TECHNICAL UNIVERSITY OF CLUJ-NAPOCA

ACTA TECHNICA NAPOCENSIS

Series: Applied Mathematics, Mechanics, and Engineering
Vol. XX, Issue xx, Month, 20xx

IMPACT BEHAVIOUR OF EXPANDED POLYSTIRENE BY EXPERIMENTAL AND NUMERICAL METHODS

Cristian Vilău, Mircea Cristian Dudescu*

Abstract: *Today, expanded polystyrene is used in almost all areas. It is very used in the field of constructions, for the insulation of building facades due to the very good thermal characteristics. The polystyrene used for insulation of facades is subjected to various stresses such as bending loads, dynamic loads and stresses by shock. The paper presents the results, obtained at the dynamic impact tests of expanded polystyrene, but also the results obtained at dynamic impact analyzes performed with the ANSYS analysis software. For dynamic tests and analyzes of the samples were used polystyrene foam type EPS 50, EPS 80, EPS 100 and EPS 120.*

Key words: *expanded polystyrene, impact tests, finite element analysis, explicit dynamics.*

1. INTRODUCTION

Polystyrene (PS) is a polymeric material (synthetic hydrocarbon) thermal processing (thermoplastic), obtained from styrene monomer. Polystyrene is of two types: expanded polystyrene (EPS) and extruded polystyrene (XPS). [1] Expanded polystyrene (EPS) is a closed cell foam that is produced by "expanding" the polymer, and extruded polystyrene (XPS) is a rigid foam, which is formed by "extruding" the polymer.

Expanded polystyrene can be used in a wide range of applications, such as: protective housings for products, panels for shock attenuation, can be used for panels with sandwich structure [2, 4, 5]. It is durable, strong and can be used as insulated panel systems for facades, roofs and floors in buildings, as a flotation material in the construction of ports and pontoons and as a light filler in the construction of roads and railways [3, 6, 7].

There are numerous cases when the EPS is used as façade isolation and its surface is impacted by various object, the study of impact results having practical relevance.

*corresponding author

2. MATERIALS AND METHODS

Experimental impact tests and numerical explicit dynamic analyzes were performed on the polystyrene EPS specimens.

The material used was Expanded Polystyrene (EPS) with the following densities:

EPS 50: density 11 Kg / m^3
EPS 80: density 15 Kg / m^3
EPS 100: density 20 Kg / m^3
EPS 120: density 25 Kg / m^3

For experimental impact tests and numerical analysis were considered the following components: the impacted sample made of expanded polystyrene, having the dimensions (L x l x h): 200x200x30mm and a metal ball with a diameter d=120 mm which strikes the surface of the polystyrene. The metallic ball was considered as a rigid body in the numerical simulation.

2.1 Experimental test

For validate the values of the deformations obtained from the simulations, an experimental stand was made (a gravitational pendulum) presented in figure 1a. In figure 1b shows the position of the specimen during the experiment.

The types of polystyrene mentioned above were impacted with the same speed and mass for which the numerical simulations were performed.

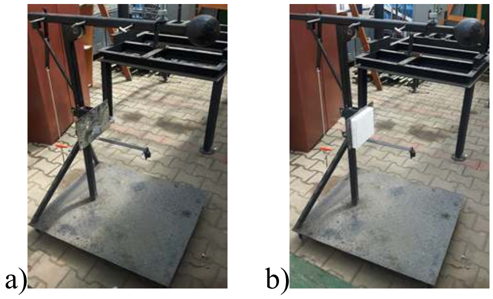


Fig.1. Experimental set-up a) gravitational pendulum, b) position of the specimen.

After performing the impact test, was measured the trace by the ball left on the surface of the sample. The surface of the specimen was hit with the ball only once. In figure 2 shows the measured value of the trace left by the ball on the surface of the sample.

Fig.2. Depth of calotte resulted after impact

2.2 Numerical simulation

The software used for the explicit dynamic analyses was ANSYS 2019R2 Academic. In order to perform the dynamic simulation, were required loading conditions (for the ball) and fixing conditions (for the EPS specimen). The ball was considered at a height (h=0,5m), and this will produce according to gravitational pendulum formulas an impact speed of 3344,2 mm/s (Fig. 3). Material model and mechanical characteristics of the polystyrene used in the dynamic analysis were determined experimentally in [8] and imported as experimental data in the Engineering Data module of the simulation software.

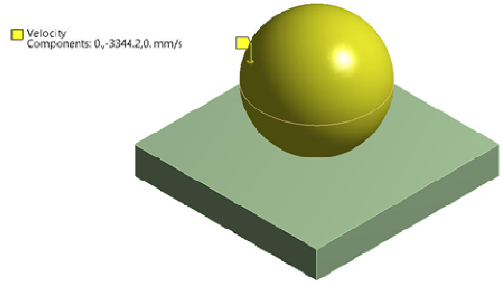


Fig.3. Loading conditions as initial speed of the ball.

Boundary conditions consider the EPS specimen fixed on the lower surface (Fig. 4).

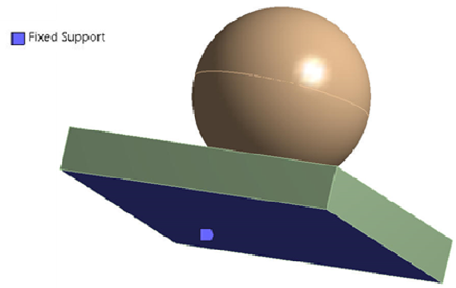


Fig.4. Fixed lower surface.

After establishing the loading and fixing conditions, was created the mesh of finite elements. For the contact areas (between the ball surface and the surface of the EPS sample) was carried out a fine mesh, the value of the element length being 1mm (Fig. 5).

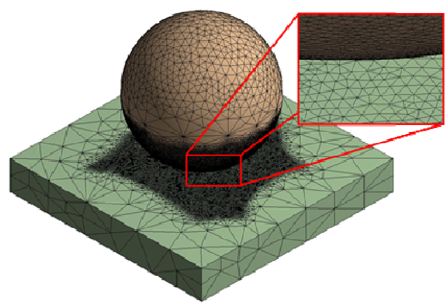
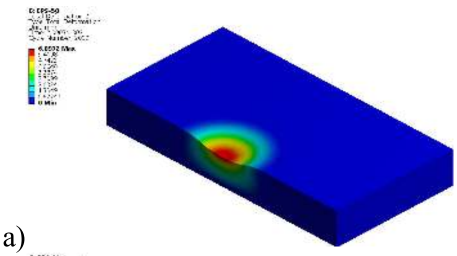


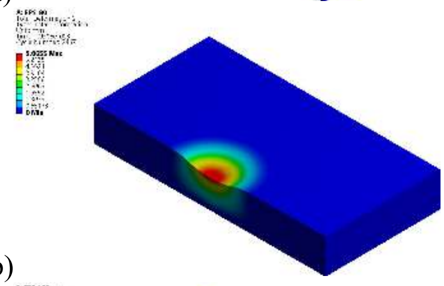
Fig.5. Mesh of the contact areas

3. RESULTS

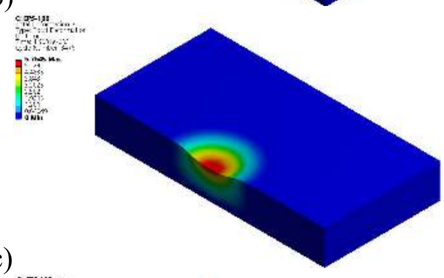
After performing the analysis were obtained values of deformations and absorbed energies for samples made of EPS with different densities. In figure 6 are shown the values of the deformations obtained from explicit dynamic analysis of impact.



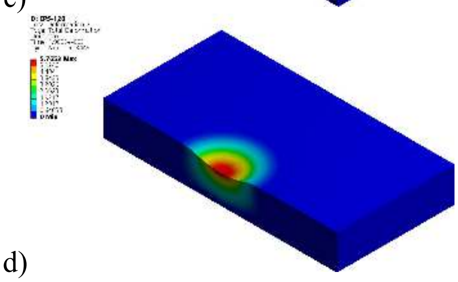
a)



b)



c)



d)

Fig.6. Numerical displacements: a) EPS 50; b) EPS 80; c) EPS 100; d) EPS 120.

Figure 7 shows the values of absorbed energies, obtained from explicit dynamic analysis after impact. Because the behaviour is similar in figure is presented the graph only for EPS 50.

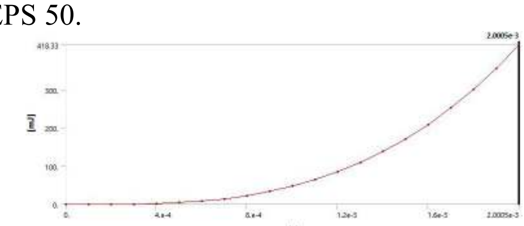


Fig.7. Internal energy variation for EPS 50

The values of deformations and internal energy obtained in numerical analysis of impact, and deformations obtained from experimental tests, are presented in Table 1.

Table 1

Displacements and Internal energy.

EPS	Displacement (experimental) [mm]	Displacement (numerical) [mm]	Internal energy [mJ]
50	5,9933	6.0972	418.33
80	5,7790	5.8655	828.32
100	5,7711	5.7645	2159.1
120	5,7560	5.7552	2648.3

For a better visualization of the results from table 1, a graphical comparison between numerical and experimental displacements is presented in figure 8.

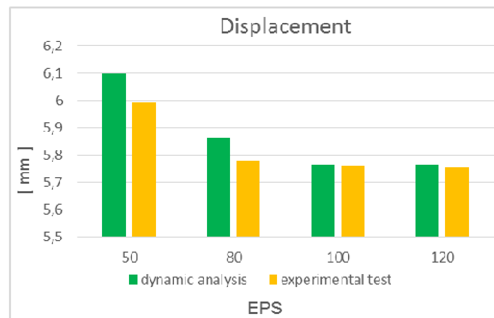


Fig.8. Comparative numerical and experimental displacement data.

Because the specimen has an elastic return, to the measured value of the mark left by the ball will be added the elastic deformation calculated based on the stress-strain curve of the material obtained after experimental compression test [8].

Thus, for example for EPS 80 the total deformation during impact will be: 4,53 mm + 1,249 mm = 5,779 mm. In this expression 4,53 mm represents the value of the trace depth after impact (permanent deformation) and 1,249 mm is the elastic deformation (spring-back) of EPS 80 resulting a total of 5,779 mm. This value was considered the experimental value of the deformation during the impact and compared with the numerical simulation results.

4. CONCLUSION

In this stage of the work, was analyzed the impact behavior of polystyrene, a phenomenon often encountered in constructions when the facade is hit with various objects. They were carried both numerical modeling using explicit analysis and curves of the material experimentally determined to compression and experimental validation of impaction by means of a pendulum type device. The results obtained by the two methods are in good convergence, which certifies their validity.

5. ACKNOWLEDGMENT

This work was supported by a grant of the Romanian Ministry of Research and Innovation, CCCDI-UEFISCDI, project number PN-III-P1-1.2-PCCDI-2017-0391 within PNCDI III.

6. REFERENCES

[1] https://www.chemicalsafetyfacts.org/polystyrene/

[2] Wensu Chen, Hong Hao, Dylan Hughes, Yanchao Shi, Jian Cui, Zhong-Xian Li, *Static and dynamic mechanical properties of expanded polystyrene*, Materials & Design, Volume 69, 15 March 2015, Pages 170-180, doi.org/10.1016/j.matdes.2014.12.024.

[3] https://omnexus.specialchem.com/selection-guide/expanded-polystyrene-eps-foam-insulation

[4] Wensu Chen, Hong Hao, *Experimental and numerical study of composite lightweight structural insulated panel with expanded polystyrene core against windborne debris impacts,* Materials and Design 60 (2014) 409–423.

[5] Yiping Liu, Dongpeng Ma, Zhenyu Jiang, Fan Xiao, Xinxiong Huang, Zejia Liu, Liqun Tang, *Dynamic response of expanded polystyrene concrete during low speed impact,* Construction and Building Materials 122 (2016) 72–80.

[6] Umut Caliskan, M Kemal Apalak, *Bending impact behaviour of sandwich beams with expanded polystyrene foam core: Analysis,* Journal of Sandwich Structures and Materials 2019, Vo l. 21(1) 230–259.

[7] U. Caliskan, M. K. Apalak, *FEM analyses of low velocity impact behaviour of sandwich panels with eps foam core,* Journal of Thermal Engineering, Vol. 3, No. 6, Special Issue 6, pp. 1544-1552, December, 2017

[8] Cristian Vilau, Mircea Cristian Dudescu, *Investigation of mechanical behaviour of expanded polystyrene under compressive and bending loadings,* Materiale Plastice (Mater. Plast.), 2020, Volume 57, Issue 2, 199-207.

COMPORTAREA POLISTIRENULUI EXPANDAT LA IMPACT PRIN METODE EXPERIMENTALE ȘI NUMERICE

Astăzi, polistirenul expandat este utilizat în aproape toate domeniile. Este foarte utilizat în domeniul construcțiilor, pentru izolarea fațadelor clădirilor datorită caracteristicilor termice foarte bune. Polistirenul utilizat pentru izolarea fațadelor este supus la diverse solicitări, cum ar fi sarcini de îndoire, sarcini dinamice și solicitări prin șoc. Lucrarea prezintă rezultatele obținute la testele de impact dinamic ale polistirenului expandat, dar și rezultatele obținute la analizele de impact dinamic efectuate cu software-ul de analiză ANSYS. Pentru teste dinamice și analize ale probelor s-au folosit spumă de polistiren tip EPS 50, EPS 80, EPS 100 și EPS 120.

Cristian VILAU, Eng., Technical University of Cluj-Napoca, Department of Mechanical Engineering, email: vilau_cristian@yahoo.com, B-dul Muncii no. 103-105, Cluj-Napoca, Romania.

Mircea Cristian DUDESCU, Prof.dr.ing., Technical University of Cluj-Napoca, Department of Mechanical Engineering, email: mircea.dudescu@rezi.utcluj.ro, B-dul Muncii no. 103-105, Cluj-Napoca, Romania.