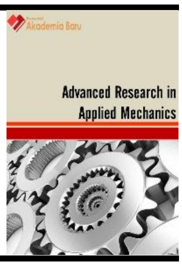
Penerbit Akademia Baru

Journal of Advanced Research in Applied Mechanics

Journal homepage: www.akademiabaru.com/aram.html
ISSN: 2289-7895



Effect of Notch and Notch Size on the Flexural Performance of Flax Fibre Composites

Open Access

Koh Chai Yee[1], Azwan Iskandar Azmi[1,*], Wan Azani Mustafa[1], Aiman Akmal Abdul Nasir[2], Tan Chye Lih[2]

[1] Faculty of Engineering Technology, Universiti Malaysia Perlis, 02100 UniCITI Alam Campus, Padang Besar, Perlis, Malaysia
[2] School of Manufacturing Engineering, Universiti Malaysia Perlis, 02000 Pauh Putra Campus, Pauh, Perlis, Malaysia

ARTICLE INFO

Article history:
Received 5 November 2018
Received in revised form 12 December 2018
Accepted 27 January 2019
Available online 29 January 2019

Keywords:
Flexural performance, flax fibre, notch, size of the notch

ABSTRACT

Demand for environmentally friendly and sustainable fibre reinforced polymer composites have been increasing steadily in recent years. Natural fibres such as flax fibres are commonly used in various applications that include automotive parts and consumer products. Therefore, mechanical properties of the flax fibre are key factors which would affect the quality of product and its acceptance in industries. Effect of drilled hole size on the mechanical performance of flax fibre composites was investigated in thisa research. In particular, the flexural strength of un-notched and notched (drilled with different hole size) flax fibre composites were evaluated. Drilling process was carried out to obtain a a notched specimen. Universal Testing Machine and ASTM D790 were used to determine the flexural data of the un-notched and notched flax fibre composites by performing three-point bendithe ng test. As expected, the notched flax fibre composites have a lower flexural strength than the un-notched flax fibre compoa sites. It was determined that the smaller notched diameter on the flax fibre composites have higher flexural strength compared to that of the larger notch diameter. Conclusively, notch size would highly affect the flexural strength of flax fibre composites.

1. Introduction

In recent years, the demand for natural fibres has been growing consistently. A number of scientific studies and researches have been carried out to develop composite materials from natural resources. Fibres, which come from natural sources such as animals, plants and minerals, are commonly used as reinforcement in the composites. It has been reported that natural fibres have been used in various applications, such as packaging, building, ship and automotive due to their extraordinary properties compared to the other synthetic fibres. One of the popular natural fibre composites is the flax fibre composites. Flax fibre composites are outstanding in biodegradability and sustainability [1]. This fibre has good recyclability that allows reutilization of the material. Prior to a

* *Corresponding author.*
E-mail address: azwaniskandar@unimap.edu.my (Azwan Iskandar Azmi)

wide range of applications of this composite, the evaluation of its strength, particularly tensile and flexural strengths are inevitable [2]. In this project, the main focus will be on evaluating the flexural strength of the flax fibre composite. Flexural strength of fibre reinforced composites can be determined from Standard Test Method for Flexural Properties of Polymer Matrix Composite Materials, ASTM D7264 and ASTM D790 using the Universal Testing Machine. It uses a three point bending system that applied to the specimen at a specific loading rate. The specimen is in the shape of a rectangular bar, cut from moulded or extruded sheets or plates. The flexural performance of fibre reinforced composites is affected by the material constituents, which include the presence of a hole in the composites. Detailed reviews on the effect of notch have been reported in several review papers [3-5]. Earlier research works have reported the effect of drilled hole on the residual tensile strength of flax fibre composites [6-7]. It is clear that delamination damage due to drilling process has a significant influence on the residual tensile strength of the aforementioned composites. Despite that study, the effect of drilled hole sizes on other mechanical performance such as flexural strength of the flax fibre composites is not well reported. Thus, these experimental works aim to evaluate the un-notched (no hole) and notched (drilled hole) flax fibre composites based on their flexural strengths.

2. Experimental Procedure

2.1 Specimen Preparation

A size of 290 mm x 290 mm flax fibre composite panel was cut into 200 mm x 105 mm for the drilling process. The fabrication of the flax fibre composite followed the same procedure as to that of our previous reported studies in [8-9]. Once the drilling process for both 6 mm and 8 mm hole has completed, the specimens were then cut into parallel strips of the 200 mm x 25 mm size for subsequent flexural tests. The cutting process was carried out under dry condition using Makita Band Saw (LB1200F).

2.2 Drilling Method

CNC milling machine; model: Tongtai EZ-5A, was used to drill a hole on the specimens for the flexural test. The tool used during the drilling process was High Speed Steel (HSS) drill bit of 6 mm and 8 mm diameter size. A hole with a diameter of 6 mm was drilled on three of the specimens and another three specimens were with 8 mm in diameter. The spindle speed and feed rate were set as 1000 rpm and 0.1 mm/rev or 100 mm/min feed speed during the drilling process. These two parameters were set constant to ensure that the effect of drilling parameters on drilling damage would be minimised [10].

2.3 Flexural Test

There were a total of 10 specimens tested for their flexural test. The flexural test was conducted under room temperature using a Shimadzu Universal Testing Machine. Three point bending test was carried out to examine the flexural strength or bending strength of the specimens. The parameter of the flexural test is shown in Table 1.

Table 1
Parameters of the flexural test

ASTM	Span Length	Testing Speed	Length	Width	Thickness
D790	160 mm	7 mm/min	200 mm	25 mm	5 mm

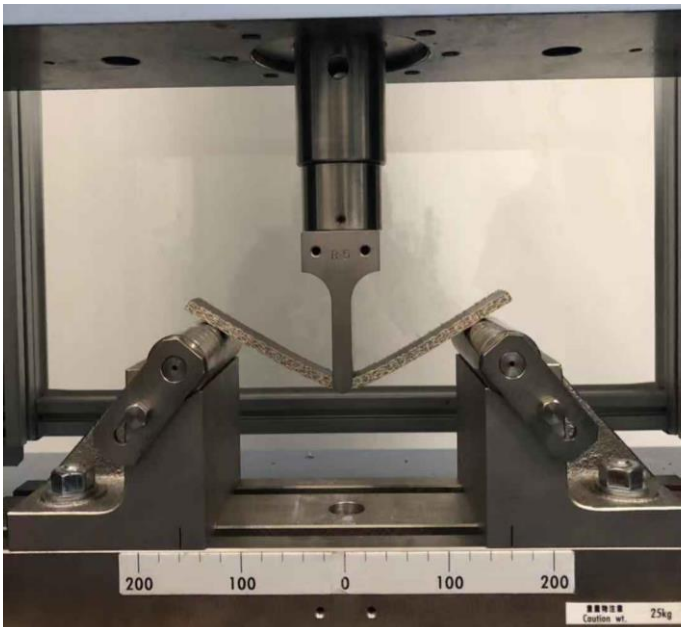


Fig. 1. Three Point Bending Test

2.4 Flexural Measurement

Flexural strength of the notched and un-notched specimens was evaluated according to ASTM D790. The maximum stress occurred at the midpoint of test specimens which defined as flexural stress was calculated by using the equation below [11-12]:

$$\sigma_f = \frac{3PL}{2bd^2} \tag{1}$$

where *σ* is the stress occurred at the midpoint in the outer fibres (MPa), *P* is the load on the load-deflection curve at the given point (N), *L* is the support span in mm, *b* is the beam width in mm and *d* is the beam depth in mm. The following equation was be used if the support span to depth ratios larger than 16/1 such that the deflection that occurred at the support span more than 10%.

$$\sigma_f = \left(\frac{3PL}{2bd^2}\right)\left[1 + 6\left(\frac{D}{L}\right)^2 - 4\left(\frac{d}{L}\right)\left(\frac{D}{L}\right)\right] \tag{2}$$

where *D* is the deflection at the middle of the support span of the centreline of the specimen in mm. A tangent is drawn to the steepest initial straight-line portion of the load-deflection curve to calculate the modulus of flexural. The equation below is used.

$$E_B = \frac{L^3 m}{4bd^3} \tag{3}$$

where E_B is the elasticity modulus in bending (MPa), m is the slope of the tangent to the initial straight-line portion of the load-deflection curve (N/mm).

3. Results and Discussion

The results of un-notched and notched specimens based on the flexural performance were obtained after hj three-point bending tests. Tables 2 below illustrate the variation of force for un-notched and notched specimens obtained through the tests. Maximum stress was determined from the plot of stress vs strain obtained from the flexural tests.

Table 2
Force of un-notched specimen

Specimen		Max Force (N)	Max Stress (N/mm²)	Max Strain (%)
Un-notched	**1**	229.38	80.65	2.08
	2	241.51	86.25	3.70
	3	236.12	84.32	3.70
	4	248.40	81.49	3.73

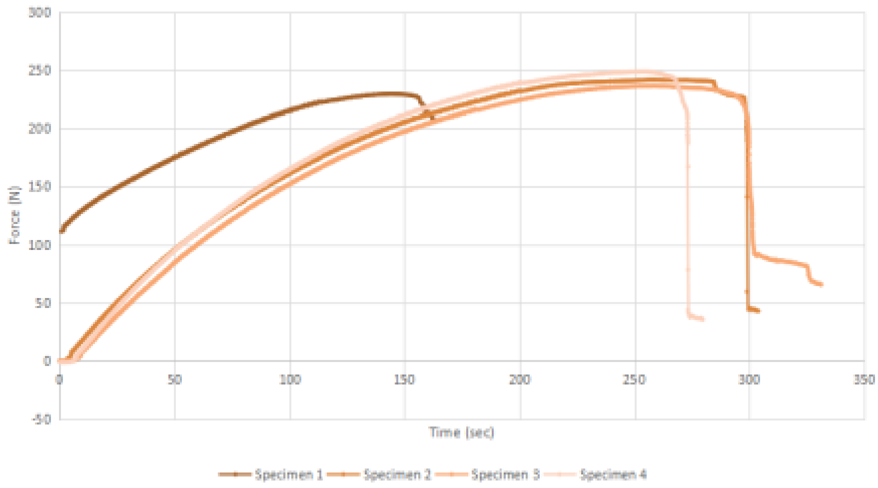


Fig. 2. Graph of the force of un-notched specimen

Table 3
Force of notched specimen with a hole of 6 mm

Specimen		Max Force (N)	Max Stress (N/mm²)	Max Strain (%)
Notched (6 mm)	**1**	194.52	69.37	2.98
	2	203.78	73.14	3.00
	3	185.87	69.84	2.86

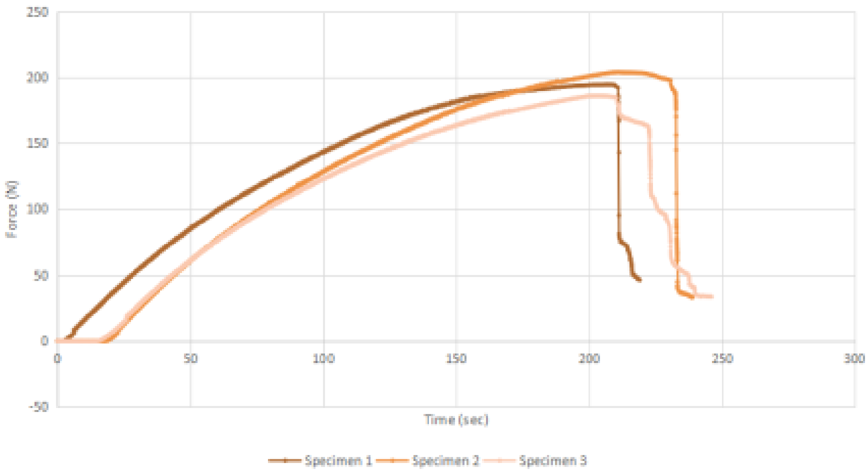


Fig. 3. Graph of the force of notched specimens with a hole of 6 mm

Table 4
Force of notched specimen with a hole of 8 mm

Specimen		Max Force (N)	Max Stress (N/mm^2)	Max Strain (%)
	1	180.55	64.06	2.76
Notched (8 mm)	**2**	171.14	61.25	2.48
	3	189.83	66.07	2.81

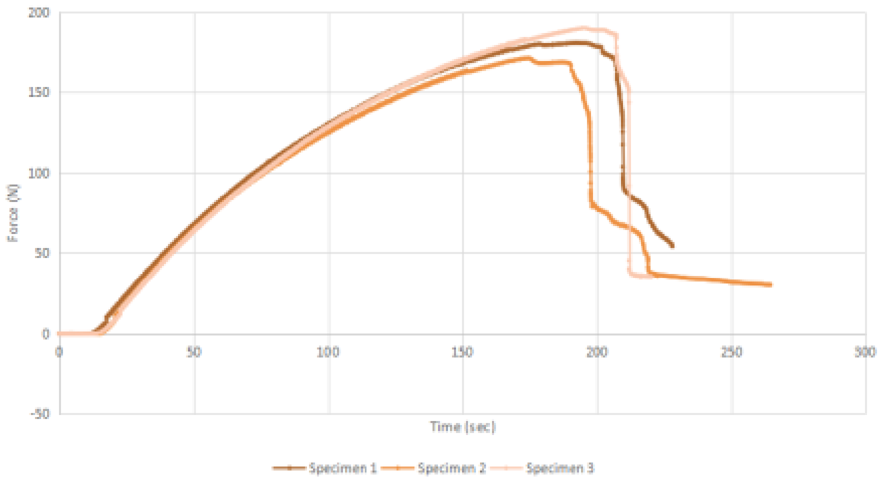


Fig. 4. Graph of the force of notched specimens with a hole of 8 mm

The flexural strengths of the un-notched and notched specimen were calculated using Eq. 1 shown earlier. The flexural strength of the un-notched specimen was 18.48 % higher than the notched specimen with a hole of 6 mm. From the value obtained, it was apparent that the flexural strength of the notched specimen with a hole of 8 mm was reduced by 7.3 % compared to the notched specimen with a hole of 6 mm.

Table 5
Flexural strength of un-notched and notched specimen

Specimen	Flexural Strength (MPa)
Un-notched	91.72
Notched (6 mm)	74.77
Notched (8 mm)	69.31

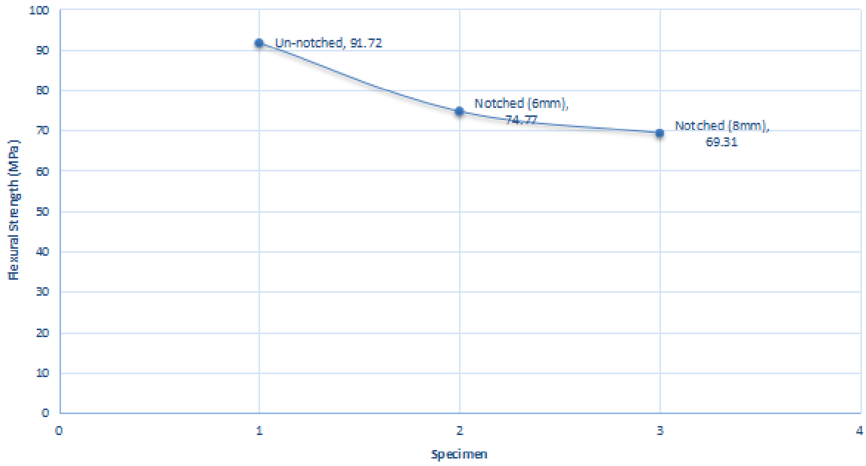


Fig. 5. Graph of flexural strength of un-notched and notched specimens

As expected, the un-notched specimen has the highest flexural strength compared with the notched specimens. The flexural strength of the notched specimen with a hole of 6 mm is higher than the notched specimen with a hole of 8 mm. As a comparison with previous research, the un-notched flax fibre composite was varied in flexural strength due to the specimen depth when conducting the three-point bending test. The flexural strength of flax fibre composite was reduced with an increase in the length of specimen and decrease in the width of the specimen. Based on the result of flexural strength of un-notched specimens, it shows that the presence of notch will have an effect on the flexural strength of flax fibre composite. The existence of notches results in deformation mechanism. Flexural strength was also influenced by the size of the hole that existed on the specimen. The flexural strength reduced gradually with the increase in the size of the hole.

4. Conclusion

It was found that the flexural strength of flax fibre composites was influenced by the presence of a notch. The flexural strength of notched flax fibre composites reduced 18.48% compared to the un-notched flax fibre composites. Besides, the size of the hole also has an effect on the flexural strength of flax fibre composites. The flexural strength of notched flax fibre composite decreased as the size of hole increased. As a result, the flexural strength of the notched flax fibre composite depends on the notch diameter. Therefore, this research study could provide more information for the application of flax fibre composite as reinforcement to enhance the functionality and usability of the flax fibre products in various industries.

Acknowledgments
The authors highly acknowledged the financial support from the Ministry of Education Malaysia

(MOE) under the Fundamental Research Grant Scheme (FRGS) with a grant number of FRGS/1/2016/ TK03/UNIMAP/02/7 (UniMAP Project Code: 9003-00605) and FRGS/1/2013/ TK01/UNIMAP/03/1 (UniMAP Code: 9003-00384).

References

[1] Yan, Libo, Nawawi Chouw, and Krishnan Jayaraman. "Flax fibre and its composites–A review." *Composites Part B: Engineering* 56 (2014): 296-317.

[2] Pit, L., F. Bensadoun, J. Pariset, and I. Verpoest. "Why are designers fascinated by flax and hemp composites." *Compos A Manuf* 82 (2016): 193-205.

[3] Chen, Yinglong, Alvaro Ridruejo, Carlos González, Javier Llorca, and Thomas Siegmund. "Notch effect in failure of fiberglass non-woven materials." *International Journal of Solids and Structures* 96 (2016): 254-264.

[4] Musselman, Eric S., David W. Dinehart, Sarah M. Walker, and Matthew L. Mancini. "The effect of holes on the creep behavior and flexural capacity of laminated veneer lumber (LVL) beams." *Construction and Building Materials* 180 (2018): 167-176.

[5] Wisnom, Michael R., and Stephen R. Hallett. "The role of delamination in strength, failure mechanism and hole size effect in open hole tensile tests on quasi-isotropic laminates." *Composites Part A: Applied Science and Manufacturing* 40, no. 4 (2009): 335-342.

[6] Nasir, AA Abdul, A. I. Azmi, and A. N. M. Khalil. "Measurement and optimisation of residual tensile strength and delamination damage of drilled flax fibre reinforced composites." *Measurement* 75 (2015): 298-307.

[7] Abdul Nasir, Aiman Akmal, Azwan Iskandar Azmi, Tan Chye Lih, Ahmad Nabil Mohd. Khalil, and Nam Kyeun Kim. "Tensile behaviour of open hole flax/epoxy composites: Influence of fibre lay-up and drilling parameters." *Journal of Composite Materials* (2018): 0021998318785955.

[8] Nasir, AA Abdul, A. I. Azmi, and A. N. M. Khalil. "Parametric study on the residual tensile strength of flax natural fibre composites after drilling operation." *Procedia Manufacturing* 2 (2015): 97-101.

[9] Azmi, A. I. "Chip formation studies in machining fibre reinforced polymer composites." *International Journal of Materials and Product Technology* 46, no. 1 (2013): 32-46.

[10] Nassar, Mahmoud MA, Ramanathan Arunachalam, and Khalid I. Alzebdeh. "Machinability of natural fiber reinforced composites: a review." *The International Journal of Advanced Manufacturing Technology* 88, no. 9-12 (2017): 2985-3004.

[11] ASTM D790. Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials. ASTM International, West Conshohocken, PA, 2015.

[12] ASTM D7264. Standard Test Method for Flexural Properties Polymer Matrix Composite Materials. ASTM International, West Conshohocken, PA, 2015.