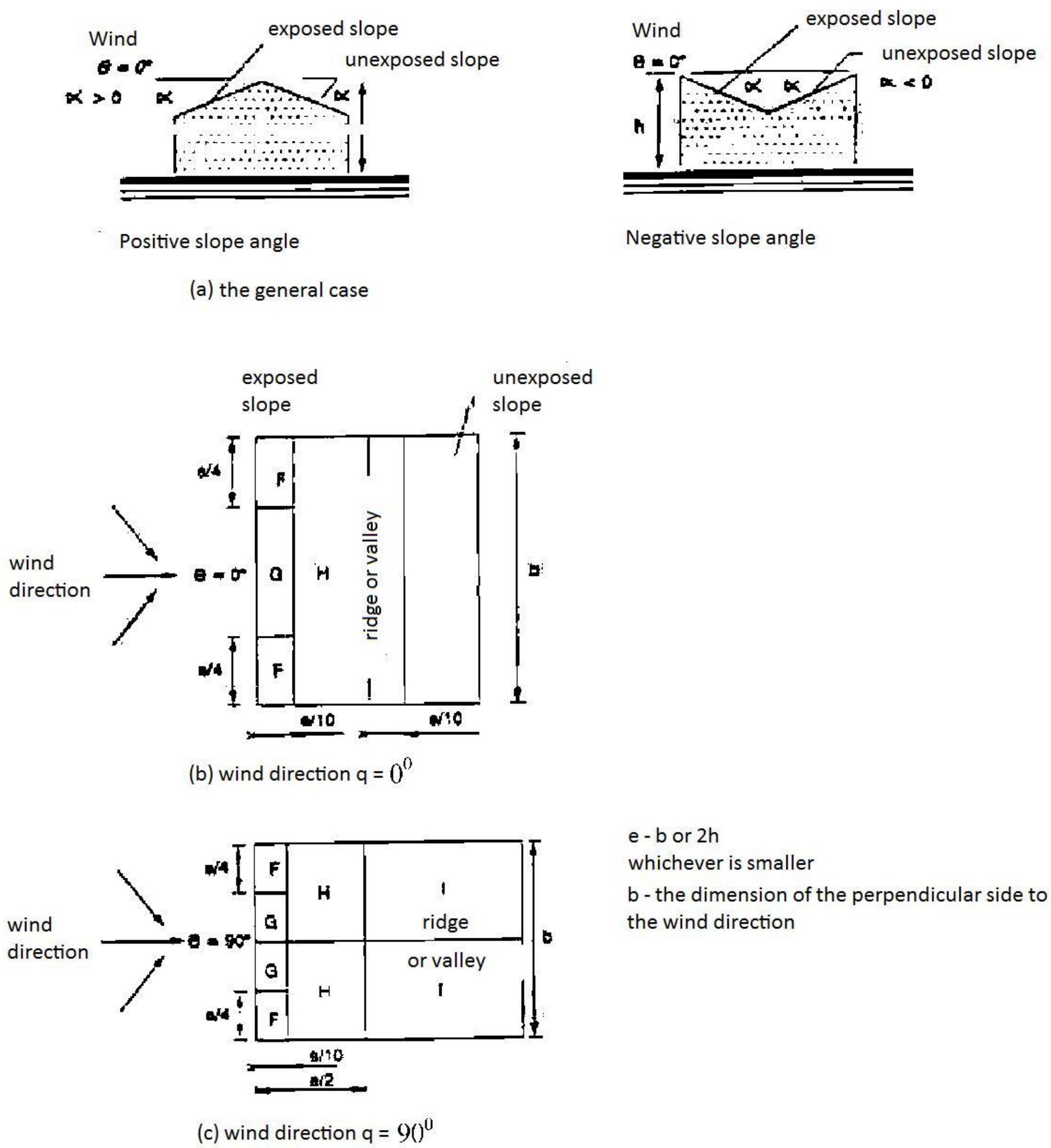


Fig. 2. *Notation for roofs with two slopes of the Code CR-1-1-4 / 2012*

Table 1.

No. model	Notations in Figures 2 and 3 and in Tables 2 and 3	Notations on studied models (Table 4)
1.	35	110
2.	30	120
3.	45	90
4.	32,5	115
5.	40	100

The roof is divided into zones as shown in Figure 3. Exposure reference height, z_e is considered equal to *h*. The coefficients aerodynamic pressure / suction for each area are given in Tables no.3.

Both in theoretical research and the experimental results were studied airflow action with different speeds in two directions to the models considered, namely the front direction and lateral direction.

Table 2a

The angle of slope, *a*	**Areas downwind q = 0°**									
	F		G		H		I		J	
	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$
-30°	-0,6	-0,6	-0,6	-0,6	-0,8	-0,8	-0,7	-0,7	-1,0	-1,5
-45°	-1,1	-2,0	-0,8	-1,5	-0,8	-0,8	-0,6	-0,6	-0,8	-1,4
-15°	-2,5	-2,8	-1,3	-2,0	-0,9	-1,2	-0,5		-0,7	-1,2
-5°	-2,3	-2,5	-1,2	-2,0	-0,8	-1,2	+0,2		+0,2	
							-0,6		-0,6	
5°	-1,7	-2,5	-1,2	-2,0	-0,6	-1,2	-0,6		+0,2	
	0		0		0				-0,6	
15°	-0,9	-2,0	-0,8	-1,5	-0,3		-0,4		-1,0	-1,5
	+0,2		+0,2		+0,2		0		0	0
30°	-0,5	-1,5	-0,5	-1,5	-0,2		-0,4		-0,5	
	+0,7		+0,7		+0,4		0		0	
45°	0		0		0		-0,2		-0,3	
	+0,7		+0,7		+0,6		0		0	
60°	+0,7		+0,7		+0,7		-0,2		-0,3	
75°	+0,8		+0,8		+0,8		-0,2		-0,3	

Table 2b

The angle of slope, *a*	**Areas downwind q = 90°**							
	F		G		H		I	
	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$
-45°	-1,4	-2,0	-1,2	-2,0	-1,0	-1,3	-0,9	-1,2
-30°	-1,5	-2,1	-1,2	-2,0	-1,0	-1,3	-0,9	-1,2
-15°	-1,9	-2,5	-1,2	-2,0	-0,8	-1,2	-0,8	-1,2
-5°	-1,8	-2,5	-1,2	-2,0	-0,7	-1,2	-0,6	-1,2
The angle of slope, *a*	**Areas downwind q = 90°**							
	F		G		H		I	
	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$
5°	-1,6	-2,2	-1,3	-2,0	-0,7	-1,2	-0,6	
15°	-1,3	-2,0	-1,3	-2,0	-0,6	-1,2	-0,5	
30°	-1,1	-1,5	-1,4	-2,0	-0,8	-1,2	-0,5	
45°	-1,1	-1,5	-1,4	-2,0	-0,9	-1,2	-0,5	
60°	-1,1	-1,5	-1,2	-2,0	-0,8	-1,0	-0,5	
75°	-1,1	-1,5	-1,2	-2,0	-0,8	-1,0	-0,5	

Note:

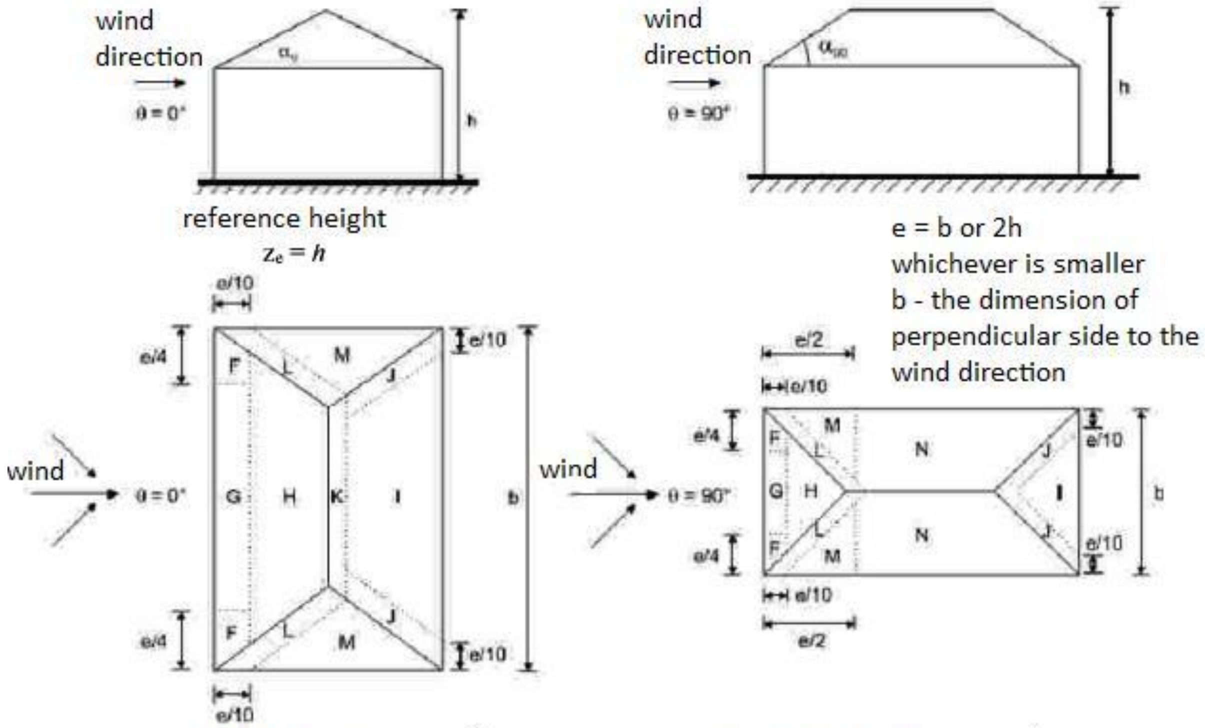
Marked angles of slopes are valid for theoretical and experimental models studied in the paper. Values marked the aerodynamic coefficients are matched against the results of experimental research

- ***The aerodynamic coefficients of pressure / suction and force for roof with four slopes***

One of the models studied theoretically by simulation FEM and two of the investigated experimental wind tunnel had roofs with four slopes. One of the patterns is identical to the diagram of Figure 4, and the other four slopes has a symmetrical construction.

The roof is divided into zones as shown in Figure 3. The reference height, z_e is considered equal to *h*. The coefficients aerodynamic pressure / suction for each area are given in Table 3.

On the model with two symmetrical roof with two slopes were analyzed pressures, forces, and aerodynamic coefficients for the front and side directions of the air stream to the position of the pattern. Model with four symmetrical slopes was considered one direction of the wind.



(a) wind direction $q = 0^0$ (b) wind direction $q = 90^0$

Fig.3. *Notation for roofs with four slopes of the Code CR-1-1-4 / 2012 Wind direction*

Table 3

The angle to slope a_0 *for q* = 0°; a_{90} for *q* = 90°	Areas downwind for q =0° and q =90°																	
	F		G		H		I		J		K		L		M		N	
	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$
5°	-1,7	-2,5	-1,2	-2,0	-0,6	-1,2	-0,3		-0,6		-0,6		-1,2	-2,0	-0,6	-1,2	-0,4	
	0		0		0													
15°	-0,9	-2,0	-0,8	-1,5	-0,3		-0,5		-1,0	-1,5	-1,2	-2,0	-1,4	-2,0	-0,6	-1,2	-0,3	
	+0,2		+0,2		+0,2													
30°	-0,5	-1,5	-0,5	-1,5	-0,2		-0,4		-0,7	-1,2	-0,5		-1,4	-2,0	-0,8	-1,2	-0,2	
	+0,5		+0,7		+0,4													
45°	0		0		0		-0,3		-0,6		-0,3		-1,3	-2,0	-0,8	-1,2	-0,2	
	+0,7		+0,7		+0,6													
60°	+0,7		+0,7		+0,7		-0,3		-0,6		-0,3		-1,2	-2,0	-0,4		-0,2	
75°	+0,8		+0,8		+0,8		-0,3		-0,6		-0,3		-1,2	-2,0	-0,4		-0,2	

Note:

Marked angles of slopes are valid for theoretical and experimental models studied in the paper. Values marked the aerodynamic coefficients are matched against the results of experimental research.

2.4 The theoretical research by FEM simulation of influence form greenhouse on mechanical strain exerted by wind

The modeling and analysis CFD (Computational Fluid Dynamics) air flow greenhouses aims to determine the forces and moments acting on the greenhouse, forces and moments generated by the action of wind and air flow visualization forms the exterior surfaces of the greenhouse. To achieve this, using ANSYS 15.0 software, which is based on the finite element method [1].

The modelings and analysis refers to two types of greenhouses on the roof has 2 or 4 slopes symmetrical angles 110^0, 120^0, 115^0, 100^0 and 90^0 from one another, a situation pursued further and experimental research, where they studied five models of greenhouses, which had the same arrangement of slopes acoperişurilor.Trebuie stated that the practice of constructive models validated those that are almost generalized crops of vegetables and flowers, offering environmental conditions satisfactory to the majority of plant species, but also resistance necessary to mechanical stress [4]. There will be two sets of research, one in front and one wind acting on the wind side of the acting position established by the Code conventional CR-1-1-4 / 2012.

The geometric design is shown in Figure 4, where the greenhouse is built in a field of type cuboid, an area where it is considered that there is air flowing at a speed of 10 m / s, 15 m / s, 20 m / s, 25 m / s, 27.5 m / s and 30 m / s, i.e. the same speed at which and experimental researches have been in the wind tunnel.

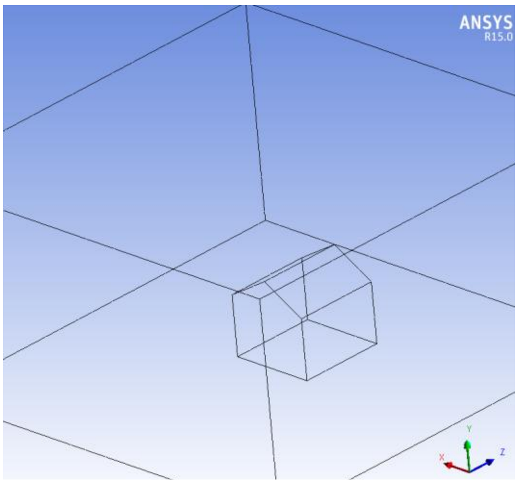


Fig. 4. *The geometric design of the problem*

For modeling is considered tetrahedral finite elements, meshing after yielding 257 826 finite elements and 48 559 nodes. Boundary conditions relate, on the one hand, imposing a constant speed in laminar flow at the entrance to the air flow and the imposition of 101.325 *Pa* normal atmospheric pressure in that area; the second condition refers to the imposition of border normal atmospheric pressure of 101.325 *Pa* at the outlet of the air flow.

As noted above, the analysis is performed for sets of values of wind speed of 10 m / s, 15 m / s, 20 m / s, 25 m / s, 27.5 m / s and 30 m / s, the front action and values of speed for the action of the air stream side.

Solving with finite element of the model involves selecting a number of iterations needed to stabilize calculating residual error. By choosing a sufficient number of iterations - 50 - stabilization of the residual error is obtained in both cases.

2.5 The experimental research of the influence of greenhouse form of the mechanical strain exerted by wind

The objects for experimental research are the five models of greenhouses (Figure 5), made of plastic with a thickness of 2.5 mm. In order to compare the results of experimental research among themselves but also with those of theoretical investigations, it was established that land bases and heights of all the models are identical, the differences between them consisting in the number of pitches roofs, angles thereof and useful volume.

The models with numbers 1, 2, and 3 have roofs made of two slopes (according to Figure 2 of CR 1-1-4 / 2012); model 4 is made up of four roof slopes (in accordance with Figure 3 of 1-1-4 CR / 2012), which forms a ridge, and the model no. 5 has roof slopes formed of four identical, forming a peak. Mockups to give sufficient rigidity to the action of wind, plastic panels were bolted profiles modeled on sheet thickness of 1.5 mm.

Since the tunnel is provided with 16 tubes with outer diameters of 3 mm used for measurement of the pressure exerted by the wind, the vertical walls and front side as well as the slopes of the roof have been applied in positions considered to be representative, a plurality of apertures with diameters of 3 mm. The holes that have not been used to measure pressures were covered with adhesive tape.

Also, the measurement of thrust forces exerted by the wind on the models of all of the openings have been covered.

Fig. 5. *The greenhouses models developed for experimental research*

To all the models it was performed in the base plate by a hole with a diameter of 30 mm which were introduced into the models and were fixed in holes in the walls and roofs tubes for measuring pressure / depression wind. Hole in the base plates served and fixing clips using appropriate layouts in the wind tunnel.

Table 4

Model no.	$\alpha_1{}^0$	$\alpha_2{}^0$	A_b, cm^2	H, *cm*	V, cm^3	A_{fv} cm^2	A_{fac} cm^2	A_{lv}, cm^2	A_{lac}, cm^2	A_t cm^2
1.	110	-	400	20	6600	330	-	260	240	1660
2.	120	-	400	20	7000	350	-	300	220	1740
3.	90	-	400	20	6000	300	-	200	280	1560
4.	115	120	400	20	5600	250	80	250	180	1520
5.	100	100	400	20	5200	250	120	250	120	1480

The geometrical characteristics of the models used in experimental research are given in Table 4, the notations have the following meanings: α_1- angle formed by the main slopes of the roof; α_2 - side slope angle of the roof; A_b-base area equal to all the models; H -înălțimea layout, equal on all models; V layout of the interior volume; A_{fv} vertical front wall area; Business frontal surface area of the roof; A_{lv} - vertical side wall area; A_{lac}.-side roof surface area; A_t - area of the walls and roof.

It should be noted that the forms of the 5 models of greenhouses were not chosen by chance, they are the result of analysis of most forms of greenhouses that are currently being used on the ground or on rooftops. Forms also means that not only meet environmental requirements for a large number of plants, but meeting and economically, meaning the use of materials and equipment available under the aspect ratio reliability / price being checked by practice.

The main tool used in experimental research has been wind tunnel HM170 Educational Wind Tunnel. G.U.N.T. Gerätebau GmbH. Barsbüttel, Germany [8] found in Wind Energy Laboratory for the Study of the Departamentului.de Product Design, Mechatronics and Environment at the

University of Braşov, whose general view is presented in Figure 6.

Fig. 6. *HM 170 Aerodynamic Educational Wind Tunnel G.U.N.T. Gerätebau GmbH. Barsbüttel, Germany [11], [8]*

This is a subsonic tunnel (air velocity up to Mach 0.1), the open-circuit (the outside air is taken in and expelled all the outside with higher speed. The area of measurement is the length of the section of 287x287 mm and 365 mm, it is made of plexiglass and superstructure moving longitudinally inserting and removing the models subject experimental research.

3. Results and Discussion

3.1. The measurement results of force exerted by the wind on the greenhouses superstructure

Table 5

Model \ Wind speed	10, *m/s*	15, *m/s*	20, *m/s*	25, *m/s*	27,5, *m/s*	30, *m/s*
1	4.0	9.0	11.6	13.2	14.4	15,9
2	4,0	8.6	11.4	13.2	14.2	15.8
3	3.6	7.8	11.8	13.0	14.8	16,o
4	3.4	7.0	10.2	12.6	13.0	14.4
5	3.4	7.4	11.2	12.8	13.6	15.2

Table 6

Model \ Wind speed	10, *m/s*	15, *m/s*	20, *m/s*	25, *m/s*	27,5, *m/s*	30, *m/s*
1	5.0	11.0	12,6	15.0	16.2	17.8
2	5.2	10.6	12,4	14.6	15.8	17.6
3	4.6	10.0	11,8	13.8	15.2	17.0
4	4.0	8.6	11,4	13.4	14.4	16.0
5	3.4	7.4	11,2	12.8	13.6	15.2

It notes that the the action front airflow layouts no. 1, no. 2 and # 3 opposing forces close enough resistance, especially at high wind speeds.

The smaller the pushing force was recorded, in the case of the front of the action of the wind, the model no. 4, which was about 12% lower than the mock-No. 3.

The model no. 5 thrust of frontal air stream was located at a mean value between the forces pushing the first three models and thrust of the model no. 4.

If the action lateral of the air flow is an increase by 10 - 13% of pushing forces from the models no. 1, no. 2 and no. 3, the highest value recorded to model no. 1.

Increased thrust manifests and model no. 4, but the action and side air flow that is lower than the forces recorded in the first three models by over

10%.

Distinguished look are found in the action lateral airflow to model no. 5, pushing forces of resistance are identical to those found in front of this current action and are 15 ... 18% lower than the forces measured at the first three types of models.

3.2. Aerodynamic drag coefficient values at the push of the wind action

For the calculation of drag coefficient ofresistance to the action of pushing the wind was used relation (1), where the air temperature T = 18°C, barometric pressure p = 1026 mbarr and humidity 60%, air density has value $\rho = 1225$ kg/m^3.

The aerodynamic drag coefficient c_d, calculated by equation (1), recommended in and the wind tunnel [9] and the forces pushing in Tables 5 and 6 are enrolled in Table 7 for each model layout and default speed of the wind action the frontal respectively in table 8 at its lateral action and in figures 7 and 8 plot the variations of these coefficients depending on the speed of the air flow.

Table 7

Model \ Wind speed	10, *m/s*	15, *m/s*	20, *m/s*	25, *m/s*	27,5, *m/s*	30, *m/s*	Mediu value
1	1.98	1.98	1.44	1.05	0.94	0.88	**1.38**
2	1.87	1.78	1.33	0.99	0.89	0.82	**1.28**
3	1.96	1.89	1.60	1.13	0.99	0.92	**1,41**
4	1.68	1.54	1.26	1.00	0.85	0.79	**1.19**
5	1.50	1.45	1.24	0.90	0.79	0.75	**1.10**

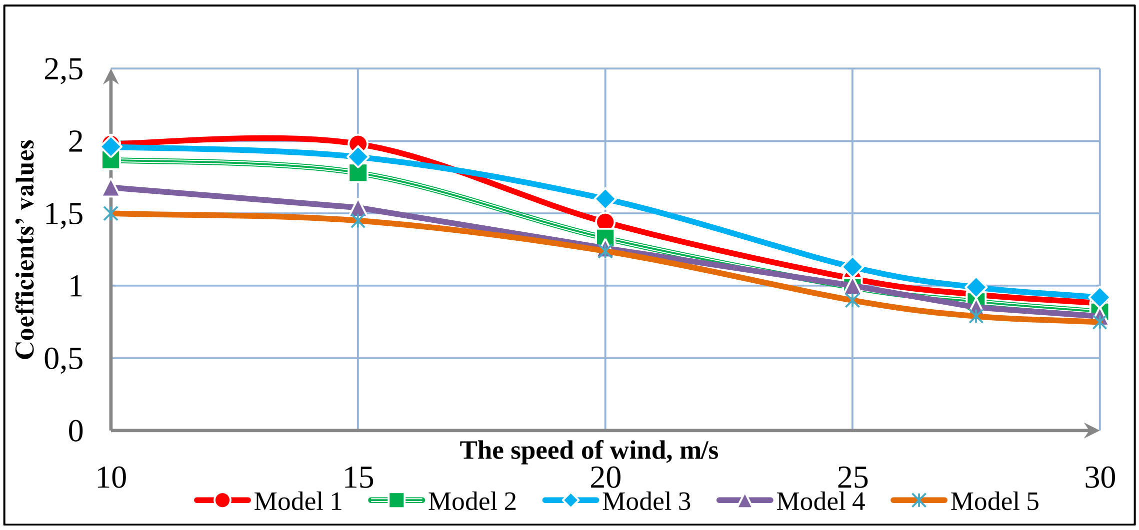


Fig. 7. *The variation of aerodynamic drag coefficient of the models by frontal airflow action*

Table 8

Model \ Wind speed	10, *m/s*	15, *m/s*	20, *m/s*	25, *m/s*	27,5, *m/s*	30, *m/s*	Medium value
1	1.63	1.60	0.98	0.78	0.70	0.65	**1.05**
2	1.63	1.48	0.97	0.74	0.66	0.62	**1.02**
3	1.56	1.51	1.00	0.75	0.68	0.64	**1.03**
4	1.51	1.45	1.08	0.81	0.72	0.68	**1.04**
5	1.50	1.45	1.24	0.90	0.79	0.75	**1.10**

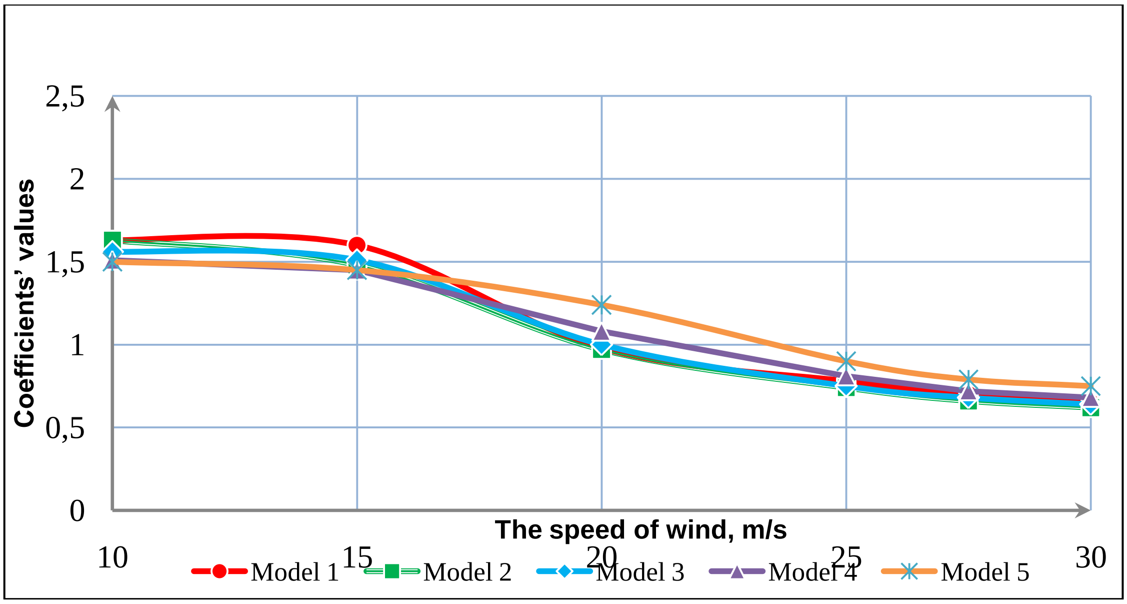


Fig.8. The variation of aerodynamic drag coefficient of the models by lateral airflow action

Conclusions

Analyzing the results listed in Tables 7 and 8 and the graphic representations of Figures 7 and 8 shows the following:

• aerodynamic drag coefficients of the models subject experimental research falls within the limits listed in Tables 2*a*, *b* and 3 of the Code of Design Assessment of wind on buildings indicative 1-1-4 CR / 2012, the amounts recommended for roofs with two slopes (1.98 - 0.75 –at models, - 1.5 – 0.6- in the tables) and four slopes (- 1.51-0.63 at models ; -1.2- 0.5 ..- in the tables);

• for all the models examined, the coefficients of the front aerodynamic resistance to the action of the air stream with 20..25% are greater than the calculated action of the air stream side. No exception model. 5, the roof of four slopes is symmetrical, so that regardless of the wind direction coefficient of aerodynamic drag has the same value;

• if models no. 1, No. 2 and No. 3, with roofs of two slopes, the lowest coefficient of aerodynamic drag in front of wind action is manifested in model no. 2, in which the angle of slope of the roof is the largest (120^0). Ascending No.1 and No.3 layouts are situated at angles of slopes are 110^0, respectively 90^0;

• to the action lateral airflow lowest values of the coefficient of aerodynamic drag model posed no. 2. where the roof slopes are less inclined from the vertical inclinations compared to other models roofs;

• to the models no. 4 and no. 5 with four slopes roof aerodynamic drag coefficients in front wind action are 15..20% lower than in the models with two-pitch roofs; Instead, to the action of the wind lateral aerodynamic drag coefficients of these forms of greenhouses were higher than the roofs of two slopes;

• to the frontal wind action, model no. 5, the roof consists of four symmetrical slopes show the aerodynamic drag coefficient lower by 10% compared with those of the model no. 4, where the slopes are symmetrical two by two; instead, to the action of the wind lateral aerodynamic drag coefficients are lower in model no. 4 5 ... 10% less than the model no. 5.

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