

## **PARAMETRIC STUDY OF THE FLEXURAL BEHAVIOUR OF SANDWICH PANELS WITH FLAX FRP FACES AND FOAM CORES USING FINITE ELEMENT ANALYSIS**

**D. Betts<sup>1</sup>, P. Sadeghian<sup>1\*</sup> and A. Fam<sup>2</sup>**

<sup>1</sup> Department of Civil and Resource Engineering, Dalhousie University  
Halifax, NS, Canada

<sup>2</sup> Department of Civil Engineering, Queen's University  
Kingston, ON, Canada

Email: dillonbetts@dal.ca, pedram.sadeghian@dal.ca, amir.fam@queensu.ca

\* Corresponding Author

### **ABSTRACT**

To meet the growing demands for increased sustainability in infrastructure, it is important to consider the use of more environmentally-friendly materials, such as plant-based fibre-reinforced polymers (FRPs). Plant-based FRPs, such as flax FRPs (FFRPs), can be used to replace their synthetic counterparts in applications where the high strength of synthetic FRPs is underutilized, such as sandwich structures. In this study, the performance of one-way sandwich beams with FFRP faces and foam cores is investigated numerically using the commercially available finite element analysis (FEA) software, LS-DYNA. The main parameter of the study was the effect of the foam core density on the structural performance of sandwich beams loaded under both quasi-static flexural loading. The main modelling challenge for this project was the selection of appropriate material models to accurately predict the behaviour of FFRPs, which are known to exhibit a nonlinear mechanical behaviour. The results of the FEA models were compared to a previous experimental study on panels with core densities of 32 kg/m<sup>3</sup>, 64 kg/m<sup>3</sup> and 96 kg/m<sup>3</sup>. This is on-going research and more results will be available at the time of the conference.

### **KEYWORDS**

Flax, Natural, FRP, Sandwich Panel, Numerical, FEA

### **INTRODUCTION**

Sandwich panels are efficient structures made of two relatively strong and stiff faces separated by a lightweight core. The separation of the two faces provided by the core increases the moment of inertia which gives these panels a high stiffness and flexural rigidity. The faces resist the majority of the bending force, while the core resists shear force. As lightweight foams with high insulative properties can be used as the core material, these structures are ideal for applications where light weight and high insulation are required, such as building cladding materials.

As the core material is typically significantly weaker than the face materials, the capacity of these structures is often limited by the core strength. Traditional sandwich panel faces include: aluminum, glass fibre-reinforced polymers (GFRPs) and carbon fibre-reinforced polymers (CFRPs). As these traditional face materials are underutilized, there is an opportunity to replace these materials with weaker, but more sustainable materials, such as flax fibre-reinforced polymers (FFRPs). The material properties of FFRPs and other natural fibre-reinforced polymers have been investigated and the results show that they exhibit a nonlinear stress-strain response (Betts et al. 2018; Christian and Billington 2011; Sadeghian et al. 2018)

Recently, FFRP-foam sandwich panels have been investigated under flexural loads (Betts et al. 2018; Mak et al. 2015; Mak and Fam 2019; Sadeghian et al. 2018) and axial loads (Codyre et al. 2016). Some



studies have been completed on experimental and finite element (FE) modelling of FFRP-cork sandwich panels under impact loads (Boria et al. 2018). However, in the study by Boria et al. (2018), the nonlinear behaviour of the FFRP faces is not considered. There are currently no studies providing an in-depth look at the behaviour of FFRP-foam sandwich structures under flexural loads using the finite element method (FEM). Therefore, this study will work to fill this gap research by presenting a finite element model of FFRP-foam sandwich panels with different foam densities and including the nonlinear behaviour of the faces.

**NUMERICAL PROCEDURE**

The commercially available finite element analysis (FEA) program LS DYNA was used to simulate the flexural behaviour of FFRP-foam sandwich beams. The models in this study were designed to match the two-layer FFRP-foam specimens tested by Betts et al. (2018). The faces were considered as two-ply bidirectional FFRPs and the cores were considered as polyisocyanurate (PIR) foams with densities of 32 kg/m<sup>3</sup>, 64 kg/m<sup>3</sup> or 96 kg/m<sup>3</sup>. The test matrix examined in this paper is presented in Table 1.

Table 1. Test matrix

Model I.D.	Face Layers	Core Density, kg/m <sup>3</sup>
2FL-C32	2	32
2FL-C64	2	64
2FL-C96	2	96

**Geometry and Loading**

The model layout is presented in Figure 1. To match the tests from the study by Betts et al. (2018), the models were designed as a three-point bending configuration with a 150 mm wide constant displacement at midspan. One support was modelled as a pin and the other was modelled as a roller. The FFRP faces were modelled as 2.75 mm thick, the cores were modelled as 75 mm thick. The span length of the model was 1110 mm.

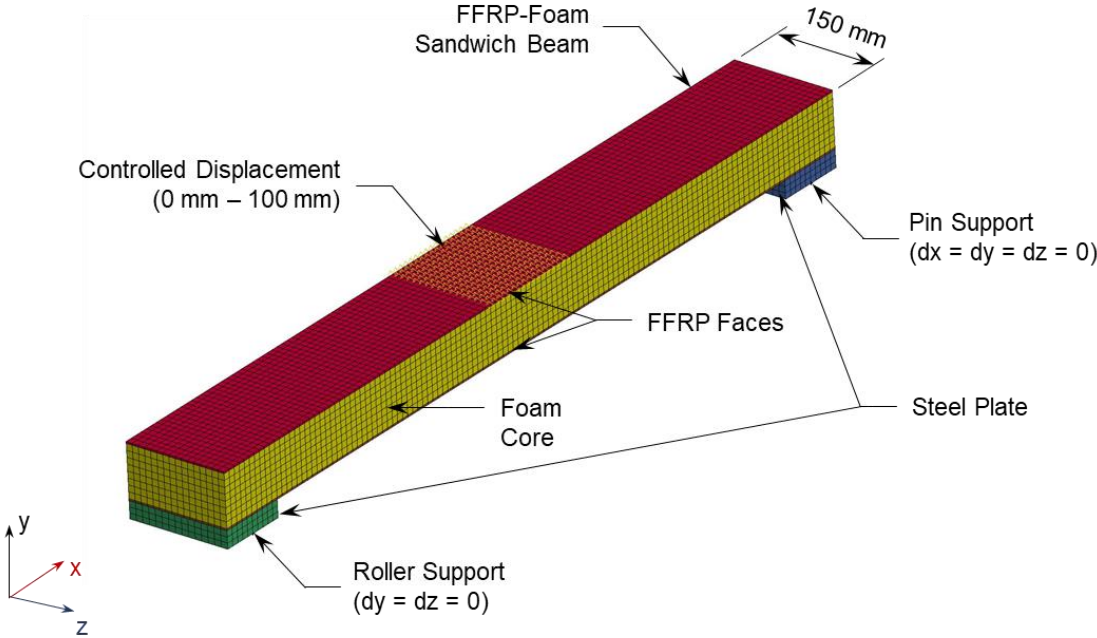


Figure 1. FEA model geometry

**Material Models**

The FE models were designed to incorporate the nonlinear behaviour of the FFRP faces and foam cores. For the FFRPs, this was accomplished by using the material model \*MAT\_NONLINEAR\_ORTHTROPIC and the face failure was considered using \*MAT\_ADD\_EROSION. Separate instances of these material types were used for the top and bottom face to capture the difference in the behaviour

of FFRPs in tension and compression. The stress-strain curves presented by Betts et al. (2018) and shown in Figure 2a were used to model the FFRPs in the longitudinal and transverse direction on the tension and compression face.

For the PIR foam cores, \*MAT\_LOW\_DENSITY\_FOAM was used. This material type can only be used for solid type element, which is why the beams were modelled in 3D. The material properties presented by Codyre et al. (2016) and shown in Figure 2b were used in the material modelling. Future work includes testing of the foams in tension, compression and shear and using the test data to improve the model.

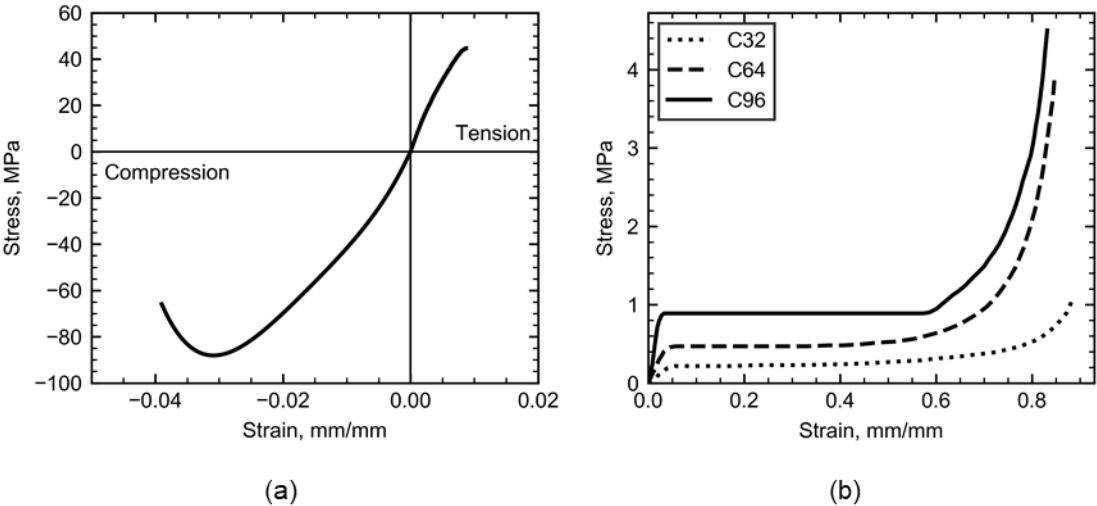


Figure 2. Stress-strain curves of (a) FFRPs (Betts et al. 2018) and (b) PIR foams (Codyre et al. 2016)

**Contacts**

Currently, the FFRP faces and foam cores are connected using the contact type \*CONTACT\_TIED\_SURFACE\_TO\_SURFACE. Future work involves improving the model by using a tiebreak contact to capture the potential failure due to delamination or wrinkling.

**RESULTS AND DISCUSSION**

The load-deflection behaviour predicted by the FEA model is compared to the test data from the study by Betts et al. (2018) in Figure 3.

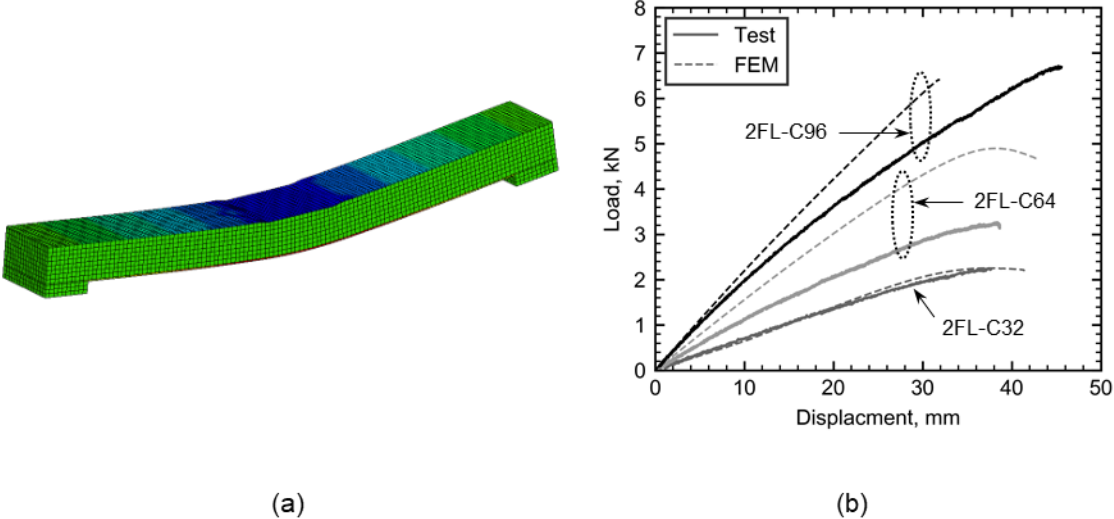


Figure 3. FEA model results (a) bending of model and (b) load-deflection behaviour compared to test data from Betts et al. (2018)

To develop the load-deflection curves, the load was obtained by taking the total resultant forces on the boundary conditions in the model and the deflection was taken as the deflection of a node at the bottom face at midspan.

The accuracy of the models presented in Figure 3 vary. The 2FL-C32 and 2FL C96 models predict the behaviour of the corresponding test specimens well. However, the 2FL-C64 model is overpredicted both the stiffness and strength. It is suspected that this overprediction is due to the use of foam data from another study. However, these are the preliminary results and the model can still be improved through: the use of tiebreak contacts and testing the foams and using the test data to model their behaviour.

## CONCLUSIONS

A finite element method model was developed using a commercially available software to predict the behaviour of FFRP-foam sandwich beams under flexural loads. The main parameter of the modelling was the foam density. The model incorporated the nonlinear behaviour of both the faces and the foam core using material models available as part of the FE software. The model was found to accurately predict the behaviour of the 2FL-C32 and 2FL-C96 specimens, but overpredicted the strength and stiffness. This will be improved in future studies through the testing of the foams under different loading conditions.

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