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A STUDY ON THE PARAMETERS THAT INFLUENCE THE PERFORMANCE OF SANDWICH PANELS WITH CHIRAL TOPOLOGY CORES

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Abstract: *The sandwich plates can be ideal components for large and lightweight structures with increased strength, stiffness and stability. The use of cores with chiral cellular geometry will lead to the development of structural components with superior elastic and impact resilient properties. This paper proposes the design of lightweight sandwich panels with aluminum skins and a core made with a chiral geometry network having circular nodes. As a reference construction, the panel with the skins joined only by means of circular bushes (without supplementary stiffeners) is considered. Finite element analyses (FEAs) are undertaken in order to characterize the behaviour of the considered panels as having supported edges, and loaded under lateral pressure.*
Keywords: *lightweight panels, chiral topology cores, FEA*

1. INTRODUCTION

There is a relatively wide range of sandwich panels that are used as components of advanced lightweight structures as automotives, aircrafts, ships, containers, and modern buildings. The typical sandwich structure consists of two relatively thin high strength face sheets separated by and bonded to a relatively thick, low density, low strength core. Thus, the sandwich structure is characterized by a high flexural strength with reduced weight.
Different types of cores as polymeric and metallic rigid foams, honeycomb structures made from different materials, corrugated plates, lattice type components and others are currently used. In aerospace the most extensively used technology is the honeycomb core sandwich structure with aluminium face sheets and aluminium or titanium honeycomb core. In this structure, the honeycomb cell generatrix is perpendicular to the face sheet and, therefore, the bonding between the honeycomb core and the face sheet can be achieved only by line contact. This is the major drawback of this type of sandwich structure, because the line-contact bonding between the honeycomb cross section and the face sheet can easily lose its bonding integrity as a result of corrosion. Also, honeycomb structures have a high strength to mass ratio in the through-plane direction, but have a low strength in in-plane directions.
Classical composite panels form naturally anticlastic surfaces rather synclastic ones. Consequently, their use to form synclastic surfaces (domes) is therefore limited by the need for complex manufacturing techniques to form those shapes.
Chiral honeycomb is a particular form of honeycomb structure in which the ligaments are joined at chiral nodes. A chiral node is one which cannot be superimposed on its mirror image. Fig. 1 shows some shapes of structures with chiral nodes having three, four and six ligaments. The most studied configuration is the hexagonal chiral system that may be considered as being construct from units (highlighted in bold in Fig. 1, e) consisting of a central bush with six attached ligaments. Chiral honeycombs are conventionally manufactured by injection moulding, by bonding together preformed strips or by cutting the honeycomb from solid material.
The peculiar properties of the new developed material are largely due to their auxetic geometry. The term auxetic refers to a novel class of materials characterized by negative Poisson's ratio, that induce beneficial effects as: increased resistance to indentation, improved acoustic properties and a natural tendency to form dome-shaped surfaces [1]-[4]. The auxetic behaviour is a scale independent property and therefore the same mechanism can operate at macro, micro and nano level.

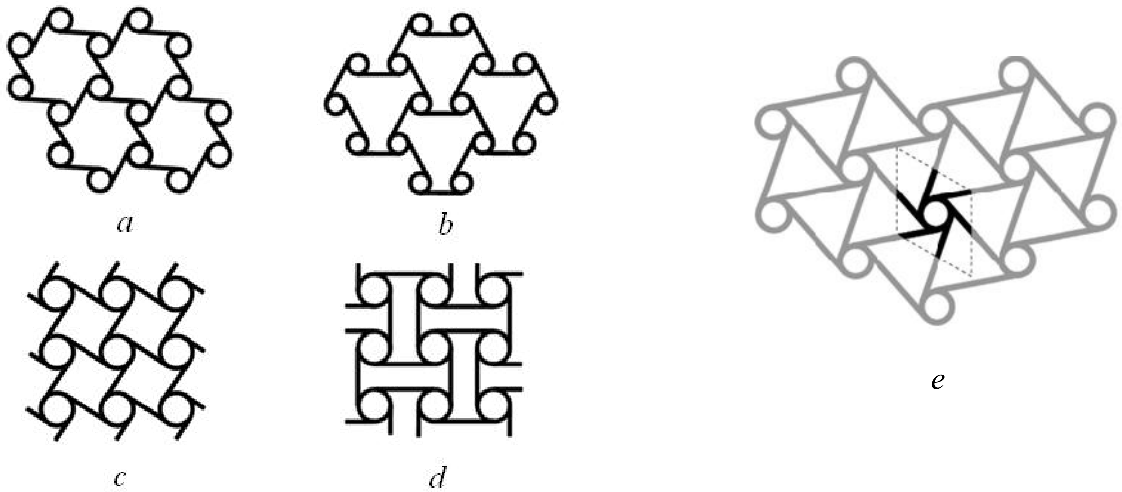


Figure 1: Some chiral structures: a) trichiral, b) anti-trichiral, c) tetrachiral, d) anti-terachiral, e) hexachiral

There are many papers which comment on the geometries and the properties of auxetic materials [1]-[7], but there is little information on the behaviour of the sandwich panels with chiral configured cores. The objective of our paper is to evaluate and to compare the performances of the four sandwich panels presented in Figs. 2-4, by using the finite element analysis.

2. THE MODELLING OF SANDWICH PANELS

The panels that are studied will be denoted as follows: SPP – the panel with the grid components parallel to the edges (Fig. 2), SPD – the sandwich panel with diagonal grid type core (Fig. 3), SPTC – the sandwich panel with a tetrachiral core (Fig. 4), SPAT-1 – the sandwich panel with a anti-tetrachiral core and an aluminium border (Fig. 5), SPAT-2 – the sandwich panel with the same geometry, but having a border form PVC. Additionally was analyzed an associated panel SPP-O obtained from the SPP structure by removing the strips.

These structures, assembled by adhesive bonding, were considered simply supported on the edges of the bottom face sheet and loaded with a lateral pressure p = 0.07 MPa applied on the upper face sheet. This is the mean value of differential pressure usually taken into account for aircraft panels.

The physical properties of the materials that are involved in the analysis are given in Table 1. Because the PVC and the araldite AV 119 (produced by Huntsman) have very close values of the elastic moduli and of the Poisson's ratios, the adhesive will be not emphasized explicitly in the numerical model, being included into the polypropylene.

Table 1: Properties of materials used in the finite element modelling of sandwich panels

Component	**Face sheets and Borders**	**Bushes, Strips and Borders**	**Adhesive**
Material	*Aluminium 2024 T3*	*Rigid PVC*	*Araldite AV 119*
Young's modulus [MPa]	72000	3200	3100
Poisson's ratio	0.33	0.35	0.34
Allowable stress [MPa]	300	40	45
Mass density [kg/m^3]	2700	1400	1380

In order to compare the five sandwich panel variants, linear and geometrically nonlinear finite element analyses were done. Each structure was discretized in shell finite elements and static, buckling and modal analyses were undertaken using ANSYS Code [8].

The geometric parameters taken into account were the following: $a = 600$ mm, thickness of face sheets $t_f = 1$ mm, thickness of the strips $t_1 = 2$ mm, thickness of the bushes wall t_2 = 1.8 mm, thickness of borders $t_3 = 2$ mm, mean radius of bushes $r = 19.1$ mm, total thickness of the sandwich panel $t = 25$ mm, $b = 75$ mm, $d = 50$ mm, $c = b/2$, $e = d/2$.

A comparison between the results of linear and geometrically nonlinear calculus was shown that the last one is a more suitable approach.

The main results of this study are presented in Table 2; the stresses which exceed the corresponding allowable values are bolded. It is to observe that the strength condition $\sigma_{eq} \le \sigma_a$ is not accomplished in the case of panel SPP-O, that is the most flexible from the all structures which were analyzed.

Table 2: Results of finite element analyses

Sandwich panel type	Maximum deflection $w_{\max}$ [mm]	Maximum equivalent stresses into the panel components [MPa]				Buckling safety coefficient	Fundamental eigenfrequency [Hz]	Mass of the panel [kg]
		faces	strips	bushes	border			
SPP	7.508	298	27.4	35.4	90.6	1.064	238	3.01
SPD	7.533	287	27.4	28.0	69.6	1.064	237	3.02
SPTC	7.663	293	31.1	27.1	97.7	1.212	227	3.18
SPAT-1	*6.932*	***310***	*32.0*	*26.2*	*79.2*	*2.022*	*224*	*3.36*
SPAT-2	*7.708*	*262*	*34.2*	*26.2*	***47.8***	*1.728*	*213*	*2.83*
SPP-O	15.32	**667**	-	**59.2**	186.5	1.024	124	2.71

The responses of variants SPP, SPD and SPTC give similar results, while the panels SPAT-1 and SPAT-2 present an increased buckling safety coefficient. The allowable stresses are slightly exceeded in the face sheet and in the border in the case of panels SPAT-1 and SPAT-2, respectively.

It is interesting to observe that the maximum deflection is of 15 mm in the case of panel SPP-O and of 7.5 mm in case of structure SPP, i.e. by adding the strips the rigidity of the panel is doubled. Also, the fundamental eigenfrequency is increasing from 124 Hz to 238 Hz.

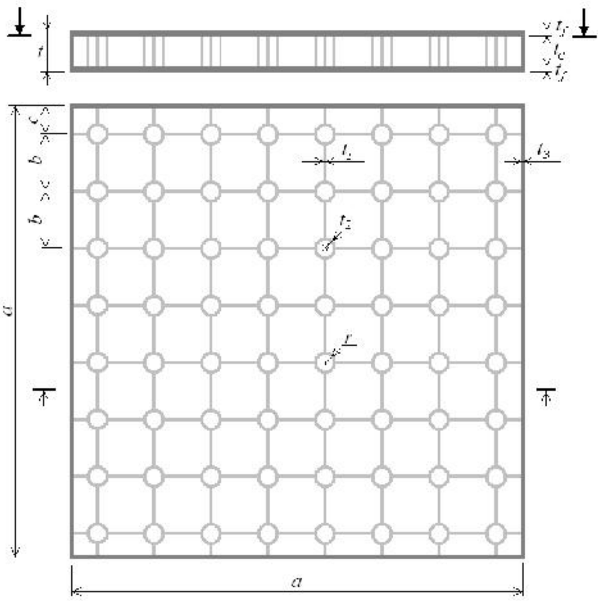


Figure 2: Configuration of panel SPP

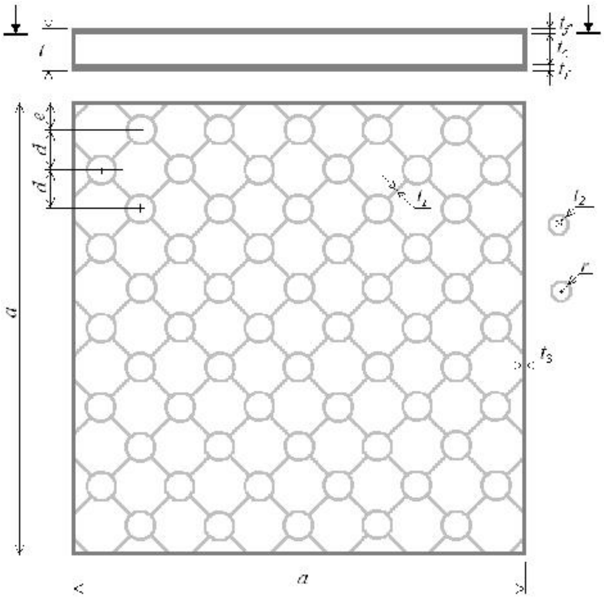


Figure 3: Configuration of panel SPD

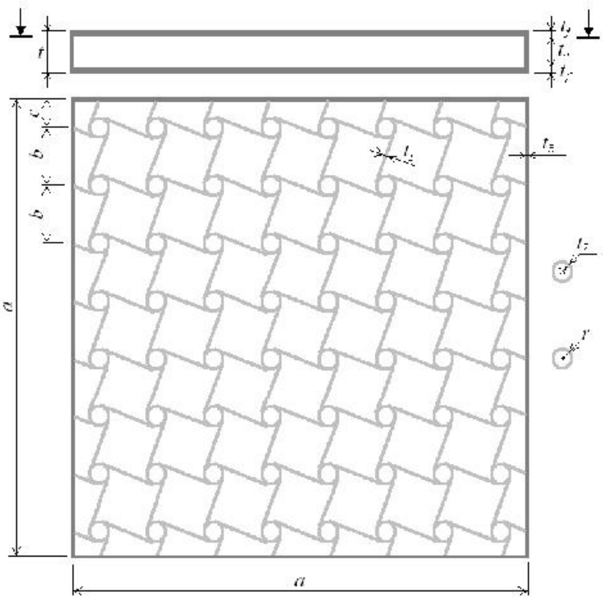


Figure 4: Configuration of panel SPTC

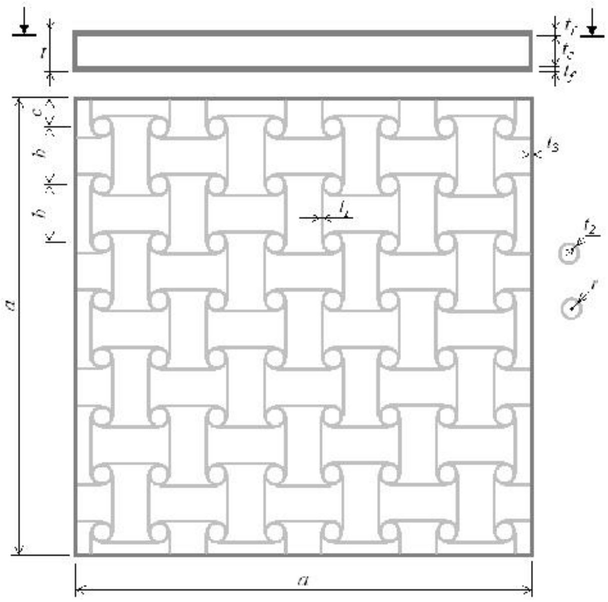


Figure 5: Configuration of panel SPAT

The values from the last but one column are referring to the first mode of local buckling that can appear in the upper sheets of the analyzed panels.
Some results obtained for the structure SPAT-1 are presented in the Figs. 6 to 12.

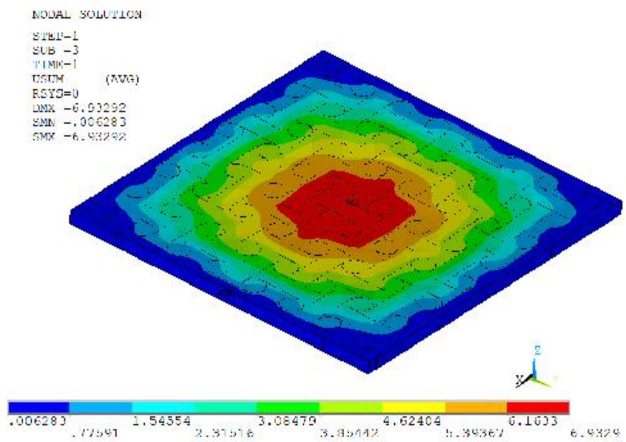


Figure 6: Normal displacements in the upper face sheet

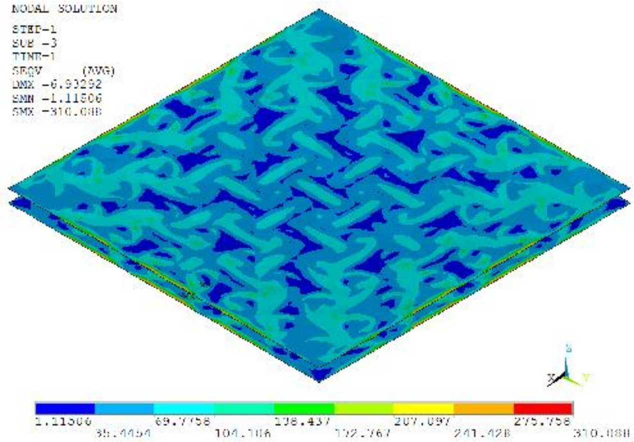


Figure 7: Equivalent stresses in the face sheets

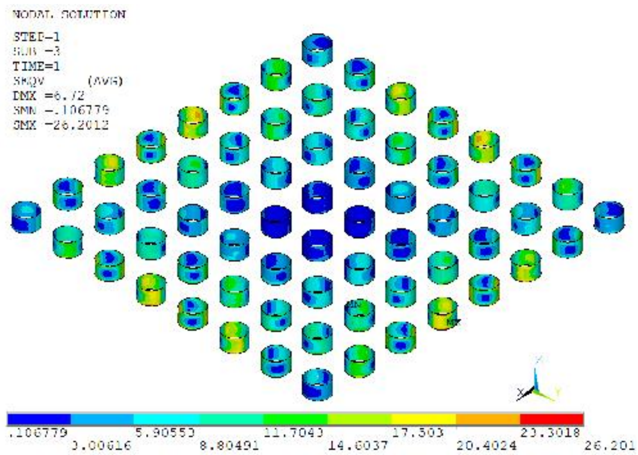


Figure 8: Equivalent stresses in the bushes

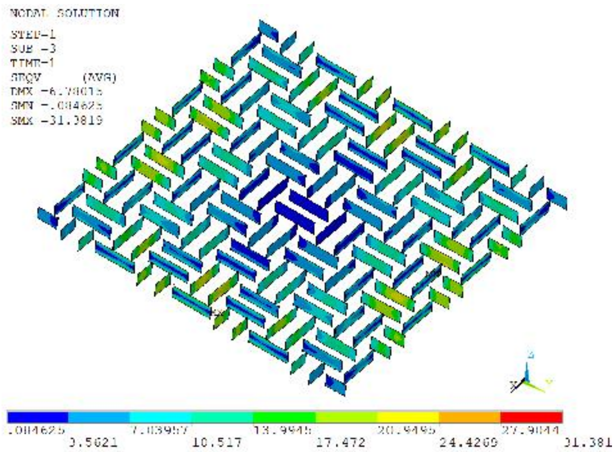


Figure 9: Equivalent stresses in the strips

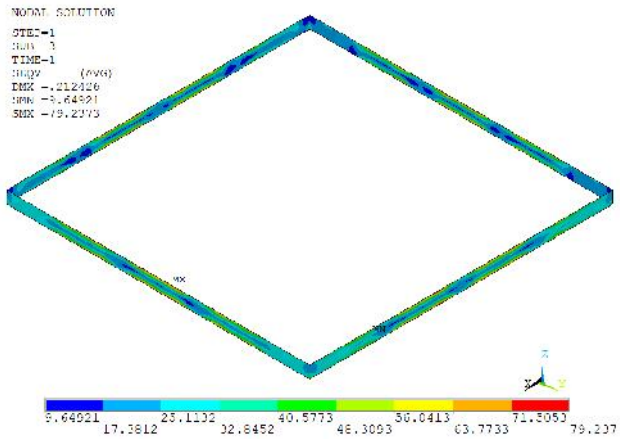


Figure 10: Equivalent stresses in the border

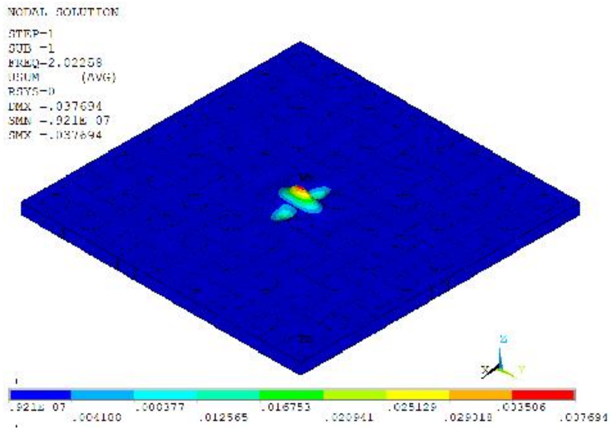
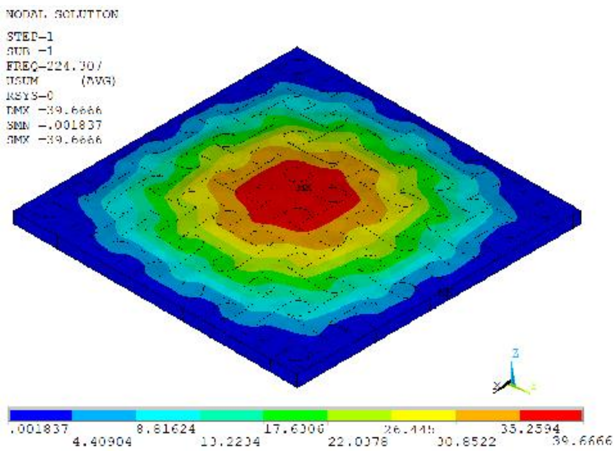
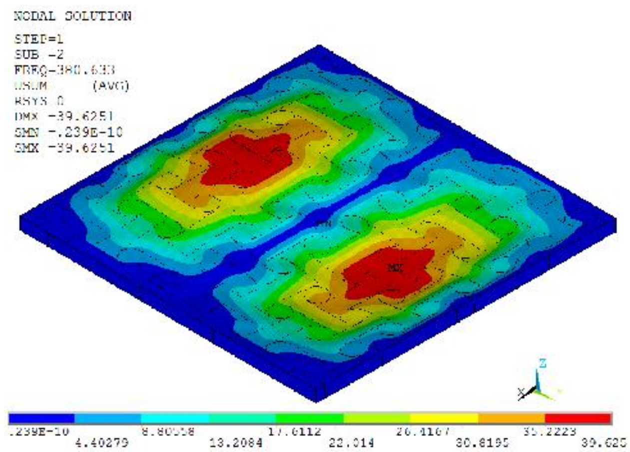


Figure 11: First mode of local buckling

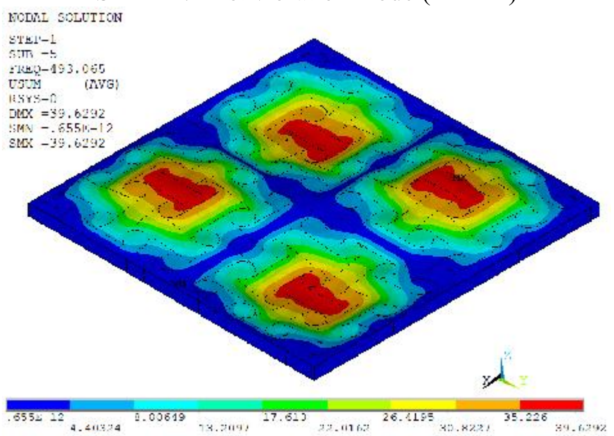
The panel SPAT-2 can be considered the most convenient because its strength, rigidity and stability and, first of all, due to its reduced weight. However, a reduction of the maximum equivalent stress in the border by thickening this component is required.
The reaction forces have a different distribution on the panel contour when the coupling with the support is considered as to stop the upper tendency of movement (Fig. 13,a) comparatively to the case of an unilateral restriction (Fig. 13,b), because in the last situation the corners of the panel tend to be lifted.



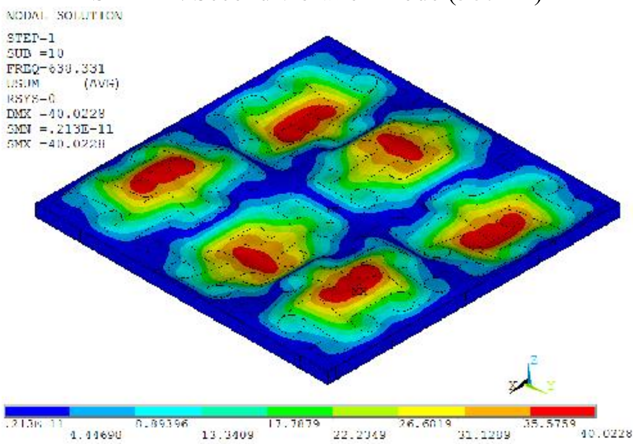
SPAT-1: First vibration mode (224 Hz)



SPAT-1: Second vibration mode (380 Hz)

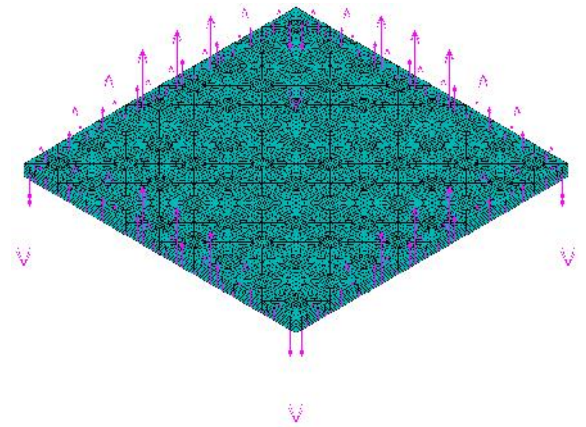


SPAT-1: The fifth vibration mode (493 Hz)

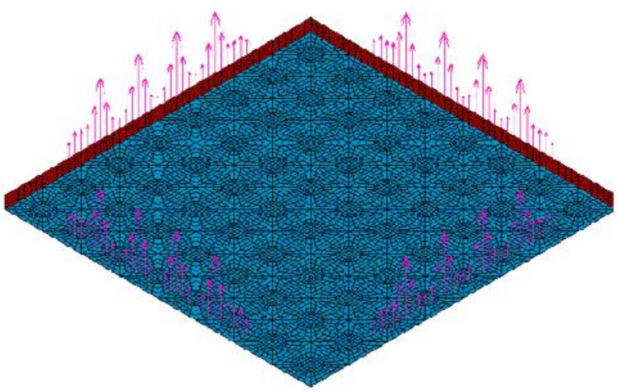


SPAT-1: The tenth vibration mode (638 Hz)

Figure 12: Four vibration modes in the case of panel SPAT-1



a



b

Figure 13: The distribution of reaction forces on the supported contour when the stand up is: a) stopped, b) free

3. CONCLUSIONS

The traditional honeycomb and different types of cores act mostly as spacer while the novel chiral cores can withstand loads very well, having also a structural function. The sandwich panels with chiral geometry honeycombs cores have more convenient mechanical properties comparatively to other similar structures, but are less analysed in the literature.
A correct dimensioning of the components and an adequate choice of the used materials can lead to enhanced properties of this kind of composite structures. Also, recycled materials can be used to manufacture the cores.
The presented study can be the start point in an extended research regarding the design of low cost sandwich panels with increased strength and stability.

REFERENCES

[1] Grima J.N., Gatt R., Farrugia P.S., On the properties of auxetic meta-tetrachiral structures, Phys.Stat.Sol., vol. 245, 2008, pp. 511-520

[2] Grima J., Alderson A., Evans K., Negative Poisson's ratios from rotating rectangles, Computational Methods in Science and Technology, 10, 2, 2004, pp. 137-145

[3] Spadoni A., Ruzzene M., Numerical and experimental analysis of the static compliance of chiral truss-core airfoils, J. of Mechanics of Materials and Structures, 2, 5, 2007, pp. 965-981

[4] Dirrenberger J., Frest S., Jeulin D., Effective elastic properties of auxetic microstructures: anisotropy and structural applications, Int. J. Mech. Mater. Des. (http://link.springer.com/aticle/10.1007%2Fs10999-012-9192-8)

[5] Meraghni F., Desrumaux F., Benzeggagh M. L., Mechanical behavior of cellular core for structural sandwich panels, Composites: Part A, vol 30, 1999, pp. 767-779

[6] Liu T., Deng Z.C., Lu T.J., Structural modeling of sandwich structures with lightweight cellular cores, Acta Mechanica Sinica, vol. 23, no. 5, 2007, pp. 545-559

[7] Ruzzene M., Applications of chiral cellular structures for the design of innovative structural assemblies, ARO Project no. 45518-EG, Final report, Georgia Institute of Technology, Atlanta, 2008

[8] * * * ANSYS Program, Swanson Analysis System, 1990

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