

# Open Hole Tension of Coir-angustifolia Haw Agave Fibers Reinforced Hybrid Composite after Drilling Process

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**Abstract.** The aim of this paper is to investigate notched (open hole) tensile strength and normalized strength of coir and *angustifolia Haw* agave fibers as reinforcement of hybrid composites. Fabrication of hybrid composite with coir and agave fibers as reinforcement and polyester as the matrix was performed. Coir and agave fibers were formed like a mat. Notched (open hole) hybrid composites were drilled with 6 mm diameter of a hole at center of samples. Tensile testing was conducted to unnotched and notched hybrid composite. Results showed that tensile strength decrease after drilling of a hole in hybrid composite sample center. Normalized strength was range between approximately 75-98%. Tensile fracture of notched samples based on the view of images was around the hole due to concentration stress.

**Keywords:** open hole tension; coir fiber; angustifolia Haw agave; hybrid composite

## 1. Introduction

Natural composites have been applied to various engineering applications such as in automotive and structural applications. Hybrid composite is one of the alternative composite which has been developed. Some researchers have been done about natural hybrid composite and combination of natural and synthetic hybrid composite. Coir/glass hybrid composite has been studied by where coir fiber as core and glass fiber as shell, and woven coir and glass fiber [4]. The tensile strength of coir/glass hybrid composite tends to rise if increasing content of glass fiber in the composite [2]. Then, eco-friendly fibers used as reinforcement of hybrid composite are coir/jute fibers [5], coir/oil palm fibers [6], coir/sisal fibers [7], coir/*angustifolia Haw* agave fibers [8]. Development of these eco-friendly fibers of the hybrid composite is alternatively to change synthetic hybrid composites.

In structural application, such hybrid composites are unavoidable machining process for drilling, milling etc. Drilling of a hole in the structural composite can reduce strength after loading process [9]. Fracture in the notched structural composite is around the hole when loading released [10]. This is caused by stress concentration [9,11].

In this paper, coir fiber and agave fiber as reinforcement in hybrid composite were developed. The tensile strength of unnotched and notched of the hybrid composite after drilling of a hole was investigated. Normalized strength and fracture tensile are also studied.

## 2. Methodology

Hybrid composite is composed of coir and *angustifolia Haw* agave fibers as reinforcement and polyester as matrix. Coir fibers were extracted from coconut husk and agave fibers were extracted from agave leaves using extraction machine. Polyester was used as matrix. This polymer was purchased from local market.

These fibers were cleaned and soaked in 5% w/v NaOH solution for 24 hours. After soaking of NaOH solution, fibers were rinsed with fresh water until NaOH neutral from fibers. Then, these fibers were dried during 2 days at room temperature followed by oven drying for 2 hours. Coir fibers were manually twisted and then twisted fibers were made as coir fiber mat [2]. Meanwhile, agave fibers were composed manually in mat form.

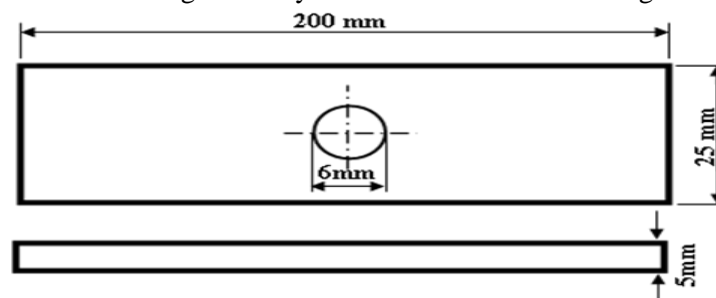


Hybrid composite with coir and agave fiber mats as reinforcement and polyester as the matrix was fabricated using a steel plate mold with hand layup method. The composition of coir and agave fibers in the hybrid composite is 30% (table 1). Coir fiber mat was as core and agave fiber was as skin [8].

**Table 1.** Volume fraction of hybrid composite

Sample	Volume fraction of fiber ( $V_f$ )		Volume fraction of matrix ( $V_m$ )
	Coir (C)	Agave (A)	
30C	30	0	70
10C20A	10	20	70
15C15A	15	15	70
20C10A	20	10	70
30A	0	30	70

Notched (open hole) samples of the hybrid composite were drilled with 6 mm diameter of a hole at the center of samples. Spindle speed of drilled hole sample was 1420 rpm. The sample size for notched tensile testing was shown in figure 1. Notched (open hole) tensile testing is based on ASTM D 5766 and unnotched (without hole) samples is based on ASTM D3039[11]. Controlab Type-200kN Universal Testing Machine (UTM) was used for the tensile testing of samples. After tensile testing, fracture samples were taken the image to analyze fracture tensile and damage behavior.



**Figure 1.** Open hole tension sample

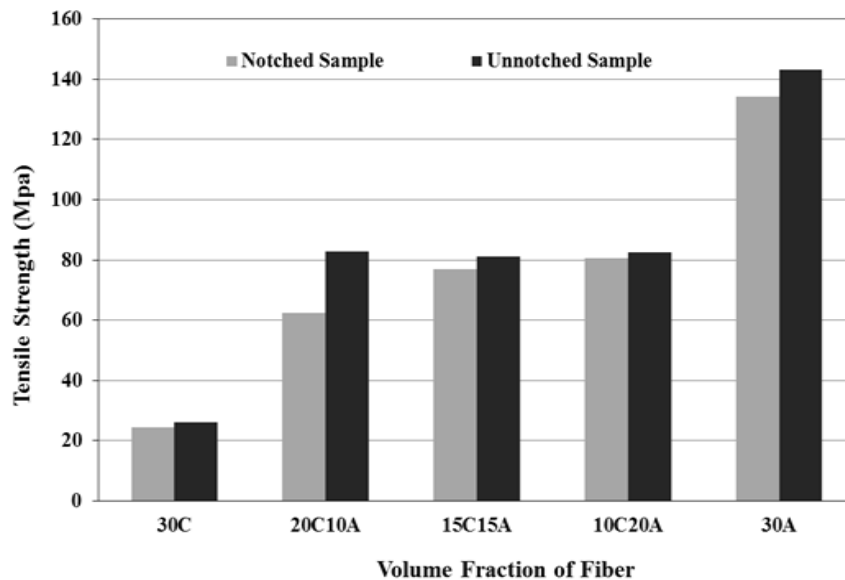
### 3. Results and discussion

#### 3.1. Tensile strength and normalized strength of hybrid composite

The tensile strength of unnotched and notched coir and agave fibers reinforced hybrid composite were shown in table 2 and figure 2. The normalized strength of hybrid composite ( $\sigma_N / \sigma_{UN}$ ) was determined. Notch or hole samples of the hybrid composite were drilled by drilling machine with 1420 rpm spindle speed. Hybridization of coir and agave fibers of composite increase the tensile strength of coir composite as can be seen in figure 2 both notched and unnotched samples. Increasing tensile strength of coir fiber composite was caused by the combination with agave fiber where agave fiber [12] has a higher mechanical property than coir fiber [13]. This condition can be seen in 30A sample which shows the higher tensile strength compared to other samples. Then, unnotched sample tensile strengths are higher than those of the notched samples. As can be seen in figure 2, 20C10A sample has a higher reducing of tensile strength compared to other samples after drilling of a hole in the sample center. Its reducing is approximately 24%. Meanwhile, the normalized strength of 20C10A sample (table 2) is lower than others about 75.35%. For 15C15A and 10C20A samples, their normalized strengths are 94.91% and 97.65% respectively. Reducing the tensile strength of samples after drilling of a hole in the center samples was induced by stress concentration around the hole [9].

**Table 2.** Tensile strength and normalized strength of hybrid composite

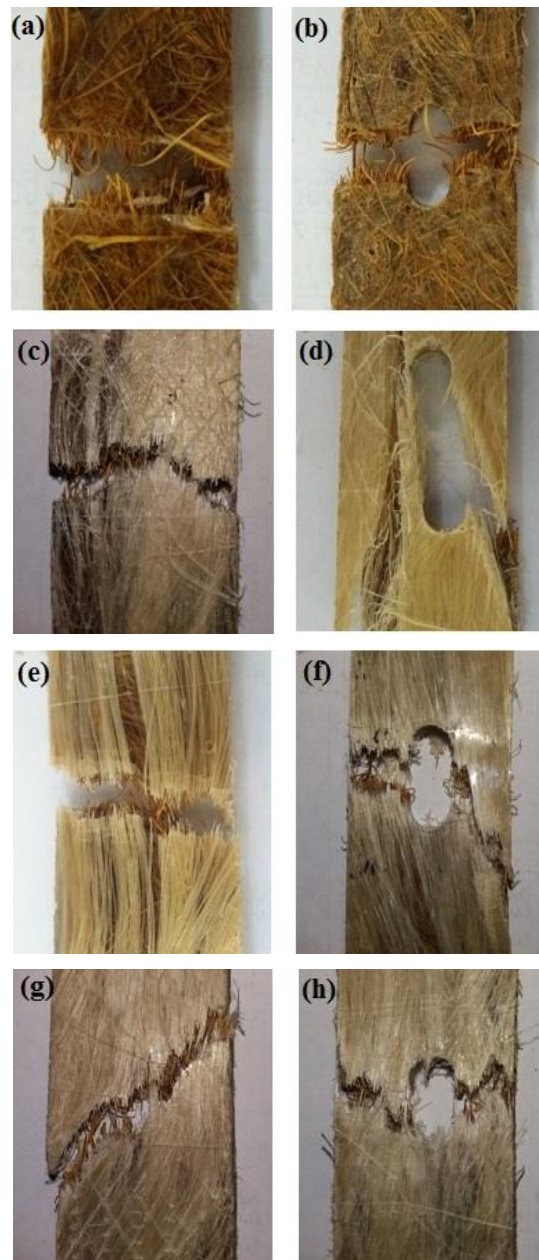
Samples	Unnotched tensile strength ( $\sigma_{UN}$ ) (MPa)	Notched tensile strength ( $\sigma_N$ ) (MPa)	$\sigma_N / \sigma_{UN}$ (%)
30C	26.23	24.44	93.17
20C10A	82.71	62.32	75.35
15C15A	81.19	77.06	94.91
10C20A	82.66	80.71	97.65
30A	143.00	134.09	93.77

**Figure 2.** Tensile strength of unnotched and notched hybrid polyester composite after drilling at the sample.

### 3.2. Tensile fracture

Figure 3 shows tensile fracture and damage behavior for unnotched and notched samples. Unnotched samples of tensile fracture are shown in the figure3. (a), (c), (e), (g) and (i) and notched samples are shown in figure 3. (b), (d), (f), (h) and (j).

Fracture behavior of unnotched and notched hybrid composites can be seen in figure 3 where notched samples are similar of fracture model for hybrid composite. All notched samples are fractured in around hole due to stress concentration when tensile testing applied [9], [11]. Unnotched and notched (open hole)samples fracture model include two models. Firstly, fracture direction is perpendicular to the loading direction of composites. Then, fracture direction is formed about 45 degrees to the loading direction of composites.



**Figure 3.** Fracture tensile of unnotched; (a) 30C, (c) 10C20A, (e) 15C15A, (g) 20C10A, (i) 30A, and notched; (b) 30C, (d) 10C20A, (f) 15C15A, (h) 20C10A, (j) 30A hybrid polyester composite

#### 4. Conclusions

Coir/agave fiber hybrid composite was fabricated by hand layup technique. The tensile testing was used in this research to analyze the effect of notched (open hole) tensile strength and normalized strength after drilled hybrid composite samples. From obtained results can be concluded that after drilling of a hole, the tensile strength of hybrid composite decrease due to concentration stress in around the hole. Then, the normalized strength of coir/agave composite hybrid is range between 75%-98%. In addition, there are two fracture models of unnotched and notched (open hole) samples; fracture direction is perpendicular to the loading direction of composites and formed about 45 degree to the loading direction of composites.

## 5. Acknowledgments

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## 6. References

- [1] Arifin A M T, Abdullah S, Rafiquzzaman M, Zulkifli R and Wahab D A 2014 *Fibers Polym.* **15** 1729–38.
- [2] Bakri B and Eichhorn S J 2010 *Cellulose* **17** 1–11.
- [3] Bakri B, Chandrabakty S and Putra K A 2017 *J. Mek.*, 8 679–685.
- [4] Bakri B, Chandrabakty S and Soe R 2015 *Int. J. Smart Mater. Mechatronics* 2 132–135. \_
- [5] Hamouda T, Hassanin A H, Kilic A, Candan Z and Bodur M S 2015 *Polym. Compos.* 1-9.
- [6] Jayabal S, Natarajan U, and Murugan M *J. Compos. Mater.* **0** 1–7.
- [7] Jayavani S, Deka H, Varghese T O, and Nayak S K 2015 *Polym. Compos.* 1–14.
- [8] Kakou C A , Essabir H, Bensalah M -O, Bouhfid R, Rodrigue D and Qaiss A *J. Reinf. Plast. Compos.* **0** 1-14\_
- [9] Kannan T G, Wu C M and Cheng K B 2012 *Europ. Conf. Compos. Mater. ICCM-15<sup>th</sup>* 1-6.
- [10] Pavithran C, Mukherjee P S and Brahmakumar M 1991 *J. Reinf. Plast. Compos.* **10** 91–101.
- [11] Salleh Z, Berhan M N, Hyie K M, Taib Y M, Kalam A, and Roselina N R N 2013 *Int. Tribol. Conf. Malays.* **68** 399–404.
- [12] Siddika S, Mansura F, Hasan M and Hassan A *Fibers Polym.* **15** 1023–28.
- [13] Silva-Santos L, Hernández-Gómez L H, Caballero-Caballero M and López-Hernández I 2009 *Appl. Mech. Mater.* **15** 103–108.