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LOAD CAPACITY OF LIGHTWEIGHT PANELS ASSEMBLED BY SPOT WELDING

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Abstract: *Spot welding is a low cost and effective method of assembling complex structures that are made from alumimium or steel thin plates. In order to ensure efficiency, safety and reliability of spot welded joints an adequate understanding of their behaviour is necessary.*
If the joint is well designed and correctly executed, the junction by spot welding ought to be as strong as the assembled components of the structure and most certainly should not be the reason for reducing the load capacity. The major factors determining the integrity of a spot welded assembling are selection of the most appropriate locations of the welding spots, adequate selection of welding equipment parameters, strict quality control in production and monitoring in service.
This work focuses on the evaluation based on finite element analyses of the load capacity of any type of steel panel with corrugated core assembled with the upper and bottom plates by spot welding.

Keywords: *spot welding, lightweight panels, FEA*

1. INTRODUCTION

There are a relatively wide range of sandwich panels that are used as components of advanced lightweight structures as aircrafts, automotives, ships, containers, 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 light weight and high flexural strength.
Different types of cores as rigid foams plates, honeycomb structures, corrugated or sine-wave plates are currently used [1]-[9]. The most extensively used in aerospace 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.
In case of sandwich panel with corrugated core it is possible to realize surface-contact bonding. The corrugated and sine-wave cores have relatively high out-of-plane bending stiffness in the direction of the corrugated axis, but they have very low out-of-plane bending stiffness in the direction transverse to the corrugation axis. However, when these cores are joined with face sheets, the overall stiffness of the sandwich structure is greatly enhanced.
Figure 1 presents sandwich panels with trapezoidal and triangular profiled corrugated cores. The first panel (fig. 1,*a*) is made from steel and assembled by laser welding, while in the second case (fig. 1,*b*), the components can be made from dissimilar materials, because the assembling is achieved by using adhesives [1]. The third variant (fig. 1,*c*) is made of steel components joined by brazing, following the procedure described in [6]-[8].
For the case of the panel with the face plates made from the same material and the corrugated core from other material an analytical study was developed in paper [2]. The calculus model is based on the assumption that the core must be treated as it is or as equivalent homogenous elastic solid. The purpose of the study was to present formulae and graphs for evaluate the elastic behaviour of the analysed kind of corrugated core sandwich plates.

There are some analytical studies regarding the mechanical evaluation of sandwich plates having triangular profiled or sine-wave corrugated cores [2]-[5].

An experimental and analytical study on steel sandwich panels with triangular corrugated cores assembled with the face plates by brazing are presented in paper [6] and a special finite element conceived to model this kind of sandwich plate is proposed in [7]. For failure mechanisms were considered: face yielding, face buckling, core yielding and core buckling.

The results obtained by the proposed analytical method have been validated by experimental measurements and finite element simulations. Square panels (305 mm × 305 mm) were tested at three points bending in two different orientations: transverse (bending plane normal to the corrugation axis) and longitudinal (bending plane parallel to the corrugation axis). Other dimensions of tested panels were the following: thickness of the face plates of 0.635 mm, thickness of the sheet used to manufacture the core of 0.25 mm, total thickness of the sandwich plate of 18.8 mm.

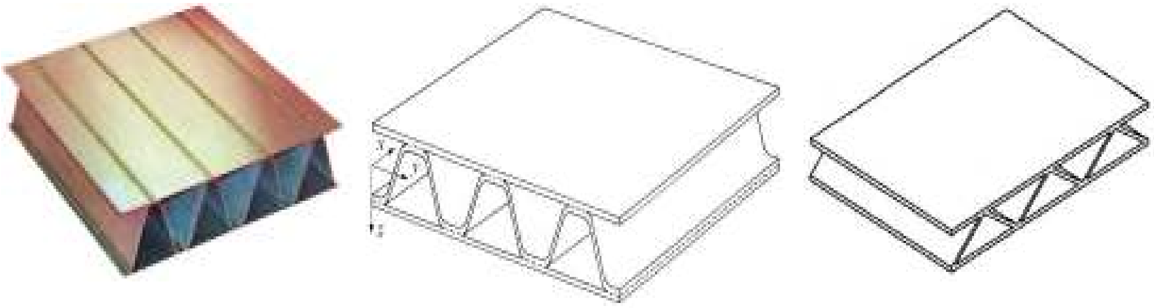

a *b* *c*

Figure 1: Lightweight sandwich plates with corrugated cores: a) steel laser-welded panel, b) panel from dissimilar materials assembled by adhesive bonding, c) metallic panel assembled by brazing

For a large number of complex structures (automotives, aircrafts, wagons, containers, ships, buildings and others) it is interesting to use metallic sandwich panels with corrugated cores made from steel or aluminium and assembled by spot welding. Because in many cases only a face of the panels are required to be smooth it is possible to realize structures as that presented in figure 2. The proposed configuration contains: the continuous face plate, the trapezoidal profiled corrugated core and instead of second face a succession of equidistant strips.

The assembling technique is very simple: in the first stage are fixed the strips on one face of the corrugated core and in the second stage the face plate are attached to the core, also by spot welding. The gaps between the strips facilitate the access of the electrodes for achieve the spot welding in the second stage of manufacturing.

2. FINITE ELEMENT MODELING OF SPOT WELDED PANELS

In figure 2,*a* are presented the steel components before and after assembling. The welding spots are placed as is shown in the detail from figure 2,*b*.

The panel will be manufactured from carbon steel having the Young's modulus of 2×10^5 MPa, Poisson's ratio equal to 0.3 and an allowable stress of 200 MPa.

Static and modal analyses were undertaken using the ANSYS Code for two different models: 1 – with shell finite elements, 2 – with brick type finite elements.

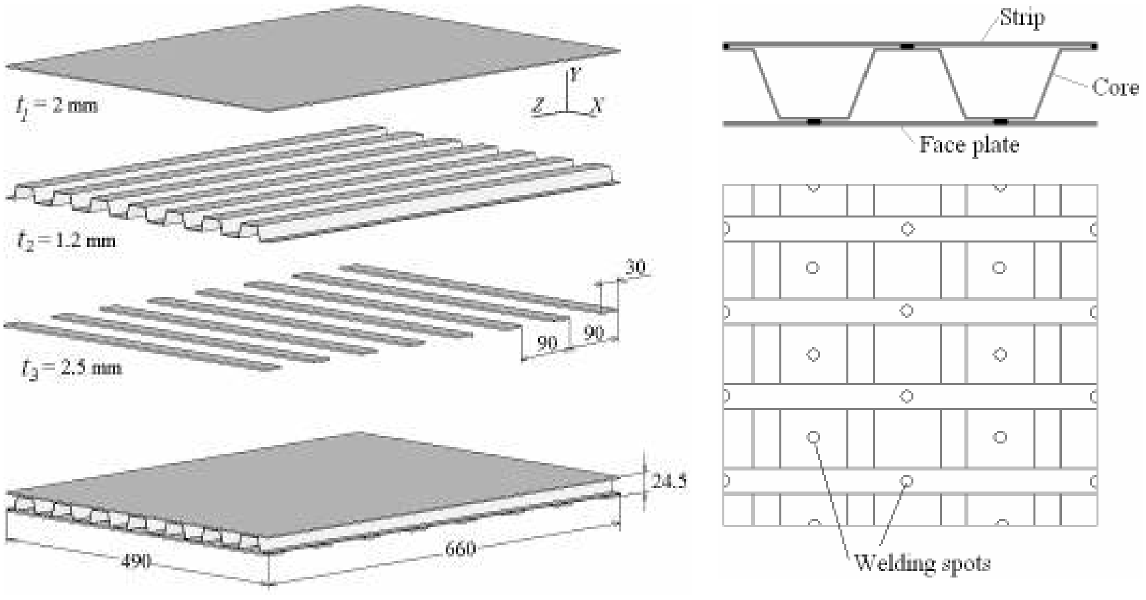
In the case of the first model it was considered the entire structure and the welding spots were described as short beams placed between the middle surfaces of the interacting components.

The analysed structures were considered as simply supported on the edges, because in many applications a panel is mounted on a mesh of a beams network. As static load was taken a pressure of 0.01 MPa uniformly distributed on the face plate. In this case the total load on the panel is of 3234 N.

Due to the symmetry, the second calculus model was obtained by meshing only a quarter of the panel with brick finite elements and by imposing the appropriate conditions on the nodal displacements in the symmetry planes. It was accepted that there are gaps of 0.4 mm between the surfaces that will be bonded and welding spots were described as cylinders having a diameter of 6 mm and a height of 0.4 mm

Because the panel is a periodical structure, in the first stage was discretized its typical cell (fig. 3), that was subsequently translated along the axes X and Z and glued in order to generate the calculus model (a quarter of panel). This model contained 94614 nodes and 62066 brick type finite elements.

It is normal that the results obtained by using brick finite elements will be more accurate than those given by the shell model, but this is simpler.



a *b*

Figure 2: Lightweight panel from steel components before and after assembling by spot welding

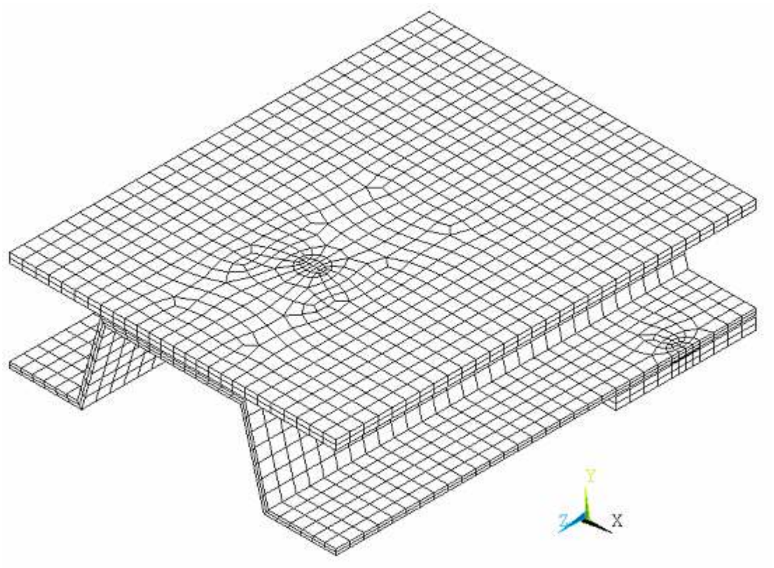


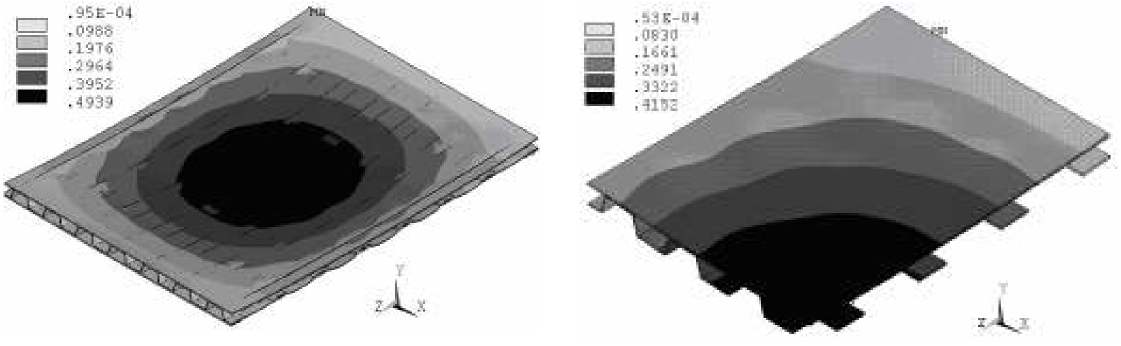
Figure 3: Typical cell for the panel periodical structure

3. FINITE ELEMENT ANALYSES AND RESULTS

For comparison, the results obtained by using the above discussed finite element models are presented as follow:

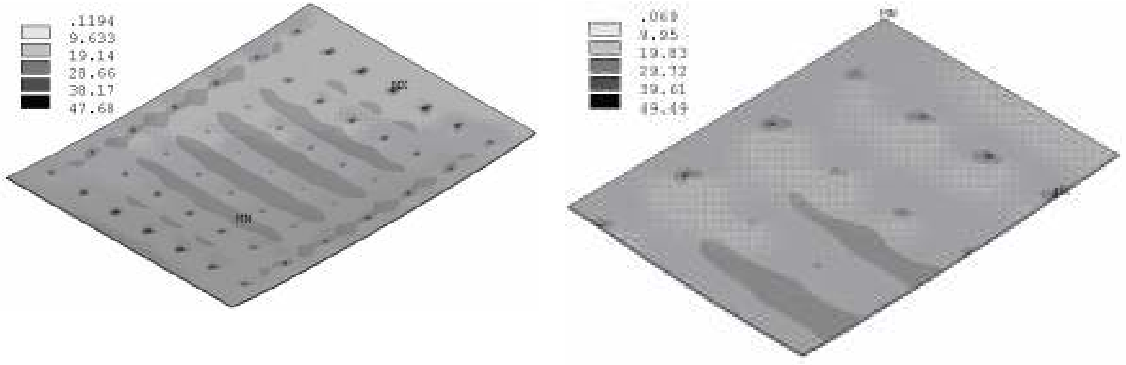
- Figure 4: distribution of total displacements induced by the normal pressure of 0.01 MPa,
- Figure 5: distribution of equivalent stresses in the face plate,
- Figure 6: distribution of equivalent stresses in the corrugated core,
- Figure 7: distribution of equivalent stresses in the strips,
- Figure 8: The first mode of natural vibrations of the panel,
- Figure 9: Equivalent stresses in the welding spots for the model with brick type finite elements: a) at the interface upper plate- corrugated core, b) at the interface core-strips.

It can be observed that local effects occur around any welding spots and in the locations where the plate supports on the strips ends. Consequently, some results (with large values) furnished by the simplified model with shell finite elements are not realistic.



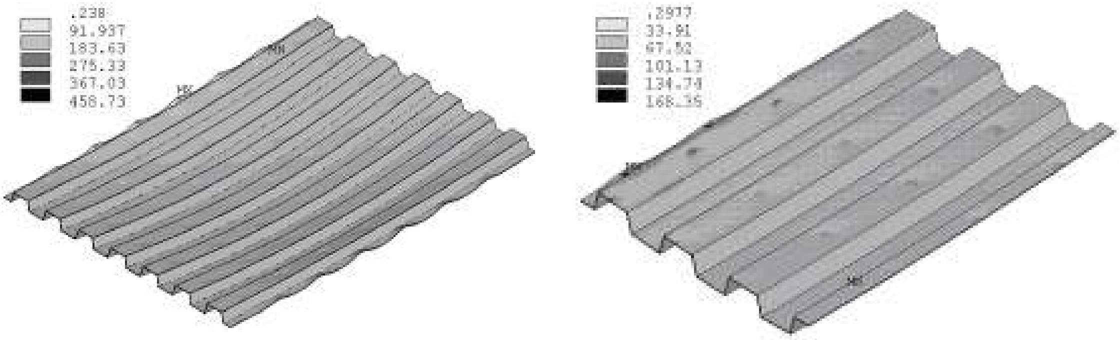
Model 1 Model 2

Figure 4: Total displacements (in mm) under a normal pressure of 0.01 MPa



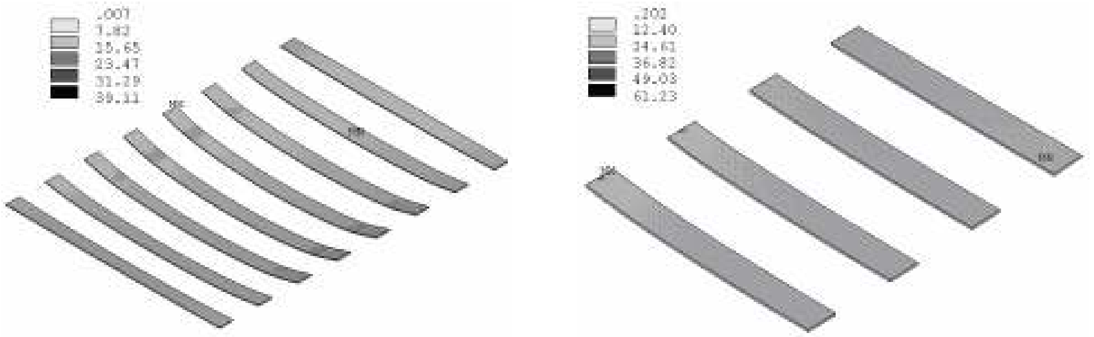
Model 1 Model 2

Figure 5: The distribution of equivalent stresses (in MPa) in the face plate



Model 1 Model 2

Figure 6: The distribution of equivalent stresses (in MPa) in the corrugated core

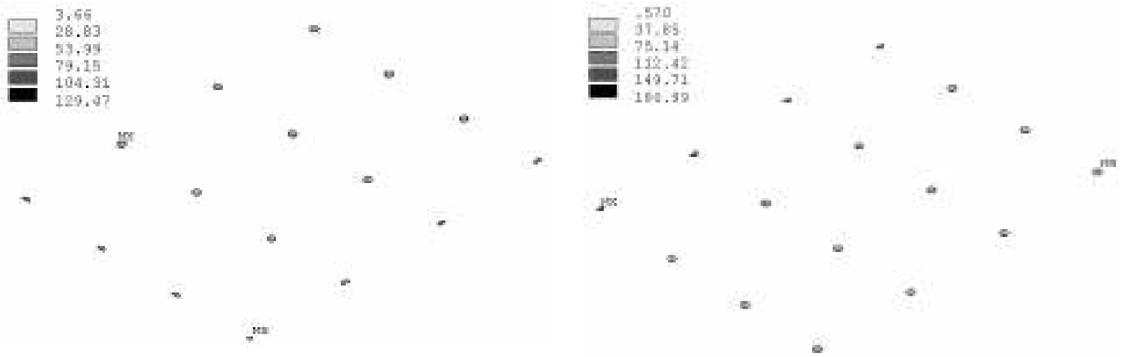


Model 1 Model 2

Figure 7: The distribution of equivalent stresses (in MPa) in the strips

Model 1 Model 2

Figure 8: The first mode of natural vibrations of the panel



a *b*

Figure 9: Equivalent stresses (in MPa) in the welding spots obtained by using the model with brick type finite elements: a) at the interface upper plate- corrugated core, b) at the interface core-strips

4. CONCLUSIONS

In order to facilitate the comparison regarding the performances of the two finite element models that were used, the main results were centralised in table 1.

Table 1: Results obtained in two variants of modeling, with shells and with brick type finite elements

FEM model	with shell finite elements	with brick finite elements
Maximum deflection at the centre of panel [mm]	0.494	0.415
Maximum equivalent stress in the face plate [MPa]	47.6	49.5
Maximum equivalent stress in the corrugated core [MPa]	458.7	168.3
Maximum equivalent stress in the strips [MPa]	39.1	61.2
Maximum equivalent stress in the welding spots [MPa]	38.7	187
Fundamental frequency [Hz]	150	164

The main conclusions of this study are the following:

- there are a good concordance in case of maximum deflection, maximum equivalent stress in the face plate and fundamental frequency,
- the modelling of welding spots as short beams is not recommended because of non-realistic stresses induced in the corrugated core,

- the welding spots located at the interface corrugated core-strips are more stressed than those placed between the corrugated core and the face plate,
- the maximum equivalent stresses obtained with brick type finite element are allowable in all components of the panel.

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