NUMERICAL ANALYSIS OF AN OPEN CELL FOAM STRUCTURE WITH THE USE OF MODELS BASED ON 2D FINITE ELEMENTS

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Abstract

The paper deals with the numerical analysis of foam materials. Open cell foam is investigated. Numerical simulations allow calculating modes of destruction and assessing effective properties of the model structures. Metal as well as polyurethane foams show out interesting properties. They are light, have good acoustic and/or magnetic isolation, have ability to absorb energy of vibration and hits. They are used for sandwich panels, hit absorbers (i.e. as elements of buffer constructions in rail vehicles), fillers of construction parts, bodies of vehicles (i.e. floating combat vehicles), dividing walls on vessels and others. Specially prepared open cell foams show out auxetic properties and shape memory effect. Such materials are very good for seats in aircrafts which may protect pilots and passengers during crashes and restrict heavy backbone injuries. Foams are used for filtering purposes. Foams themselves or in combination with different types of fillers (i.e. elastomers) or ceramic reinforcement may be used for hit energy absorbing panels for military purposes (protection against explosion shock wave and splinters). Presented work is a part of a series of numerical experiments which aim is to investigate the influence of geometry parameters onto effective properties of the foam. Different types of geometries are used for numerical experiments. All the models of single foam cell are based on Kelvin grain geometry. Numerical compression tests performed with the use of models based on 2D finite elements provide studying the process of the structure failure. Effective characteristics of investigated foams show out that such materials would be useful for energy absorbing purposes.

Keywords: *FEM modelling, open cell foam structure, effective properties*

1. Introduction

For purposes of numerical modelling of foam materials (Fig. 1a) there are used various techniques and methods. Numerical models may be constructed on base of the real structure image that may be a 2D photograph (Fig. 1b) or 3D scan. 3D scans may be obtained by use of X-ray or neutron tomography technique (Fig. 1c). Models may have smooth shape or may be based on a grid technique (Fig. 2) [1, 4, 9]. Also idealized models are used which are suitable for investigations of influence of particular geometrical or material parameters onto global properties of a foam. They may be built on the base of geometrical solids (i.e. Kelvin's polyhedron (Fig. 3) [2, 5, 6], compositon of different polyhedrons (Fig. 4), Weaire-Phelan 8-cell repeatable structure (Fig. 5) [5, 6] or on the way of Voronoi 3D tessellation [2, 7]. Idealized models may represent multi cell structures or may be reduced to repeatable fragment of geometry – single cell or their part (Fig. 6) [2, 3, 10], so they are convenient for fast comparative analysis of long series of differentiated models. There may be found models which deal with the problem of random distributions of shapes and sizes of foam cells [8].

2. FEM models

There were modelled aluminium as well as polyurethane foam structures consisted of open cells modelled as Kelvin's polyhedrons with the edges length of 1 mm. Models were built of 2D finite shell elements. Models were differentiated by the change of diameters of holes in the cells walls from 8/16 to 13/16 mm (Fig. 1). Appropriately, thickness of the walls was changed from 0.2 to 0.3 mm (for aluminum foam) and from 0.10 to 0.15 mm to keep the volume of material in the models constant (Tab. 1). Materials properties taken for calculations are shown in the Tab. 2.

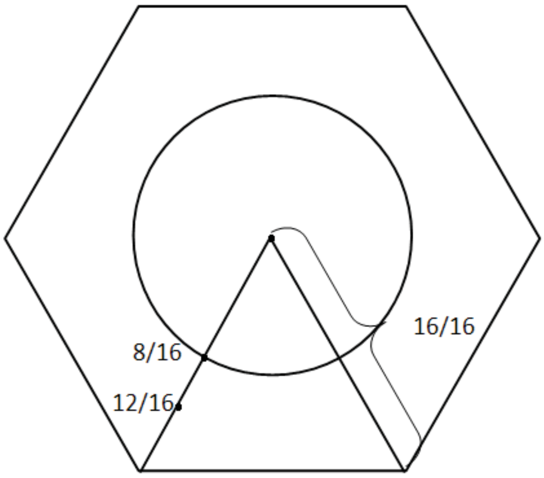
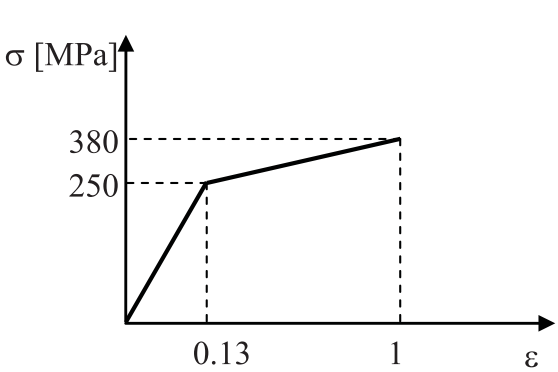
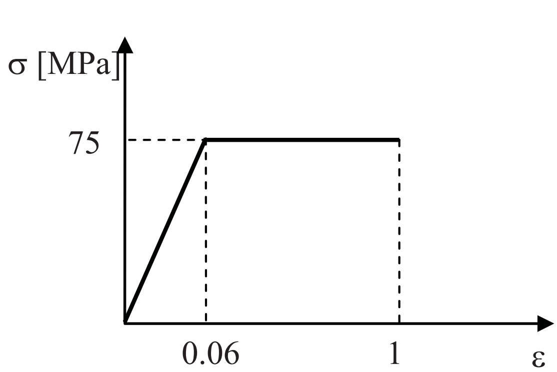


Fig. 1. Models were differentiated by the change of diameters of holes in the hexagonal walls from 8/16 to 13/16 mm

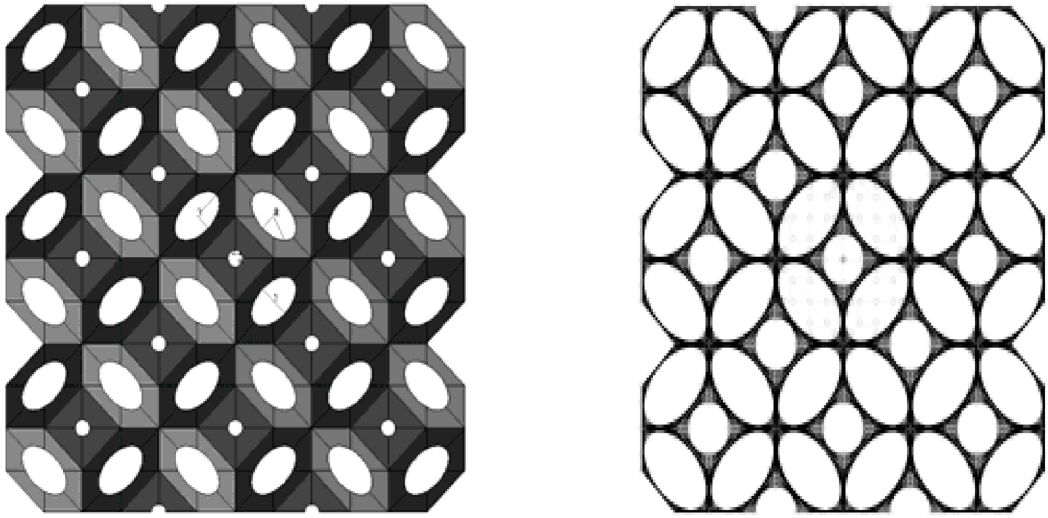
Tab. 1. Thicknesses of walls in the models

Hole diameter [mm]	Wall thickness (aluminum foam) [mm]	Wall thickness) (polyurethane foam) [mm]
8/16	0.20	0.10
9/16	0.22	0.11
10/16	0.24	0.12
11/16	0.26	0.13
12/16	0.28	0.14
13/16	0.30	0.15

Tab. 2. Material properties taken for calculations

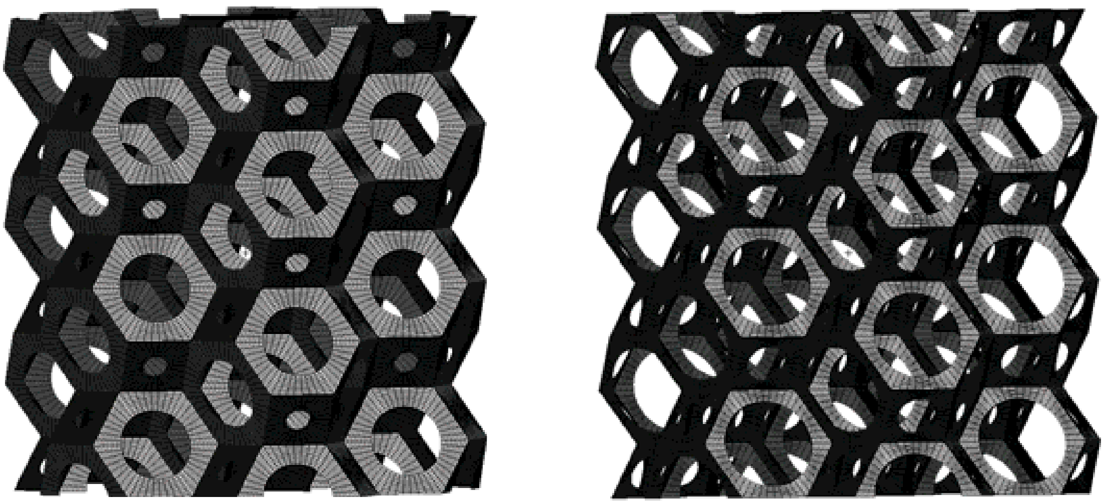
Aluminium	Poliuretan
E = 71,000 MPa, ν = 0.33	E = 4,000 MPa, ν = 0.35
	

There were considered two different ways of structures building, so the load was applicated to the square (Fig. 2) walls in the models of the type A or to hexagonal walls (Fig. 3.) in the models of the type B. Model A enables analysis in orthogonal coordinate frame.



8/16 13/16

Fig. 2. Models of the type A



8/16 13/16

Fig. 3. Models of the type B

3. Results

Calculation were conducted with the use of MSC MARC software. In the Fig. 4 examples of calculated von Mises stresses are presented for the aluminium open cell foam model of type A with holes diameters equal 8/16 mm (compare Fig. 1). In the Fig. 5 there are presented von Mises stresses for the model of types A with holes diameters equal 13/16 mm. Similar combination for polyurethane foam is shown in the Fig. 6 and Fig. 7. Behaviour of models for aluminium and polyurethane slightly differs one from other. Aluminium foam model walls perpendicular to the direction of compressive load move outside (in a global sense). Polyurethane foam model with hole diameters equal 8/16 mm shows that these walls tend to move inside. Polyurethane foam model with hole diameters equal 13/16 mm shows that these walls tend to move outside.

In the Fig. 8 and 9 there are compared equivalent stress/strain characteristics for aluminum models of type A and B adequately, both represent very initial stage of compression test (further parts of characteristics are not considered in this paper). The model of type B (in non orthogonal arrangement of the structure and the load) is stiffer than that of type A (in orthogonal arrangement).

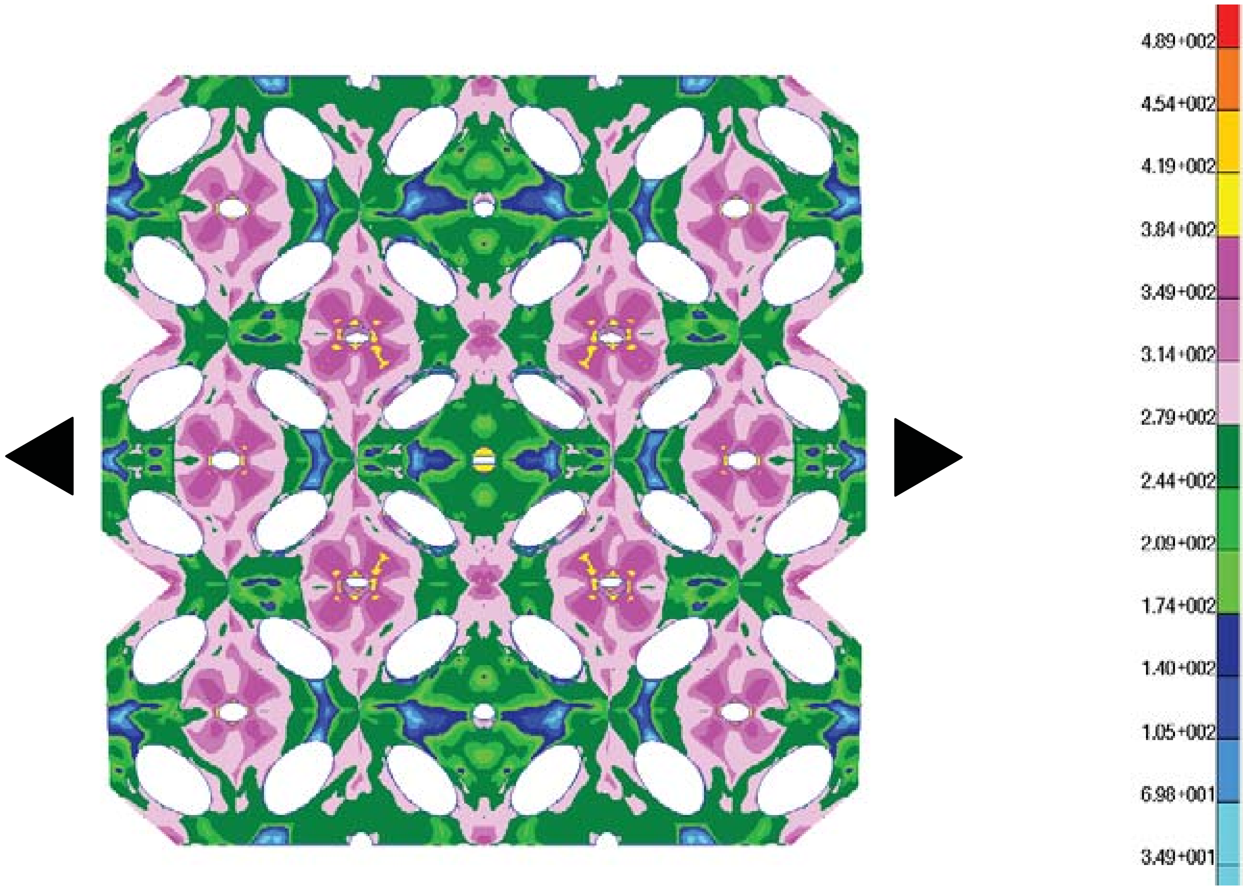


Fig. 4. Aluminum foam model, type A, (8/16), von Mises stress, MPa

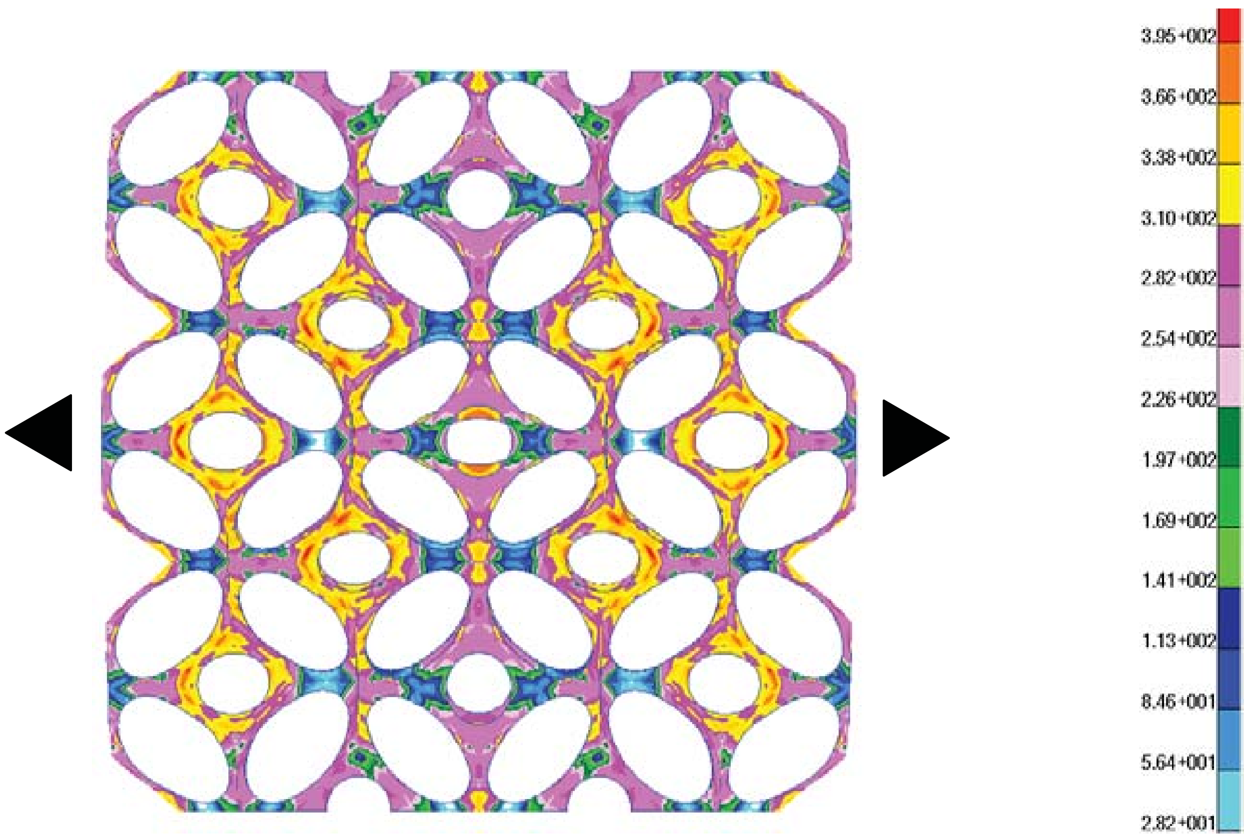


Fig. 5. Aluminium foam model, type A, (13/16), von Mises stress, MPa

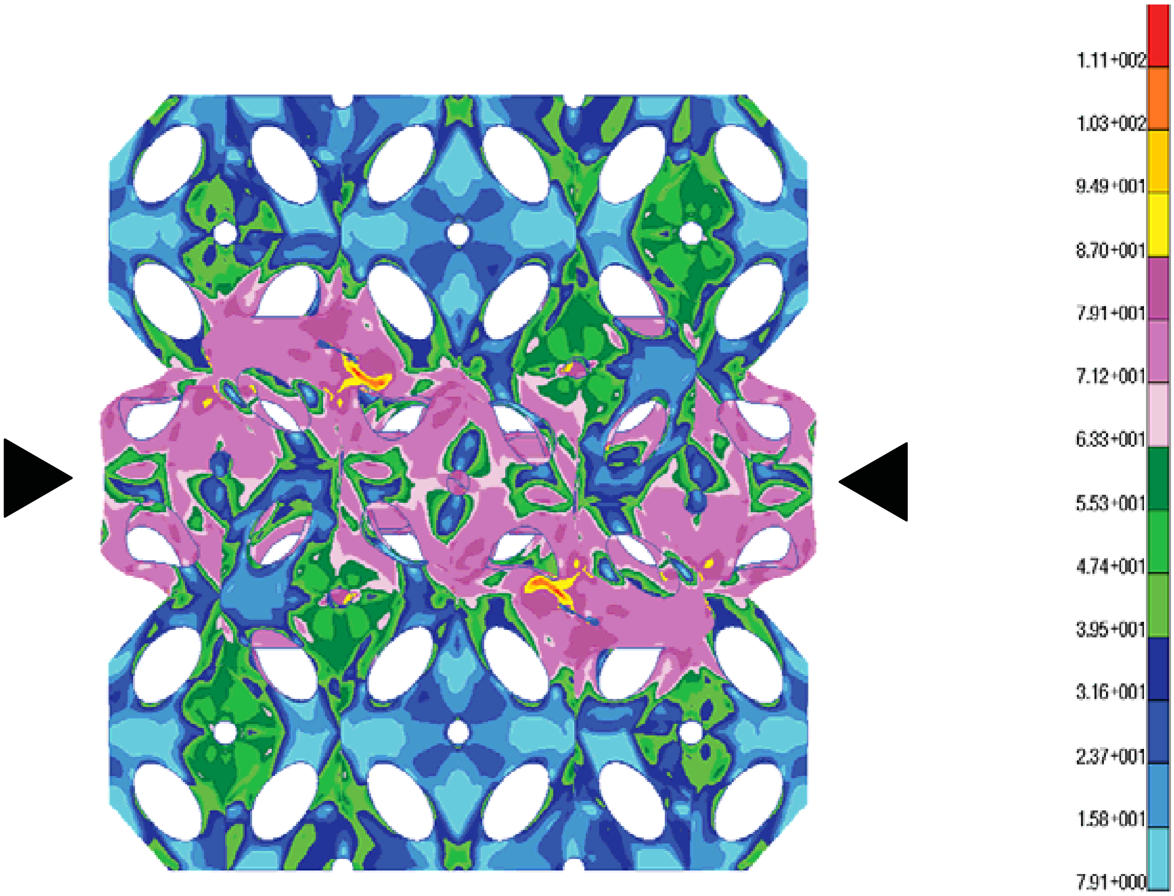


Fig. 6. Polyurethane foam model, type A (8/16), von Mises stress, MPa

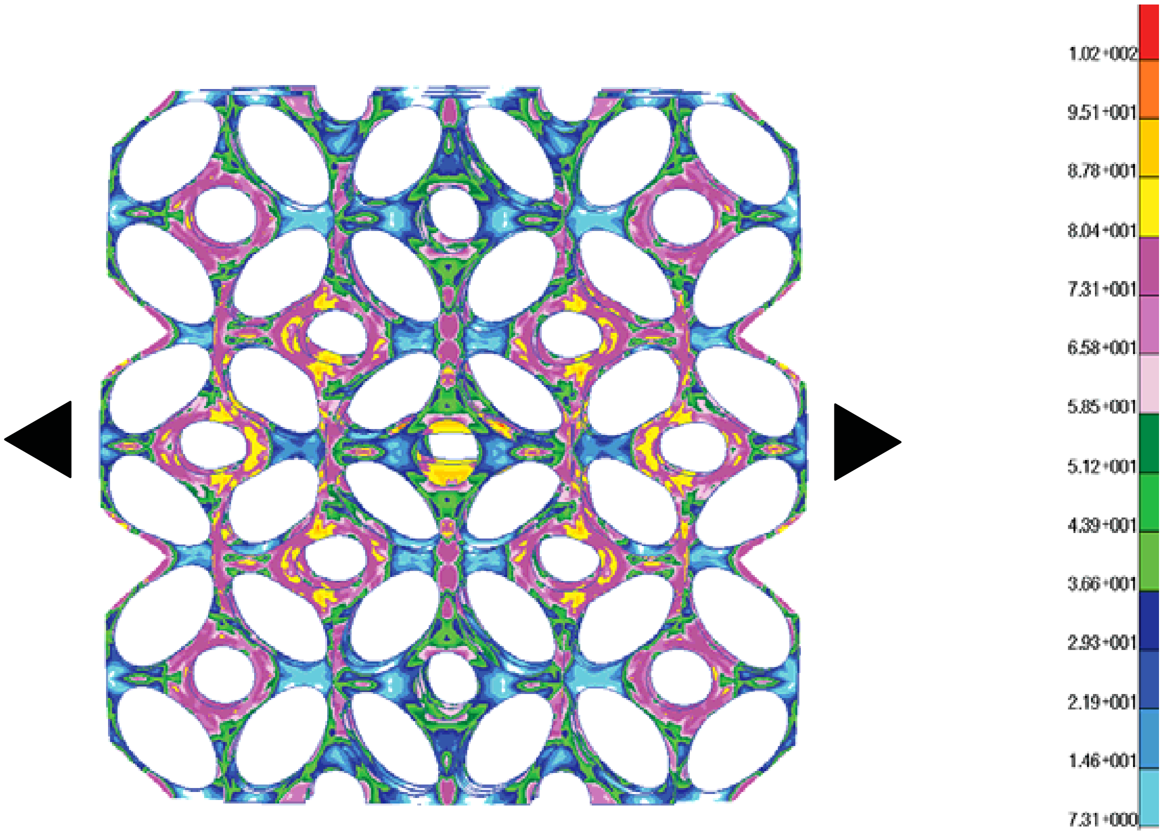


Fig. 7. Polyurethane foam model, type A (13/16), von Mises stress, MPa

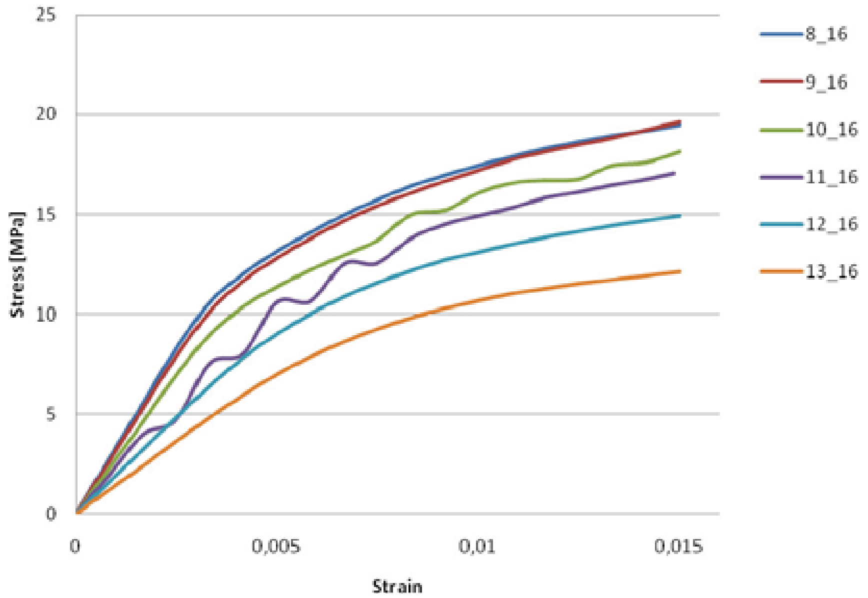


Fig. 8. Aluminium foam model, type A, stress/strain equivalent characteristics

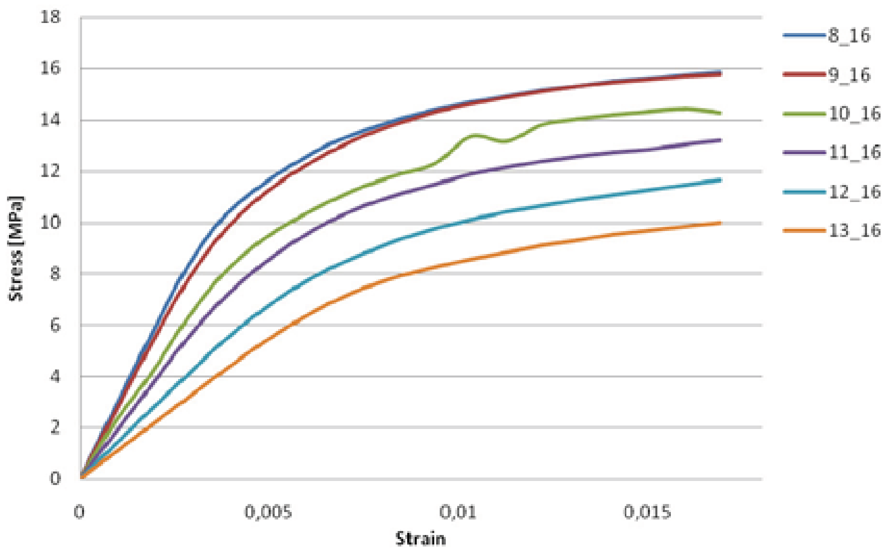


Fig. 9. Aluminium foam model, type B, stress/strain equivalent characteristics

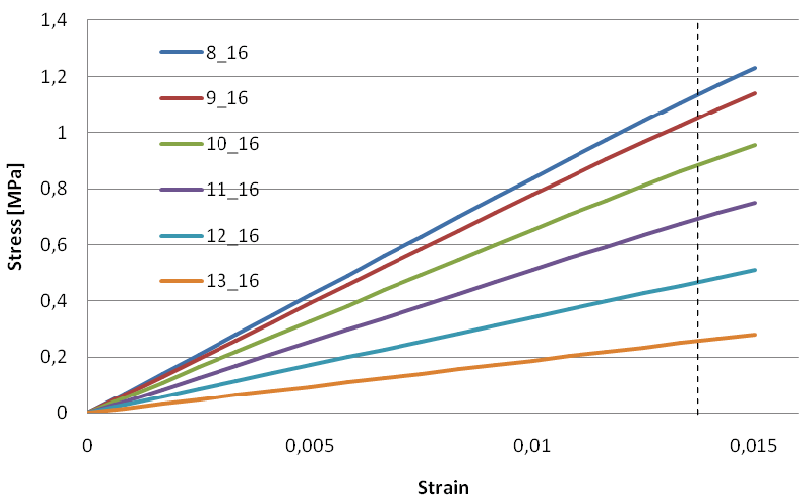


Fig. 10. Polyurethane foam model, type A, stress/strain equivalent characteristics

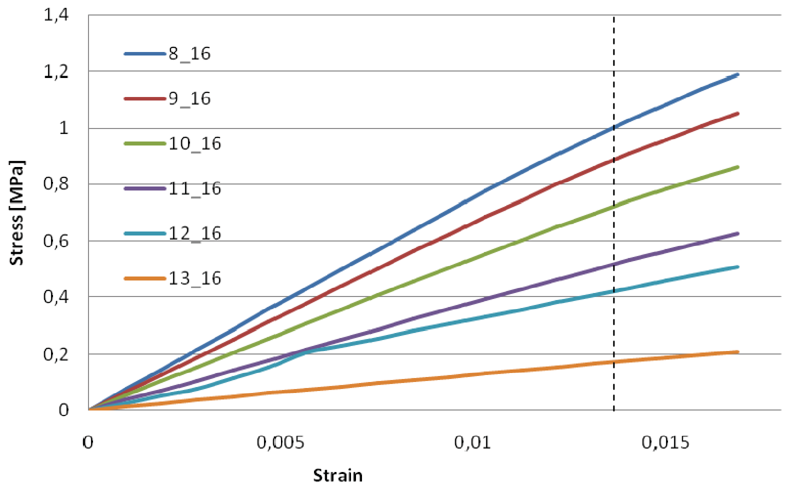


Fig. 11. Polyurethane foam model, type B, stress/strain equivalent characteristics

Polyurethane foam model of the type B is slightly non linear in considered initial stage of the test in comparison to the model of the type A. But the model of the type A is stiffer than the model of the type B.

4. Conclusions

Presented work is a part of research of foam materials in aspect of usage as energy absorbing elements in constructions of road crash barriers. For such investigations there are needed appropriate microstructure models enabling simulations of structural material destruction process and assessment of effective properties for the modelled sample. In this paper there are presented models built of two dimensional finite elements. Other models, based on combination of shell and beam elements or based on solid elements were also considered but they are presented elsewhere. Two different types of model/load arrangements were taken into considerations but both based on Kelvin's polyhedron. Models with cells oriented to provide analysis in an orthogonal coordinate frame show out different overall properties in a very initial stage of compression tests. Results obtained for aluminium and polyurethane material properties represent opposite types of behaviour. Orthogonal arrangements of model geometry may be stiffer than non orthogonal one (model of type B) when properties of aluminum are used. In case of usage of polyurethane properties the model response is reverse.

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