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THE SIMULATION OF THE SOLICITATIONS TO WHICH GREENHOUSES LOCATED ON ROOFTOPS ARE SUBJECTED BASED ON MODELING WITH THE FINITE ELEMENT METHOD

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Abstract: *The paper presents the work algorithm and results obtained by simulation of the solicitation on greenhouses, located on urban building rooftops. The simulation was performed by modeling with the finite element method and using the ANSYS 15.0 software. For the greenhouse analysis adopted model the tetrahedral finite element is considered, after discrediting yielding 257 826 finite elements and 48559 nodes. The analysis was carried out for values of wind speed of: 10; 15; 20; 25; 27.5 and 30 m/s, separately for actions on the frontal and lateral directions of the greenhouse. The air flow across the surfaces of greenhouses and the variation of thrust and lift forces as well as the overturning moment of the greenhouse, depending on specified wind speeds are presented.*

Key words: *finite element method, greenhouses, simulation of mechanical solicitations.*

1. Introduction

Modeling and the QFD analysis of air flow across greenhouses located of roofs aims to determine the forces and moments acting on them, forces and moments generated by the action of wind as well as the visualization of air flowing on their outer surfaces [1]. To achieve this, the ANSYS 15.0 software, which is based on the finite element method, is used [3].

2. Materials and Method

The modeling and analysis presented in the paper refers to a type of roof which has an angle of 120°. Two sets of analyses are taken into consideration: one in which the wind acts frontal and other in which the wind acts lateral [2].

The geometric design is present in Figure 1. The greenhouse model is embedded in a rectangular parallelepiped area type where it is considered that there is air.

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For the finite element modeling (Figure 2) the tetrahedral finite element, after mesh yielding 257826 finite elements and 48559 nodes are considered.

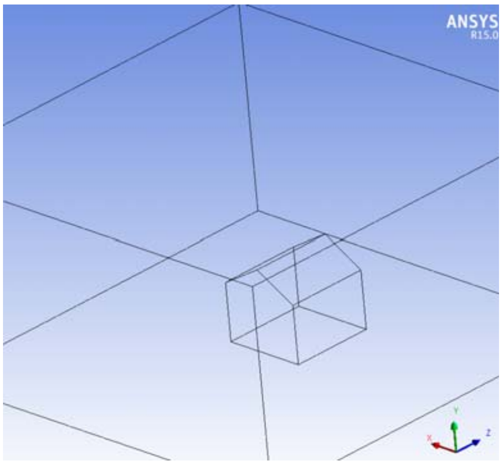


Fig. 1. *Geometric model of the problem*

The border conditions presuppose on the one hand, imposing a constant speed of the laminar air flow at its entrance (colored red zone) and an imposed atmospheric pressure of 101325. The second condition of the border is related to the imposition of 101325 Pa of atmospheric pressure at the outlet of the air flow (blue shaded area).

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, 30 m/s for the frontal and respectively lateral types of wind action.

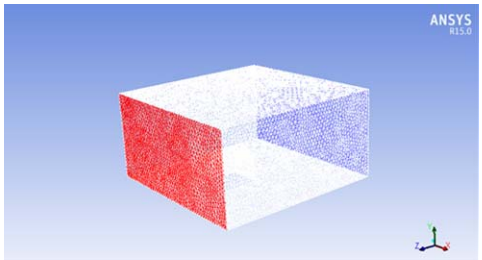


Fig. 2. *The model with finite elements*

Solving the finite element model involves choosing a number of calculus iterations needed to stabilize residual error.

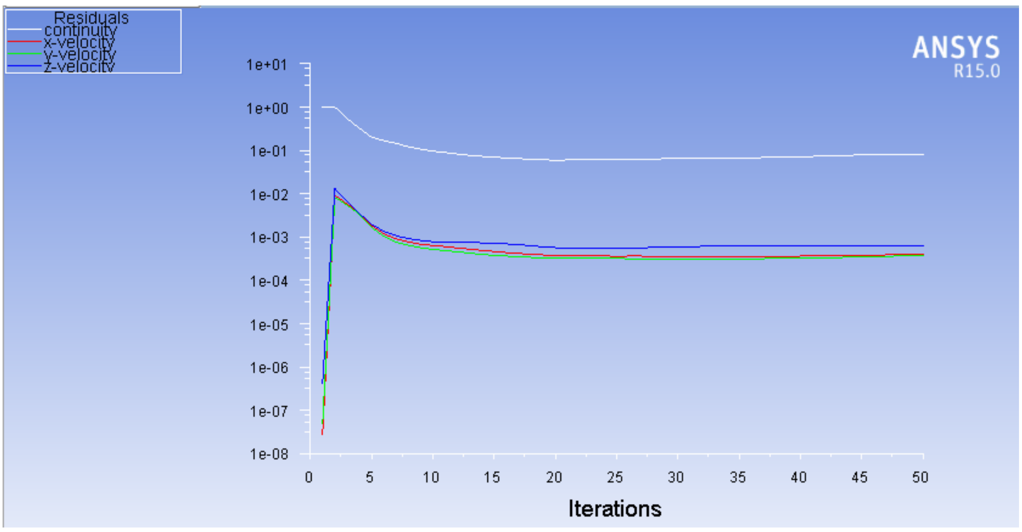


Fig. 3. *The stabilisation of the residual error considering the frontal wind action*

Figure 3 and 4 present the stabilization of the residual error with the aim of solving the model in case of frontal wind action and, respectively, lateral wind action. It was noticed that by choosing a sufficient number of iterations – namely 50 – the stabilization of residual error is obtained in both cases.

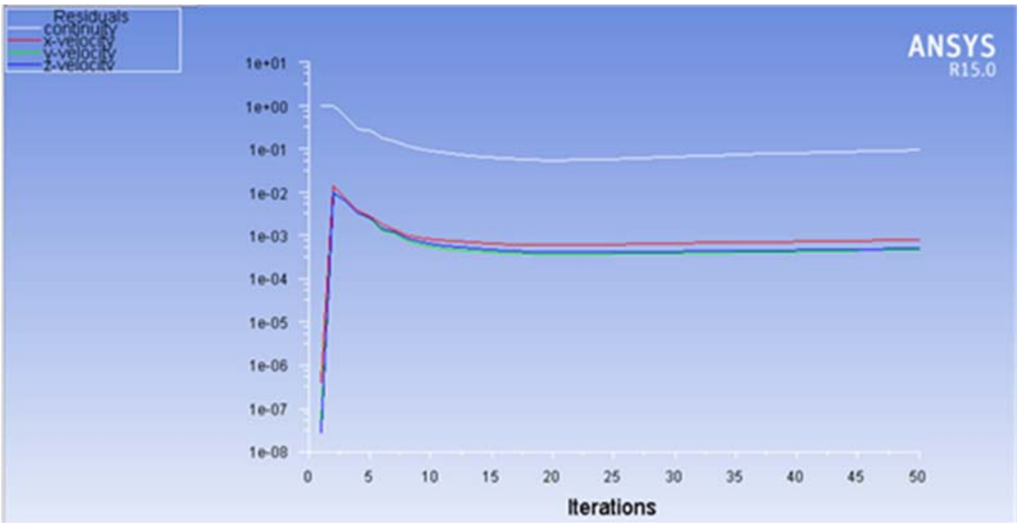
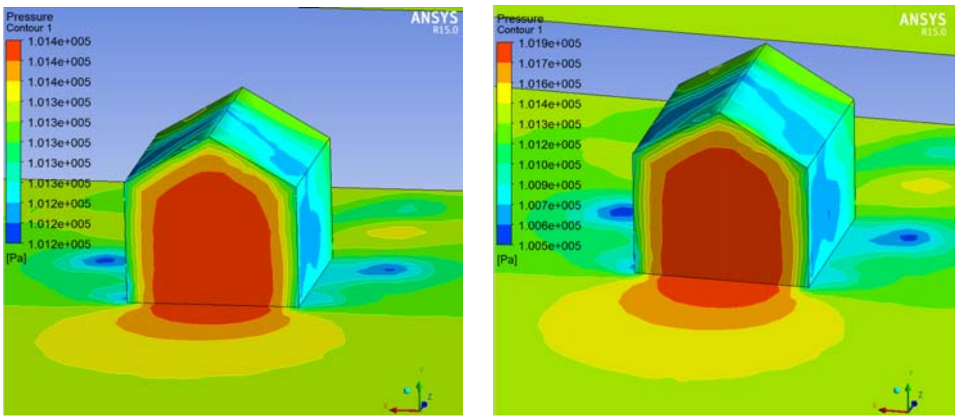


Fig. 4. *The stabilisation of the residual error considering the lateral wind action*

3. Results and Discussions

The obtained results from the analyses of the models refer to the visualization of air flowing on the outer surfaces of the greenhouse, determining the peaks of pressure and speed of air due to turbulences applied on the greenhouse and determining the pushing forces and lifting forces at the base level of the greenhouse and determining the overturning moment of the greenhouse.



v = 10 *m/s* v = 25 *m/s*

Fig. 5. *The maximum pressure of the wind on the frontal surface*

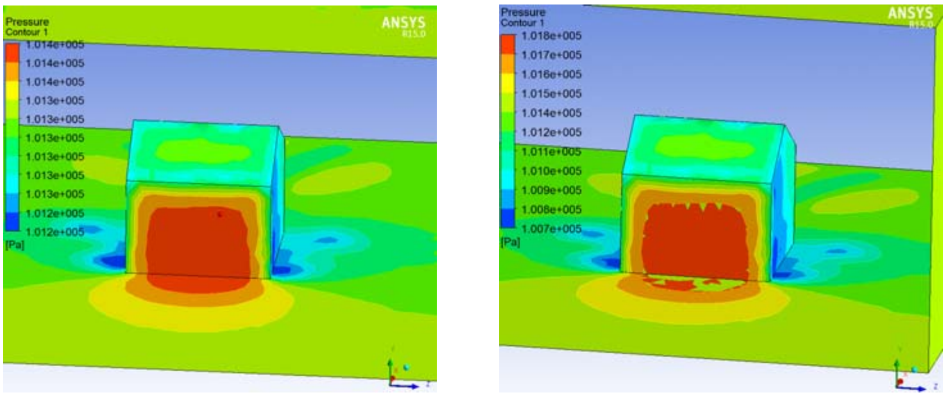
Figure 5 presents the heights of wind pressure on the front surface of the greenhouse. The maximums are located on the front surface, on the lateral surfaces on which depressurization takes place.

The maximum pressure in the case of lateral wind action, are present in Figure 6.

In both cases the action of the wind, practically, the maximum values of pressure are the same, as they appeared on the lateral surfaces of the greenhouse.

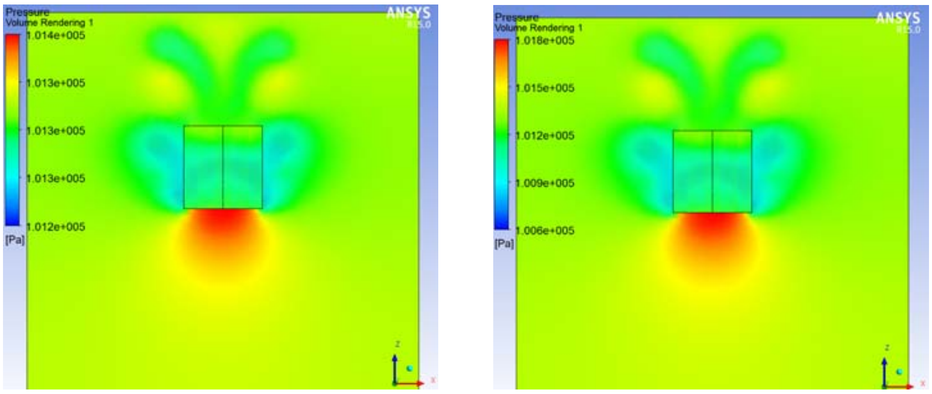
The viewing in the horizontal plane of

the air flowing is present in Figure 7, in case of the frontal action of the wind, respectively, in case of lateral wind action in Figure 8.



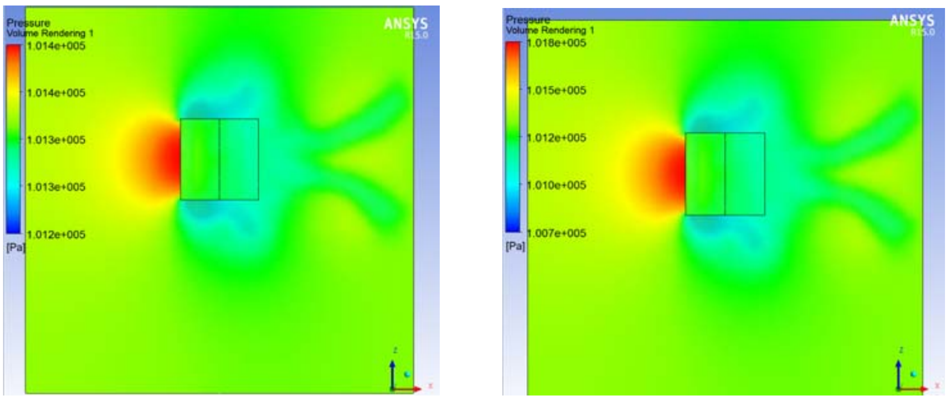
v = 10 *m/s* v = 25 *m/s*

Fig. 6. *The maximum pressure of the wind on the lateral surface*



v = 10 *m/s* v = 25 *m/s*

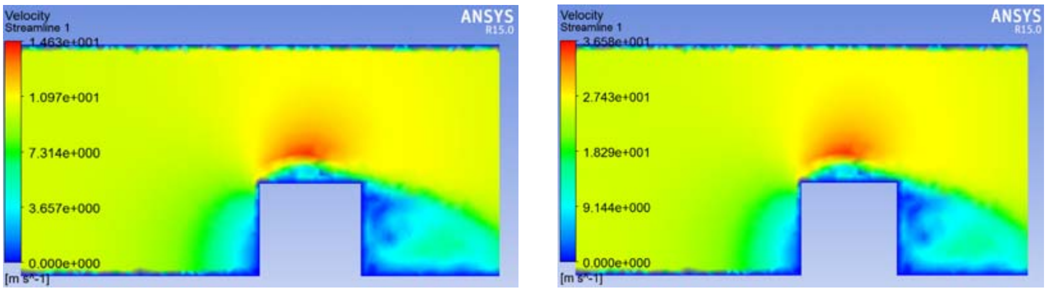
Fig. 7. *The horizontal plan view of the air flowing in case of frontal wind action*



v = 10 m/s *v = 25 m/s*

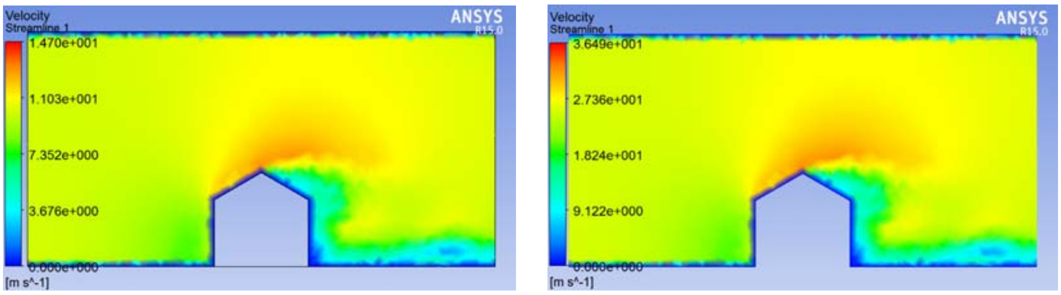
Fig. 8. *The horizontal plan view of the air flowing in case of lateral wind action*

Because of the wind action on the exterior surfaces of the greenhouse, turbulence is produced thus causing local wind accelerations in laminar flowing. The air flow in the vertical middle section of the area is presented in Figure 9, for the case of front wind action and, respectively, in Figure 10, for the case of lateral wind action. In both cases, the maximum speed values are close.



v= 10 *m/s* v = 25 *m/s*

Fig. 9. *Visualizing the air flowing in the vertical middle section of the area in the case of frontal wind action*

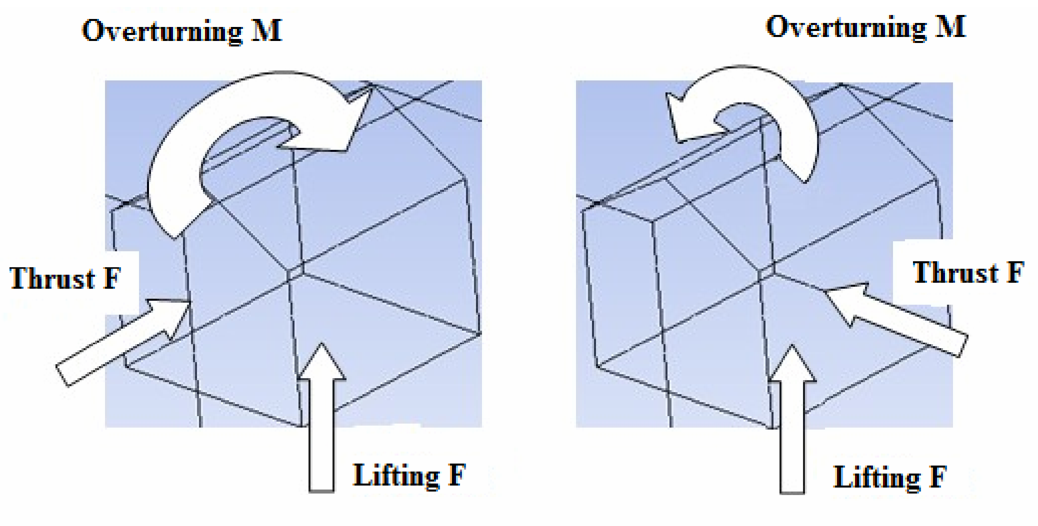


v= 10 *m/s* v = 25 *m/s*

Fig. 10. *Visualizing the air flowing in the vertical middle section of the area in the case of lateral wind action*

In the following images the variation in thrust forces, the lifting forces and, respectively, the overturning moment acting on the greenhouse depending on the wind speed and its direction are presented. In Figure 11 the action scheme of these forces, depending on the direction of the wind is presented.

Figure 12 presents the variation of the thrust force acting on the greenhouse in two situations of wind flow: frontal action, respectively lateral action. The thrust force tends to move the greenhouse plan view in the direction of action of the wind and the higher values in the case of lateral wind action (in this case, the surface normal to the direction of the wind is lower).



Frontal direction *Lateral direction*

Fig. 11. *The scheme of the thrust and lifting forces and respectively of the overturning moment acting on the greenhouse depending on the speed and direction of wind action*

Figure 13 presents the variation in lifting force applied on the greenhouse for two wind driving situations: frontal action, respectively lateral action. Lifting force tends to move the greenhouse to a vertical position, it practically tends to raise the greenhouse on its basis and has higher values for front wind action.

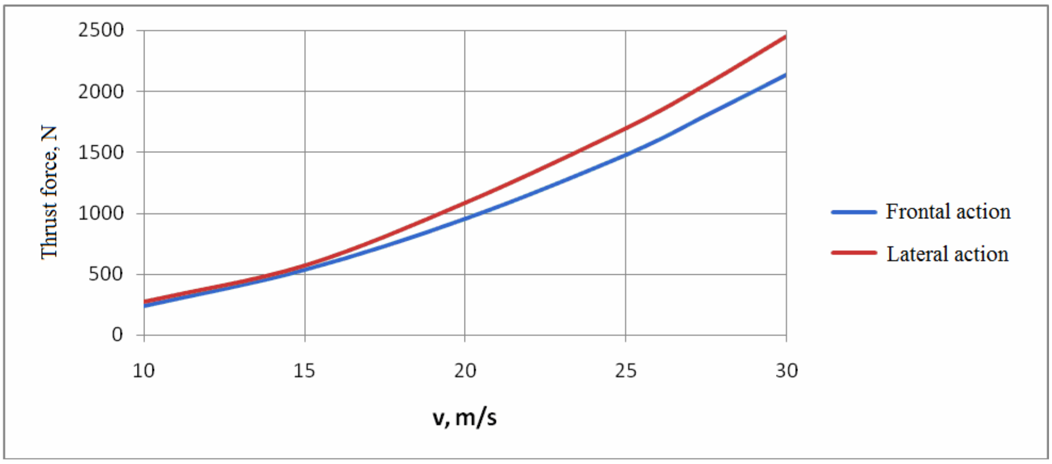


Fig. 12. *Variation of the thrust force of the greenhouse*

Figure 14 introduces the variation of the overturning moment which acts upon the greenhouses, for the two situations of wind action: front action and respectively side action.

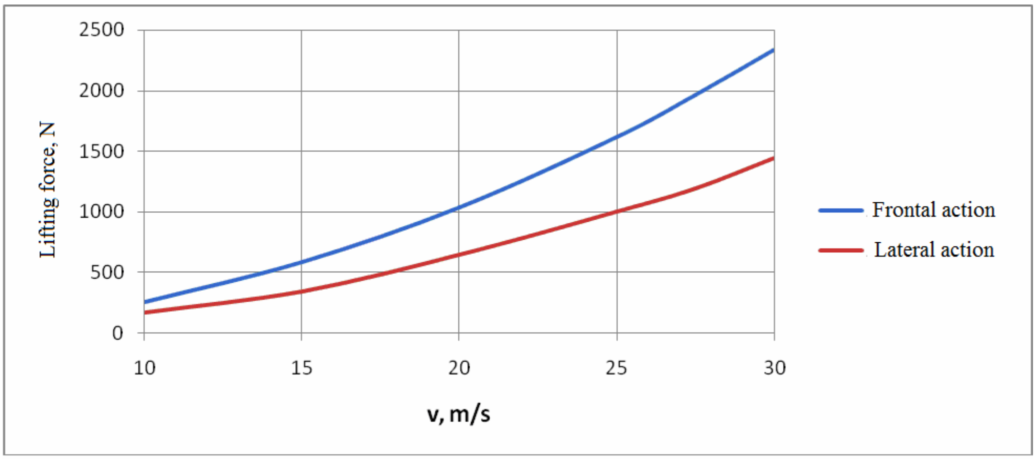


Fig. 13. *Variation of the lifting force of the greenhouse*

The overturning moment tends to overthrow greenhouses and has higher values for front wind action.

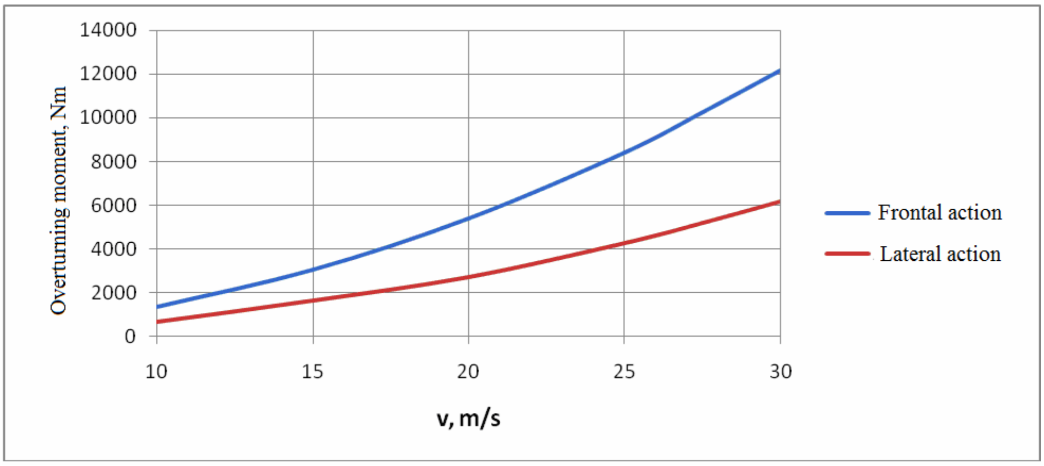


Fig. 14. *Variation of the overturning moment of the greenhouse*

4. Conclusions

- Greenhouses located on the roofs of buildings are exposed to high stresses by air currents which have speeds higher than at ground level. Knowing these solicitations is necessary for the calculation of the resistance structure of greenhouses and for the choice of materials which satisfy the requirements of plant cultivation in greenhouses and of the most difficult weather conditions.
- Study the influence of wind on the roofs of greenhouses, their resistance to mechanical solicitations can be done by means of theoretical simulation. In this paper simulation was performed trough modeling, using the ANSIS 15.0 specialized software.
- From the graphical representation of how the air flows on the surface of the greenhouse, in case of frontal and lateral wind action, the most vulnerable areas

exposed to thrust and lift forces or to overturning moments, from prevailing winds with very high speeds, have been determined.

References

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