

# Flexural Analysis for Syntactic Foam Sandwich Panels



Zulzamri Salleh, M. Islam, J. Epaarachchi, M. Zulkarnain and Yaseen Adenan Ahmed

**Abstract** The investigation on the strain value for flexural sandwich panel syntactic foam were also carried out using the FEA approach to predict the properties' behaviour in this study. It was found that the micro strain for SG1 for FEA was 17% higher than the experimental value, even though they were at the same loading setting. However, the prediction for the micro strain of SG2 was only 2.7% different, which was considered a good agreement to predict the properties of syntactic foam core sandwich panel for different loading values.

**Keywords** Syntactic foam · Strain gauge · Finite element analysis

## 1 Introduction

The syntactic foams known as closed foams possess a higher density than open cell foams, and it is difficult to synthesis the existing porosities in syntactic foams. However, syntactic foams have considerable superior mechanical properties that make it possible for them to be used in load bearing structural applications. The presence of porosity inside hollow particles, called microballoons, leads to lower moisture absorption and lower thermal expansion, resulting in better dimensional stability [1, 2]. The size and distribution of porosity can be controlled very closely in these foams by means of microballoon volume fraction and wall thickness. A previous study also indicated that mechanical properties are varied with different filler content [3]. A comprehensive understanding of the influence of microballoons/matrix adhesion, and wall thickness of the matrix on the compressive failure mechanisms

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Z. Salleh (✉) · M. Zulkarnain · Y. A. Ahmed  
Malaysian Institute of Marine Engineering Technology, Universiti Kuala Lumpur,  
32200 Lumut, Perak, Malaysia  
e-mail: [zulzamri@unikl.edu.my](mailto:zulzamri@unikl.edu.my)

M. Islam · J. Epaarachchi  
Centre for Future Materials and School of Mechanical and Electrical Engineering, Faculty of Health, Engineering and Sciences, University of Southern Queensland, Toowoomba, QLD 4350, Australia

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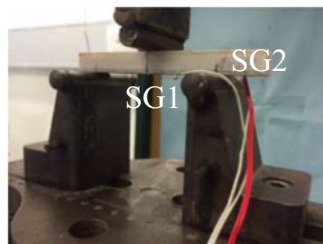
of these foams is still lacking [4]. This is also supported by Gupta et al. (2004) who noted that to achieve better mechanical properties wall thickness and volume fraction need to be considered [5]. These parameters always correlate with the density of glass microballoons and filler content. Previous reports show that the void content or porosities are less when the density of glass microballoons is increased [6]. Therefore, all these main parameters need to be considered in this study to ensure a better understanding for exploring marine applications. Thus, increasingly demanding for lightweight materials had gained their usage not limited due to higher good mechanical strength for aerospace [7], marine, thermal insulation and packaging [8] but also environmentally user friendly.

This foam is also known as low density foam, which is used in buoyancy aid facilities for offshore applications [9]. Many studies have reported that the presence of porosity inside a thin wall thickness shell promises to give a better result during environmental test conditions such as moisture absorption and thermal analysis [1, 2]. At the same time, the stress concentration factor (SCF) around the hole for homogenous material, such as syntactic foam, can be determined using a strain gauge (SG) unit.

In this case, mechanical properties such as the modulus elasticity and Poisson's ratio are dependent on the composition of the composite material is observed, highlighting the need for developing the composites material. Poveda et al. (2010) found that different types of glass microballoon with different sizes cause the Poisson's ratio to vary [10]. Other experimental work also showed that the modulus of epoxy or vinyl ester matrix syntactic foams can be tailored within a range of 1–3 GPa while their strength can be controlled in the range of 30–110 GPa [5, 11]. Beside of experimental work, theoretical studies also tend to assume the Poisson's ratio using the model particularly in FEA. Previous report also mentioned that lack of availability of Poisson's ratio values is a limitation for modelling efforts [12]. The determination of both the modulus of elasticity and Poisson's ratio from the experiment can be used in FEA modelling to finalise the SCF value of syntactic foam. Desirable to composite plate subjected to various transverse static loading conditions [13]. They found, that the peak stress concentration factor occurs on the boundary of the hole and that the stress concentration factor was also strongly influenced by the uniformly distributed normal and equivalent stresses. Limitation of availability the characteristic such as modulus elasticity and Poisson's ratio in functional graded material like syntactic foam lead to focus in this study using the modelling FEA methodology.

This paper presents the characterisation of the tensile properties of a dog bone specimen glass microballoon/vinyl ester syntactic foam. The main objective of this work is to investigate the behaviour of syntactic foam under tensile loading by using FEA. Tests on coupons and full-scale specimens were undertaken to determine the tensile properties of syntactic foam. The tensile tests on coupons were conducted. On the other hand, the tests on full scale specimen were performed using the procedures available in previous studies. The details of these tests are presented in the next sections. Aside from these tests, a finite element analysis (FEA) particularly stress concentration factor (SCF) was carried to simulate the tensile behaviours of full-scale

**Fig. 1** Strain gauges attached to the specimen with indication SG1 and SG2



specimen by using the Strand7 software. The results obtained from the experiment were compared with those of FEA.

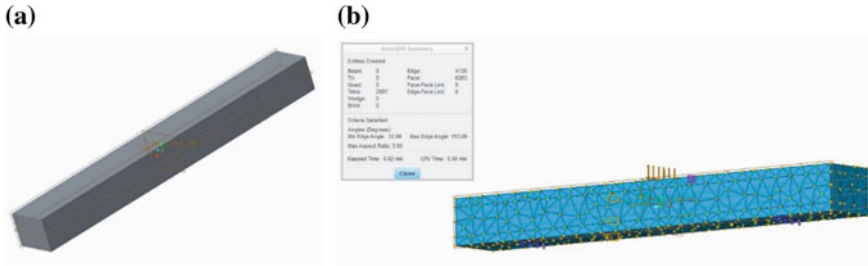
## 2 Methodology

### 2.1 *The Flexural Syntactic Foam Core Sandwich Panel*

The flexural syntactic foam sandwich panel has been used for the evaluation, using the FEA modelling method. The strain gauges, also supplied by Bestech Australia Pty. Ltd, were attached with glue in the middle of the top (SG1) and bottom (SG2) of the skin sandwich panel as shown in Fig. 1. The strain gauge was manufactured by Tokyo Sokki Kenkyujo Co. Ltd. with the general specification: type FLG-02-11, gage factor 2.05, length 0.2 mm and width 1.4 mm, resistance 120  $\Omega$  (Bestech 2015).

### 2.2 *The FEA Finite Element Analysis(FEA) Modelling*

The study of the mechanical properties, particularly the tensile specimens, assumed that the panels were constructed with one homogeneous layer with diameter hole, diameter: 3 mm, as indicated in Fig. 2a. The flexural specimen, taken from the sandwich syntactic foam, was assumed to be constructed with two homogeneous layers, which is shown as two skin layers for top- bottom and core in the middle, as shown in Fig. 2b. The diagram was illustrated and simulated using CREO 3.0 Parametric software, which includes simulation analysis and refined meshing methods. The considered sandwich panels were symmetric, i.e., its skins had an identical thickness  $t$ . The thickness of the core was denoted by the symbol  $c$  as the syntactic foam. With reference to the terminology used by Allen, the sandwich panels can be classified as thick skins and non-antiplane core (Allen 1969). The deflection of a thick-skinned and non-antiplane core can be computed using solutions. The first solution was the



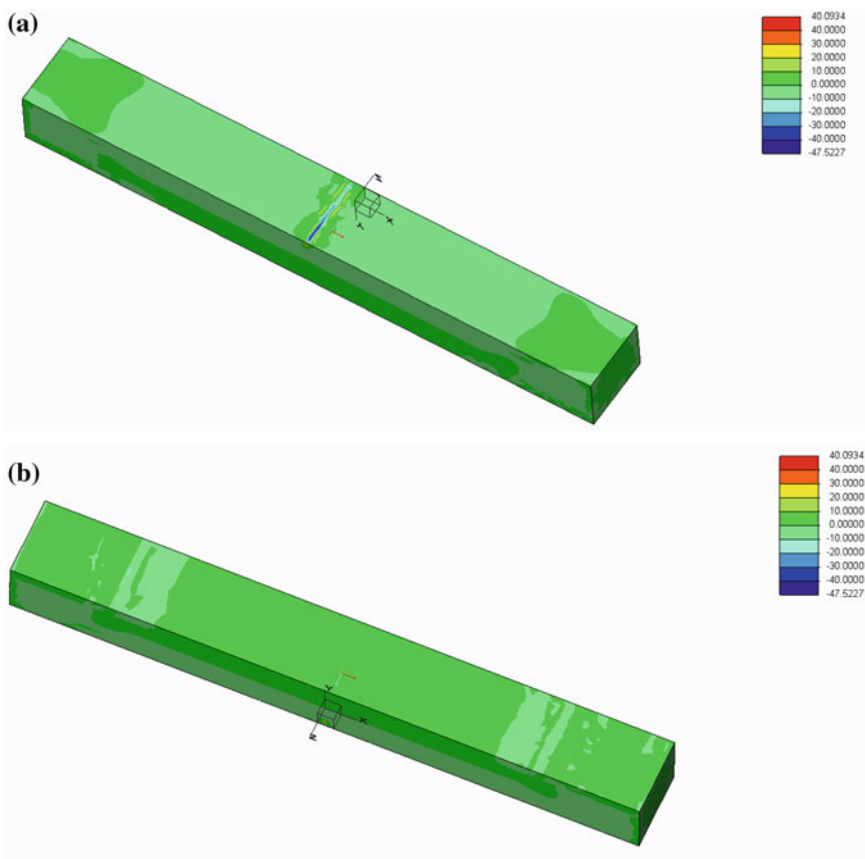
**Fig. 2** Typical flexural 3-point bending specimen is illustrated using CREO 3.0 parametric software for **a** Flexural dimensioned **b** Redefined automesh

approximation that the field along the sandwich core is linear, and the second solution used the Total Potential Energy theorem. Because this study was most likely to use the actual size of the specimens, it was beneficial to continue with this solution. The constitutive model utilised for the foam was considered as a crushable foams plasticity model (Deshpande and Fleck 2000).

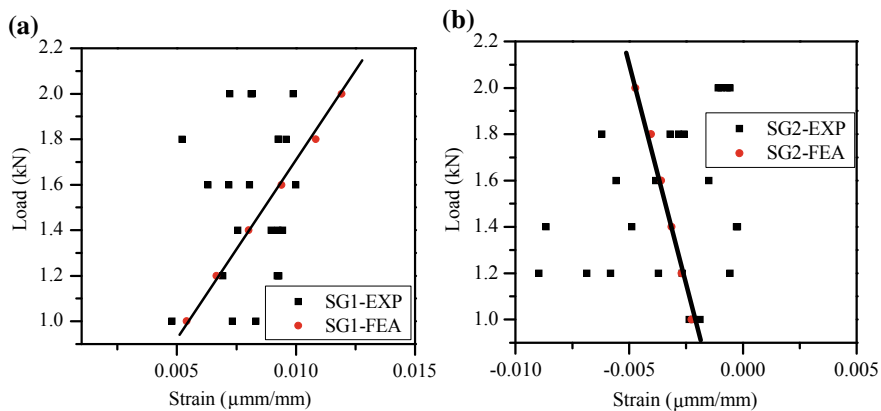
### 3 Result and Discussion

The failure mode pattern of flexure specimens, tested under a 3-points bending test and a FEA analysis using CREO simulation software, is revealed in Fig. 3. The failure mode observed in the flexural test, which was characterised by compressive failure, was also revealed to be due to de-bonding unsymmetrical shear failure between the skin and core areas that were in direct contact with the loading ramps. The crack formation under the flexure testing, due to compression, could clearly be seen in the simulated failure mode shown in Fig. 3a. It was apparent from the simulated failure that the side area (the initial compression zone) was imminent. In the figure, the cracked portion is represented by a blue and red-coloured strip at the side edge area. It is worth noting that whilst the surface contact with the loading rams provided a concave green-coloured shape, the middle area produced a small convex line at the side of the sandwich panels. This simulation confirmed the results obtained from the load-strain relationship that whilst this region is compressed during the initial loading, the increase of the loading until failure shifted the surface into tension mode, as revealed in Fig. 3b, for the support beam condition.

Figure 4 shows the load- $\mu$ strain relationships obtained from both the flexural testing and the FEA simulation. It should be noted that the micro strain values indicated in the figure are the values at the top of the skin (SG1), while another strain gauge (SG2) was located exactly perpendicular with the loading ramp at the bottom mid-span section of the sandwich panel. As can be seen in Fig. 4a, the linear fitting line represented as the FEA simulation was correlated with the experimental micro strain SG1, and then with tabulated data. The peak load obtained from the experiment



**Fig. 3** Comparison of the flexural failure mode of syntactic foam core sandwich panel **a** FEA flexural simulation **b** Support beam dented



**Fig. 4** Comparison of **a** Flexural testing and **b** FEA simulation for SG1 and SG2

SG1 was found to be 2 kN at failure strain  $0.00989 \mu\text{strain}$ . On the other hand, the predicted failure load using the FEA simulation at 2 kN is showed a  $0.01191 \mu\text{strain}$ . In this case, the  $\mu\text{strain}$  value predicted from the FEA simulation was 17% higher than the experimental value. This difference of the value was found to be reasonable, indicating that the FEA simulation predicted the flexural behaviour of syntactic foam sandwich panels well. The peak load obtained from the experiment SG2, for example at 1.2 kN, was at failure strain  $-0.002665 \mu\text{strain}$ . A similar observation applied to the FEA simulation at this loading condition where the strain failure could be  $-0.002743$ . The differences in value between SG2 and the FEA simulation was about 2.7%. Again this value reasonably indicated that the FEA was in good agreement for another comparison  $\mu\text{strain}$  value.

## 4 Conclusion

The prediction of strain value between local strains from the experimental strain gauge was compared with the FEA simulation when their varied load in longitudinal and transverse axes was applied to flexural sandwich panel's syntactic foam. For the tensile specimen, the determination of the stress concentration factor (SCF) used one strain gauge, which was attached near the hole in the middle of the extensometer length. The results show that the SCF values were comparable between experiments with extensometer and SG values, with different percentages from 0.40 to 1.36%. The investigation of SCF for two SG were investigated using a specimen of 10 wt%, which was attached near the hole area at the same position as previous tensile specimens. The comparison and prediction were made between experimental values and the FEA analysis results. It can be estimated that the experimental values of around 90–70% followed the FEA values for SG1 and SG2, respectively. The investigation on the strain value for flexural sandwich panel syntactic foam were also carried out using the FEA approach to predict the properties' behaviour in this study. It was found that the micro strain for SG1 for FEA was 17% higher than the experimental value, even though they were at the same loading setting. However, the prediction for the micro strain of SG2 was only 2.7% different, which was considered a good agreement to predict the properties of syntactic foam core sandwich panel for different loading values.

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