

NUMERICAL AND EXPERIMENTAL INVESTIGATIONS ON THE BEHAVIOR OF THERMOSYSTEM SUBJECTED TO WIND LOADS

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Abstract: *The main objective of this paper is to study the behavior of the polystyrene EPS 80 subjected to wind loads in different areas. The properties of the material were determined experimental and an appropriate material law was used in order to model the material. The tested polystyrene samples were cubes having 100x100x100 mm and they have been cut from slabs of 1000x500x100mm. Numerical investigations considering suction wind load for façade's thermosystems have been done and conclusions were drawn based on the results. Finite element code Abaqus was used in order to conduct the nonlinear analysis.*

Key words: *crushable foam, nonlinear analysis, wind loads, Abaqus.*

1. Introduction

The behaviour of the building's façade thermosystem have been very little or at all analysed regarding possible failures when subjected to wind loads. Polystyrene as a material has been analysed in experimental tests and numerical simulations by many authors [1-6]. In order to get results related to real life behaviour a proper material law should be assigned when conducting an analysis using a finite element model. For this reason as depicted in the available literature the „Crushable foam plasticity” [7] material model was chosen for modelling the polystyrene using the finite element method software Abaqus [8].

After experimental test to determine the

compressive curve of the polystyrene a finite element model was developed and calibrated with the experimental results. Other numerical models were analysed to study the wind effect on panels that are fixed with 6 or 8 anchors and adhesive on the building facade.

2. Compression test and calibration of FEM model

The stress-strain curve of EPS80 polystyrene was experimentally determined in the laboratory „Actions in constructions and Structures” from the department of Mechanics of structures at the Technical University of Cluj-Napoca, Faculty of Civil Engineering. The

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polystyrene samples had the dimensions of 100x100x100 mm and they have been cut from 1000x500x100 mm panels. The experimental testing was done using a Loyd LS 100 plus pressing machine. The results of the testing led to the results presented in figure 1.

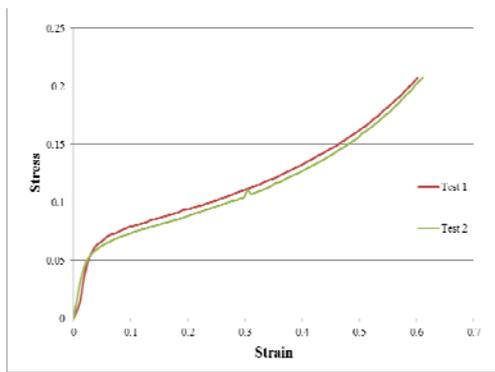


Fig. 1. *Compressive Stress-Strain*

The finite element model of the compressive test was done using C3D8R tridimensional solid elements with 8 nodes and reduced integration. The boundary conditions and pressure loads were introduced accordingly to experimental ones. After a mesh convergence study a mesh size of 15 mm was adopted. The results are in good agreement with the experimental ones as showed in figure 2.

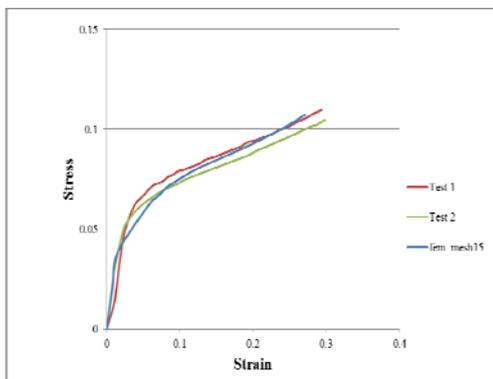


Fig. 2 *FEM model vs Experimental*

3. Numerical investigations on thermoystem

3.1. Introduction

For the study of façade panels behaviour under wind loads a model consisting of 7 panels with 500x1000 mm was analysed. The panels thickness was 15 cm a value usually used in the retrofitting of façade panels regarding the thermal behaviour. The geometry configuration is described in figures 3 and 4.

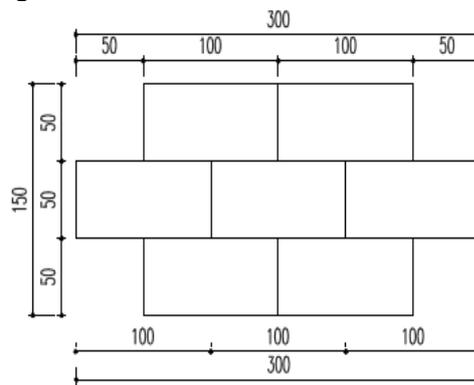


Fig. 3 *Panels configuration*

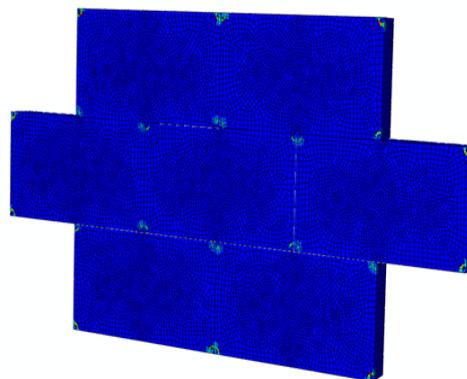


Fig. 4 *Numerical model assembly*

The interaction between the panels has been done using a general contact with a coefficient of friction of 0.5 and with hard normal behaviour. For the boundary conditions the panels have been considered to be fixed with no degree freedom on the exterior part. On the exterior parts the surface has been considered to be glued together with adhesive. This surface has been considered to be 40% of the surface

of panels taking into account the recommendation of SR EN 13499:2004 for the fixing of thermosystems. Regarding the anchors the fixing has been considered to be the equivalent area of the upper part of an anchor.

The wind suction loads have been uniformly distributed on polystyrene panels. The introduced values have been obtained using CR 1-1-4/2012 standard for wind loads and the worst case scenario was

adopted.

The building is a block of flats, with GF + 4F, with the following geometrical characteristics: length $d = 19.90$ m, width $b = 12.20$ m and height from ground level to the highest point $H_{total} = 16.70$ m.

The location of the building was considered to be the reference value of the dynamic wind pressure $q_b = 0.5$ KPa, with mean recurrence interval of 50 years.

Suction loads

Table 1

	Dynamic wind pressure $q_b=0,5\text{KPa}$				
	Terrain				
	0	I	II	III	IV
Wind suction	-2,024	-1,882	-1,665	-1,178	-0,798
Wind suction according to (CR 0-2012)	-3,036	-2,823	-2,498	-1,764	-1,197

In figure 5 the boundary conditions are showed and the loads applied in figure 6.

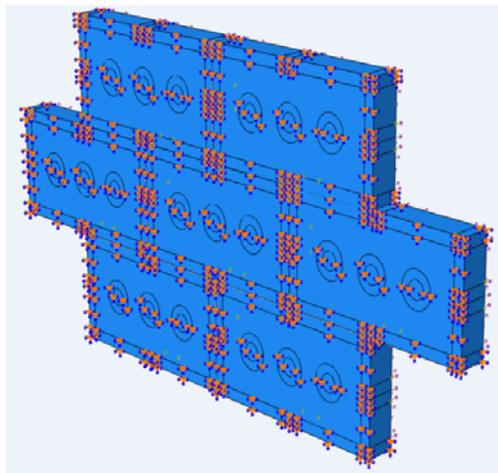


Fig. 5 Boundary conditions

In order to maintain the accuracy of result the data that was analysed are for the central panel. This is also the only panel which has interactions on every lateral surface with other panels so that the transmission of normal and tangential stress is for every one of these 4 surfaces.

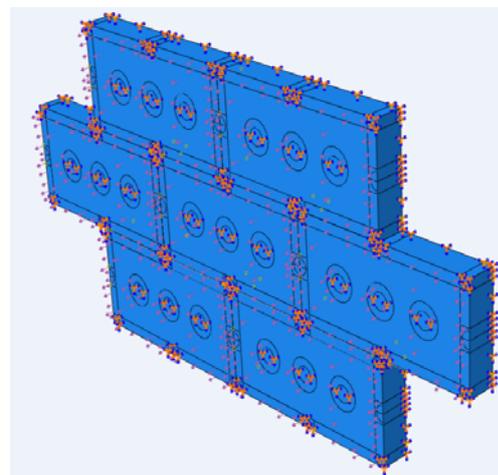


Fig. 6 Loads and boundary conditions

3.2. The analysis of panels fixed with anchors

For the analysis of the panels fixed with adhesion and supplementary with 6 anchors per square meter uniform distributed loads have been used that represent the wind suction. The loads were obtained using the type of building, the

reference dynamic pressure of the field and field category. All the values are corresponding to A zone of suction from the maximum suction value based on CR 1-1-4/2012 standard.

In figures 7 and 8 are presented the possible ways of fixing for panels

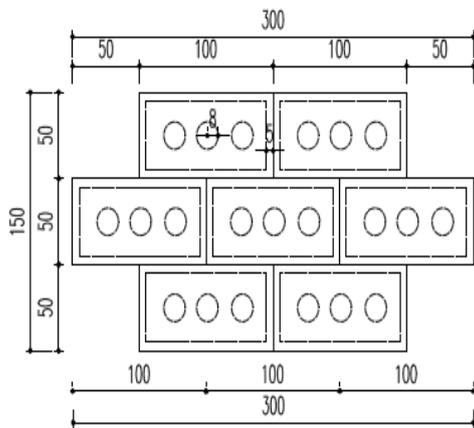


Fig. 7 Adhesive fixing

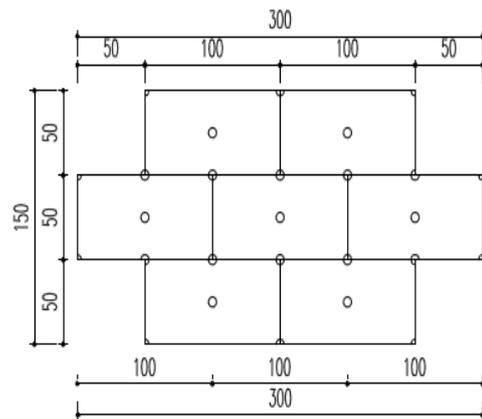


Fig. 8 Anchors fixing (6/m²)

In the case of the panel fixed with adhesive and 8 anchors per square meter the analysis conditions are the same with the panel presented before (figure 9).

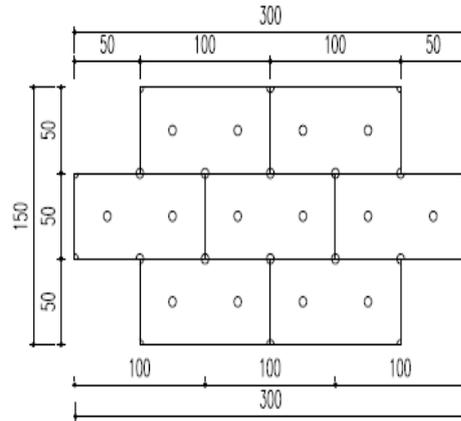


Fig. 9 Anchors fixing (8/m²)

In figure 10 the plastic strain values are showed that were obtained from the analysis of a wind suction equal to 3,036 KPa for fixing with adhesive and 6 or 8 anchors. Considering the nule values it means that for this value the results are still in the elastic region.

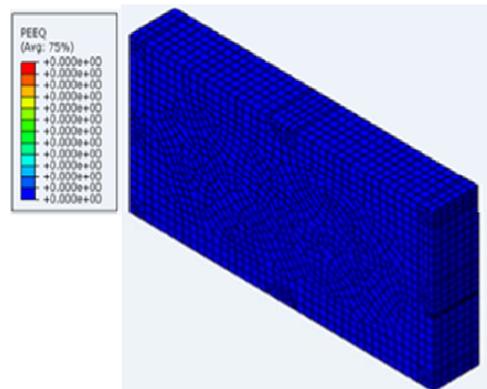


Fig. 10 Plastic equivalent strains for 6 or 8 anchors plus 40% adhesive

The displacements values for the load value of 3,036 KPa wind suction are shown in figure 11. From the appearance evolution of the displacements it can be seen that for the panel with 8 anchors they concentrate more on the middle of the panel. Regarding their value for both cases they are pretty low around 0.34 mm.

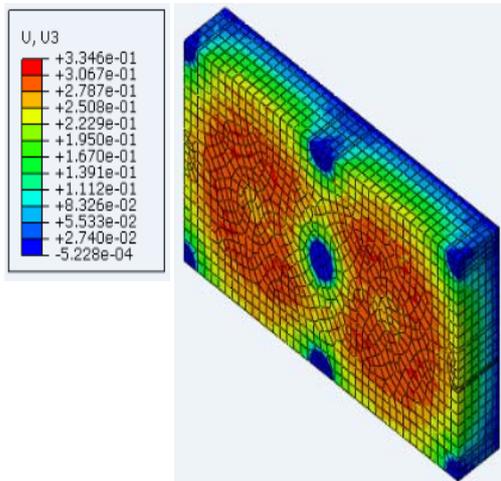


Fig. 11 Displacements for $wA=-3.036$ KPa (6 anchors/m²)

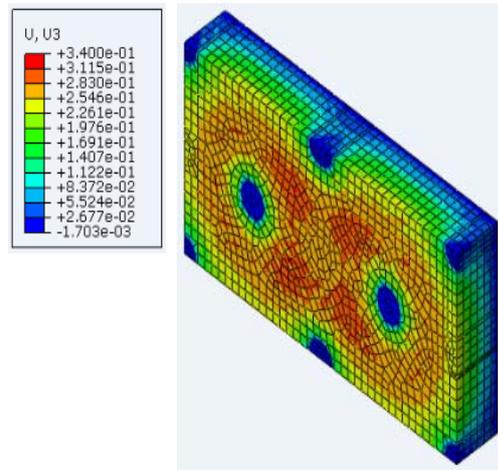


Fig. 13 Displacements for $wA=-3,036$ KPa (8 anchors/m²)

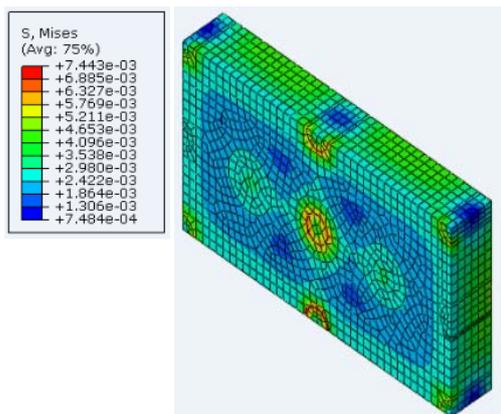


Fig. 12 von Mises stress for $wA=-3.036$ KPa (6 anchors/m²)

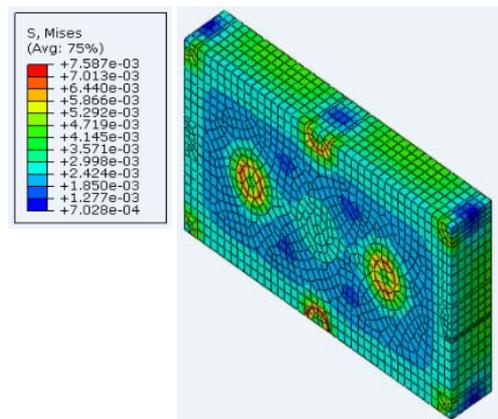


Fig. 14 von Mises stress for $wA=-3.036$ KPa (8 anchors/m²)

The distributions of loads from wind suction for anchors and adhesive is presented in table 2 as it follows.

Loads distribution

Table 2

	Wind suction [KPa]	Anchors force [KN]	Force/anchor [KN]	Adhesive tension [KPa]	Force distribution [%]	
					Anchors	Adhesive
6 anchors	3,036	0,1358	0,0453	6,692	9	91
8 anchors	3,035	0,1906	0,0476	6,347	13	87

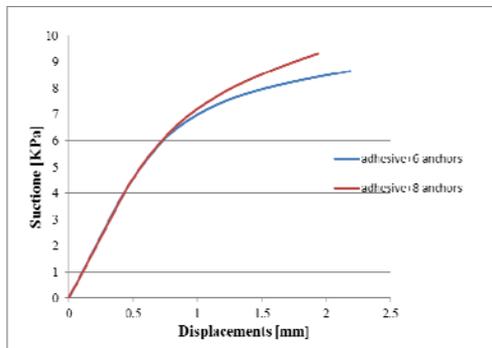


Fig. 15 Suction-displacements for 6 and 8 anchors

Conclusions

Based on the centralised results in the case of thermosystem with adhesive and 6 anchors per square meter it has been noticed that the suction wind loads are distributed approximately 91% for the adhesive and a rest of 9% for anchors.

In the other case with adhesive and 8 anchors per square meter a redistribution of loads it appears which is caused by the supplementary fixing with one plus anchor on the middle of the polystyrene panel. This redistribution is caused by the increase of area at the exterior of the panels. diblu.

For the pane with adhesive and 6 anchors the 40% of the applied area with adhesive it leads to a grow 2.2 of the attracted suction wind loads. Some modifications are appearing for the case of 8 anchors and

adhesive where a growth on only 2.1 was reported.

References

1. Ozturk, U. E., & Anlas, G. (2011). *Finite element analysis of expanded polystyrene foam under multiple compressive loading and unloading*. *Materials & Design*, 32(2), 773-780.
2. Seitzberger, Markus, et al. "Crushing of axially compressed steel tubes filled with aluminium foam." *Acta Mechanica* 125.1-4 (1997): 93-105.
3. Li, Q. M., Mines, R. A. W., & Birch, R. S. (2000). *The crush behaviour of Rohacell-51WF structural foam*. *International Journal of Solids and Structures*, 37(43), 6321-6341.
4. Rizov, V. I. (2006). *Non-linear indentation behavior of foam core sandwich composite materials—A 2D approach*. *Computational Materials Science*, 35(2), 107-115.
5. Rizov, V., Shipsha, A., & Zenkert, D. (2005). *Indentation study of foam core sandwich composite panels*. *Composite structures*, 69(1), 95-102.
6. ABAQUS, *Finite element software*, Hibbit, Karlsson & Sorensen
7. ABAQUS, *ABAQUS: User's Manual. Crushable Foam Plasticity*, Hibbit, Karlsson & Sorensen