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The Influence of Woven Density on Tensile Properties of Hybrid Kenaf/Glass Composites

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ABSTRACT

The synergy of natural fibre and synthetic fibre reported to overcome natural fibre drawback. This study focus on, plain weave of kenaf fibre with different weaving density effects on its tensile properties in hybridization with non-woven mat glass. The weaving density directly affect composites fibre loading, increased in weaving density hence increase fibre loading and composite weight. Two type of woven kenaf fabrics were weaved by lab scale self-designed hand loom, varies in warp direction. For comparison purposes, kenaf composite for both type of woven kenaf fabricated by compression moulding. The tensile properties and its failure mechanism were revealed in this study. Kenaf composite with higher woven density shows slightly reduce it tensile strength even though increased in composite fibre loading. Both kenaf composites achieved tensile strength at 83.85 MPa and 75.61 MPa respectively. However, tensile modulus calculated as comparable for both composites with results as 8.92 MPa and 8.29MPa. Hybrid kenaf/glass composites however exhibits, drastic drop in tensile strength and modulus effect of weaving density. Drop in tensile strength about 28% with increased in weaving density, hybrid kenaf low woven density tensile strength measured at 85.5 MPa meanwhile hybrid kenaf high weaving density composites dropped to 51.7 MPa. Tensile modulus for the composites measures at 9.88 MPa and 6. 75 MPa for low and high woven density hybrid composites respectively. Failure mechanism analysis has found that fracture was dominantly by kenaf yarn in both parameters.
KEYWORDS: Woven Density, Kenaf Composites, Hybrid Kenaf/Glass Composites, Tensile Properties, Mechanical Properties.

INTRODUCTION

Hybrid composites are fabricated by combining two or more fibres in a matrix provides the synergy effect reported by [1] to provide better properties than mono-fibre reinforced composites. In order to meet the dynamic engineering requirement composites may fulfil advantages of it hybridization ability results in variation of composites mechanical properties. Sensible in mechanical properties according to the engineering requirement is the aim of hybridization composites, however predicting their properties and behaviour upon synergistic effects between both fibres and the fabrication process will be a challenged. It has been reported that, mechanical properties of hybrid composites primarily affected by fabrication process, fibre type and fibre structure such as fibre-resin fraction, fibre stacking arrangement, number of fibre layers, fibre treatment and environmental exposure [1-2]. However, there are lack of study on influence of weave density on mechanical properties of hybrid woven composites especially on hybrid kenaf composites. Kenaf scientifically known as Hibiscus cannabinus is a natural or bio-fibre that are abundantly available in Malaysia feasible for a wide range of structural applications at comparatively lower cost. It has been reported that kenaf fibre provide high mechanical properties on composites which suitable for structural application [3]. In structural application, both long and woven fibre forms are used as reinforcement [4]. Woven fabric composites are more advantageous than unidirectional(UD) composites in multidirectional loading and high impact resistance by suppressing interlaminar delamination [5]. The study on the effect of kenaf weaving density in kenaf composites is important to provide high-performance material in term of light-strength ratio, since weaving density affect fibre resin percentage and composites weight [6].

LITERATURE REVIEW

Weaving Density

The plain weave structure is determined by yarns interweave in 90 degree angle namely as weft and warp yarn alternately in a single yarn. The weaving characteristics mainly define by crimp percentage, the crimp percentage measured by the waviness of the yarns [7]. The structure of woven fabric determined by many factors;

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properties of yarn, weaving density and direction thus relatively influenced the composite mechanical properties and behaviour reported by [8].

Weaving density may be presenting in many ways one of them is crimped percentage, which plays an important role in the configuration of weaving characteristics. Warp and weft yarn crimps percentage in fabric samples were measured according to ASTM D3883 [9]. Crimp percentage is defined as the mean difference between the straightened thread length and the distance between the ends of the thread while in the cloth, expressed as a percentage [10]. The crimp percentage was calculated using Equation (1).

$$\text{Weaving Crimp \%} = \left(\frac{\text{Straightened yard distance} - \text{Yarn in fabric distance}}{\text{Yarn in fabric distance}}\right) \text{ x } 100\% \quad (1)$$

According to [11], warp and weft densities affect the crimped structure of each yarn in the fabric and increased the crimped yarn in the perpendicular to the load direction reduce the flexural strength of the polymer matrix composite. In tensile properties of off-axis woven composites studied by [8] agreed with [20], multi-stitched woven structure are lower compare to unstitched composite. The tensile strength of woven fabric are effected by crossing points of warp and weft yarns interlace. When a fabric is under uniaxial or biaxial tension, the yarn-yarn interactions at the crossing points are dominant to stress [7].

Tensile Testing

Tensile properties of composite materials is one of the most important mechanical properties to investigate before used in structural applications. Tensile strength define as the ability of a material to resist breaking under tensile load [12]. The theory and schematic diagram of tensile specimen as illustrated in Figure 1 to define tensile properties, specifically tensile strength and its modulus represented as equation below. The determination of tensile strength and tensile modulus will be calculated by using Equations (2) and (3):

$$\delta_\tau = F/A \quad (2)$$

$$E = \sigma / \varepsilon \quad (3)$$

where δ_τ = Composite tensile strength (MPa) and F = Applied force (kN).

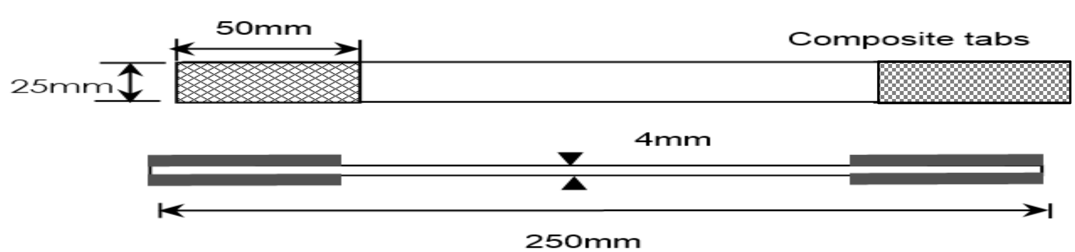


Figure 1: Tensile specimen schematic diagram

where A = Composite sample area cross section (mm^2), E = Composite tensile modulus (MPa), σ = Applied stress(MPa) and ε = experimental strain (mm/mm). Tensile test specimens will be tabbed using woven glass composites of 55x25 mm^2 size.

METHODOLOGY

Materials

The kenaf yarn fibre was supplied by Innovative Pultrusion Sdn. Bhd, Seremban, Malaysia, kenaf yarn linear density measured at 1000tex. The glass fibre non-woven mat and unsaturated polyester wax resin with density 1.3 g/cm^3 used as matrix in this study obtained from S&N Chemical Sdn. Bhd. Properties of all fibres involved are shown in Table 1 [14-15]. The kenaf yarn then weaves using a lab scale self-designed handloom.

Table 1: Kenaf and E-glass properties

Property	Kenaf	E-glass
Fibre Diameter	1000 Tex	12.5 □m
Binder Type	•	Styrene
Weight/Area Density g/m^2	Woven density $1500 g/m^2$	30
Density g/m^3	1.27	1.57
Length	Long Fibre	2 mm

Woven kenaf fabric weaved as illustrated in Figure 2, measured as unbalance plain weave fabric as the weft and warp direction of yarn are not at the same number [6]. Detailed description of weaving fabric described below, weaving type 1 name as K1-kenaf higher density and weaving type 2 name as K2-kenaf lower density.

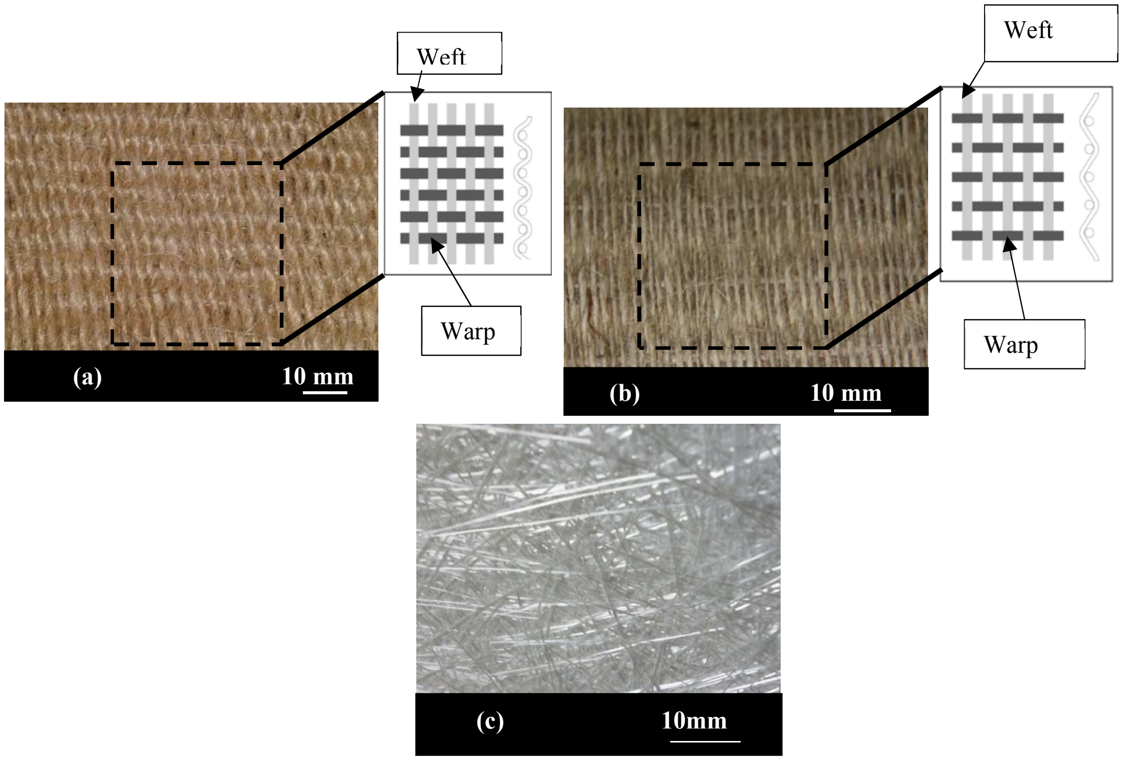


Figure 2: Different kenaf weaving density structures (a) K1-high density (b) K2-low density (c) Non-woven E-glass fibre

Preparation of Hybrid Kenaf Composites

Closed mould compression moulding method was selected for fabrication the kenaf composites. Unsaturated polyester was mixed with methyl ethyl ketone peroxide (MEKP) hardener with 1% wt percentage by the resin. The mixture was then poured and spread evenly on the fibre placed in Aluminium 36cm x 36cm closed mould before compressed at constant one bar pressure. The hybrid composites consist of two layers of kenaf fabric stacked in the same orientation interlayer with glass fibre mat. The density of polyester resin is 1.3 g/cm^3, density of kenaf is 1.4 g/cm^3 [3] and glass mat 1.57 g/cm^3. The composite was let to cure for 24 hours at room temperature before cut into tensile specimen size accordingly.

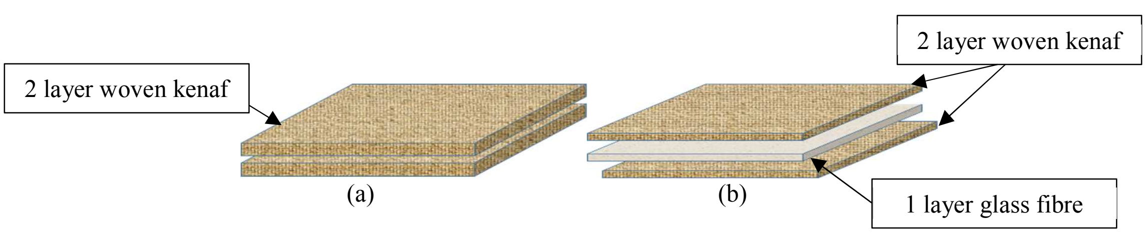
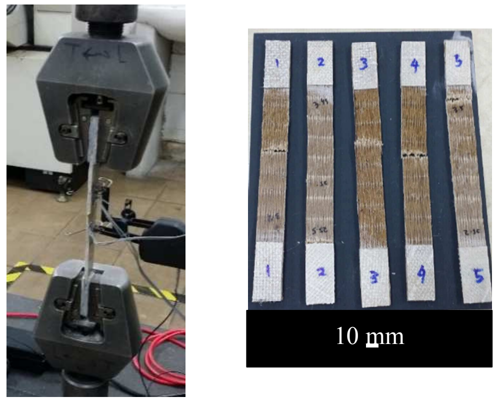


Figure 3: Layering (a) kenaf composites and (b) kenaf/glass composites

Then, the composite plate was cut in the weft direction using band saw into samples size of 250 mm x 25 mm and 150 mm x15 mm for tensile tests according to ASTM D3039 [13]. Tensile test sample were tabbed at both end with woven glass/polyester composites size of 50 mm x 25 mm size.

Testing

Tensile test was performed at the crosshead speed of 2 mm/min using the universal testing machine as illustrated in Figure 4(a). An extensometer was clipped on the specimen with gauge length of 50 mm to measure the elongation of the specimen. Tensile strength, stress, elongation, strain and modulus of kenaf and kenaf/glass composites for both weaving type K1 and K2 were measured by Instron Machine 5980 according to ASTM D3039 [13]. Five replication were done on each composite samples as shown in Figure 4(b) and average results tabulated as in Table 2.



(a) (b)

Figure 4: (a) Tensile test configuration and (b) Tensile specimens

RESULTS AND DISCUSSION

Table 2 shows the results for the weaving type characteristic's, weaving type K1 measured a same weft yarn count per meter length as weaving type K2, 780 yarn/meter length. However, the warp yarn count for K1 is higher compared to K2 with 120 yarn/meter and 80 yarn/meter respectively. The fabric weight per meter square measured as 1750 g/m^2 for K1 and 1500 g/m^2 for K2, with fabric weaving crimp percentage measured using equation 1 56% for K1 and 4.0% for K2, results in higher in fabric weight and crimp percentage for K1. K2 crimp percentage lower as 28.6% compared to K1, and the fabric weight reduced by 14.3% comparing K2 to K1. K2 using less more than 30% of yarn in warp direction and both weaving type is considered as unbalanced plain weave as referred to [16].

Table 2: Specification of different weaving structure

Weaving Type	Weft Yarn Count (yarn/m)	Warp Yarn Count (yarn/m)	Fabric Weight (g/m^2)	Crimp %
Weaving type K1	780	120	1750	5.6
Weaving type K2	780	80	1500	4.0

Table 3, shows the tensile properties and percentage composite fibre volume fraction. K1 composite fibre volume fraction calculated as 37.22% increased to 38.98% when hybridization with glass un-woven mat. K2 composites decreased its percentage composites fibre volume fraction to 33.98% as decreased in woven fabric crimp percentage. Hybrid K2/glass shows increased in fibre volume fraction measured as 35.49%.

Table 3: Tensile properties of kenaf and hybrid kenaf/glass composites

Sample	Composite Fibre Volume Fraction, %	Max. Load (N)	Extension (mm)	Tensile Strain	Tensile Strength (MPa)	Modulus Young's (GPa)
K2	33.98	7441.49	4.30	0.01	83.85	8.92
K2/glass	35.49	8232.21	3.69	0.02	85.49	9.88
K1	37.22	7594.03	4.21	0.01	75.61	8.29
K1/glass	38.98	7195.57	4.45	0.01	57.69	6.75

The tensile properties of composites samples presented in Table 3 shows the higher tensile strength achieved by hybrid K2 and glass, 85.49 MPa, increased from K2 kenaf composites without glass interlayer. This results agreed by studied done [17-18].

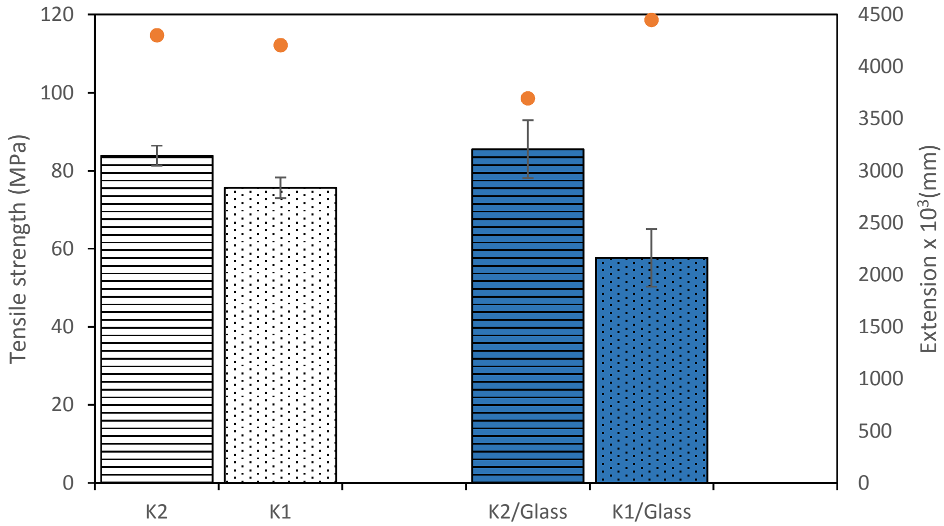


Figure 5: Graph tensile strength and extension

The hybridization kenaf with synthetic fibre increased it tensile properties due to increase in fibre resin percentage [17-18]. However, in high density woven kenaf K1, even though fibre resin percentage increased, tensile strength drop drastically from 75.61 MPa to 57.69 MPa with glass hybridization. K1 composites also shown low in tensile strength value compared to K2 composites, even fibre volume fraction increased by 10%. This results shows others factors affect composites mechanical properties composite fibre resin percentage. According to [19], the formation of the fabric structure may affect the composites tensile strength.

Studied done by [20] found that weaving activities including shedding, insertion and beat-up process results in fibre yarn damage. The continual process during the weaving process persuaded scrape on fibre yarn affect the yarn fibre strength hence influenced the composites mechanical strength. This results agreed with the researcher findings knitting woven process such as fibre interlace tension, weaving density number of warp yarn layers and fibre type influenced composites mechanical properties.

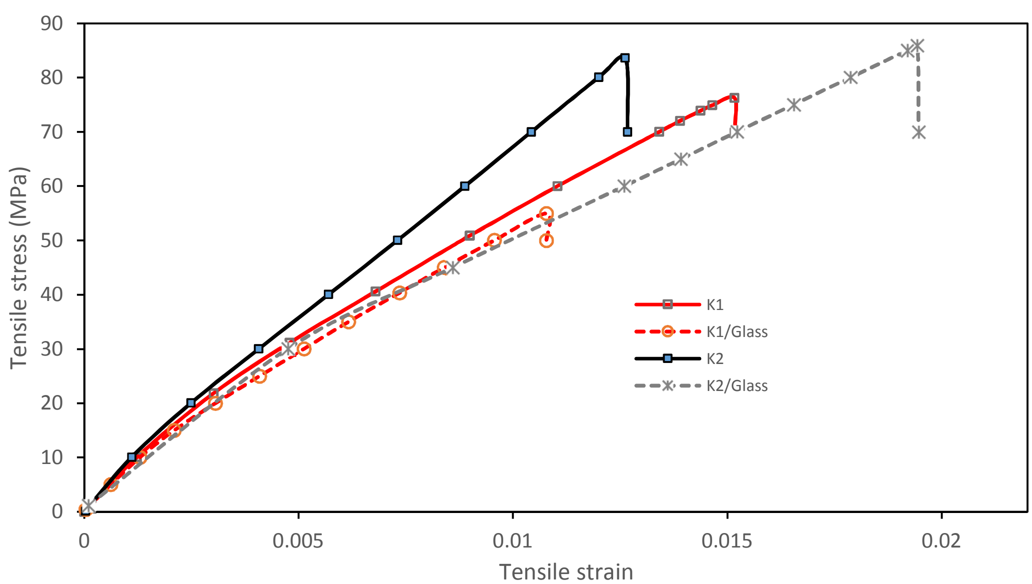


Figure 6: The tensile stress-strain curve kenaf and hybrid kenag/glass composites

Figure 6 shows the behaviour of tensile stress-strain curve during tensile test for selected samples. K2 composites shows linear relation between tensile stress and tensile strain. Hybrid K2 and both K1 composites shows slightly non-linear relation before reach 20MPa stress. Tensile modulus, tensile strength and elongation achieved the best with configuration of K2/Glass referred Table 3.

Failure Modes and Morphology Studies

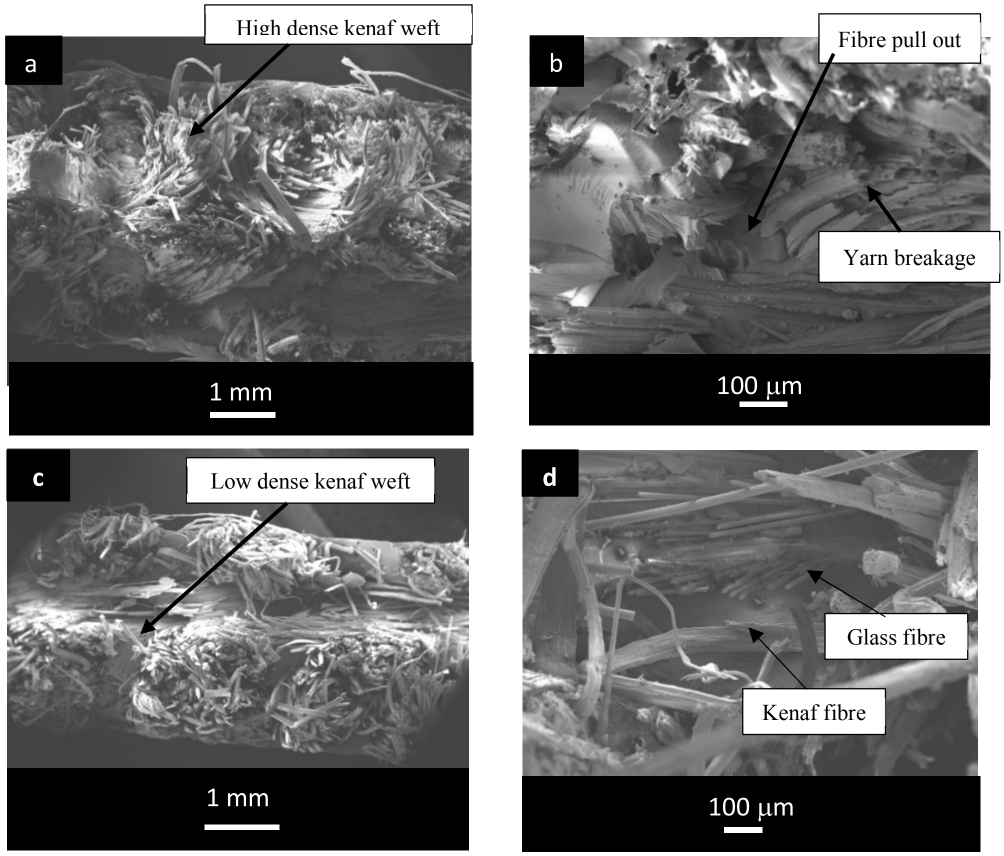


Figure 7: SEM micrographs showing (a), (b) K1 composites (c) K2 composites (d) K2/glass composites

CONCLUSION

The tensile properties of hybrid woven kenaf/glass composites successfully studied, and their performance was compared to control sample kenaf composites focused on influences of weaving density. The hybridization effect proved to increased composites tensile properties only in low density woven. Increased the woven density measured by woven crimp percentage reduce its kenaf composite tensile properties and hybrid kenaf/glass composites. Fibre resin volume percentage influenced the hybrid kenaf/glass on on low density woven. Yarn damage and overtension due to high crimp on higher density woven kenaf results in kenaf yarn damage leads to its decreased in tensile properties. Lowest tensile properties measured on hybrid high woven density, interlayer glass fibre seem worsen the interface of damage yarn as describe in morphology studies.

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REFERENCES

1. Nunna, S., P.R. Chandra, S. Shrivastava and A. Jalan, 2012. A Review on Mechanical Behavior of Natural Fiber Based Hybrid Composites. Journal of Reinforced Plastics and Composites, 31 (11): 759-769.
2. Swolfs, Y., L. Gorbatikh and I. Verpoest, 2014. Fibre Hybridisation in Polymer Composites: A Review. Composites Part A: Applied Science and Manufacturing, 67: 181-200.
3. Atiqah, A., M.A. Maleque, M. Jawaid and M. Iqbal, 2014. Development of Kenaf-Glass Reinforced Unsaturated Polyester Hybrid Composite for Structural Applications. Composites Part B: Engineering, 56: 68-73.
4. Salleh, Z., M.N. Berhan, K.M. Hyie, Y.M. Taib, A. Kalam,and N.R.N. Roselina, 2013. Open Hole Tensile

Properties of Kenaf Composite and Kenaf/Fibreglass Hybrid Composite Laminates. Procedia Engineering, 68: 399-404.
5. Karahan, M., 2014. Effect of Weaving Structure and Hybridization on the Low-Velocity Impact Behavior of Woven Carbon-Epoxy Composites. Journal of Reinforced Plastics and Composites, 33 (2): 212-222.
6. Samian, M.P., 2014. 2 dimension woven kenaf reinforced unsaturated polyester composite. PhD thesis, Universiti Tun Hussein Onn Malaysia, Johor.
7. Pan, N., 1996. Analysis of Woven Fabric Strengths: Prediction of Fabric Strength Under Uniaxial and Biaxial Extensions. Composites Science and Technology, 56 (95): 311-327.
8. Bilisik, K. and G. Yolacan, 2014. Off-Axis Tensile Properties of Multistitched Plain Woven E-Glass/Polyester Composites. Fibers and Polymers,15 (3): 589-598.
9. ASTM International, 2016. ASTM D3883-04(2016): Standard test method for yarn crimp and yarn take-up in woven fabrics. Retrieved from http://database.texnet.com.cn/db-stan/view--310.html.
10. Akgun, M., 2015. Assessment of the Effect of Fabric Constructional Parameters on Surface Roughness of Wool Fabrics. Journal of the Textile Institute, 106 (8): 845-852.
11. Peled, A. and A. Bentur, 2003. Fabric Structure and Its Reinforcing Efficiency in Textile Reinforced Cement Composites. Composites Part A: Applied Science and Manufacturing, 34 (2): 107-118.
12. Alavudeen, A., N. Rajini, S. Karthikeyan, M. Thiruchitrambalam and N. Venkateshwaren, 2015. Mechanical Properties of Banana/Kenaf Fiber-Reinforced Hybrid Polyester Composites: Effect of Woven Fabric and Random Orientation. Materials and Design, 66: 246-257.
13. ASTM International, 2008. ASTM D 3039/D 3039M - 95a: Standard test method for tensile properties of polymer matrix composite materials. Retrieved from http://www-eng.lbl.gov/~dw/projects/DW4234_Material_Testing_234_OriginalFolder/ASTM_D3039.pdf.
14. Saba, N., M.T. Paridah, K. Abdan and N.A. Ibrahim, 2016. Effect of Oil Palm Nano Filler on Mechanical and Morphological Properties of Kenaf Reinforced Epoxy Composites. Construction and Building Materials, 123: 15-26.
15. Nishino, T., K. Hirao, M. Kotera, K. Nakamae and H. Inagaki, 2003. Kenaf Reinforced Biodegradable Composite. Composites Science and Technology, 63 (9): 1281-1286.
16. Hani, A., A. Rashid, C.T. Seang, R. Ahmad and M.J. Mustapha,2013. Impact and Flexural Properties of Imbalance Plain Woven Coir and Kenaf Composite. Applied Mechanics and Materials, 271: 81-85.
17. Yahaya, R., S.M. Sapuan, M. Jawaid, Z. Leman and E.S. Zainudin, 2015. Effect of Fibre Orientations on the Mechanical Properties of Kenaf–Aramid Hybrid Composites for Spall-Liner Application. Defence Technology, 12 (1): 52-58.
18. Yahaya, R., S.M. Sapuan, M. Jawaid, Z. Leman and E.S. Zainudin, 2015. Effect of Layering Sequence and Chemical Treatment on the Mechanical Properties of Woven Kenaf-Aramid Hybrid Laminated Composites. Materials and Design, 67: 173-179.
19. Saiman, M.P., M.S. Wahab and M.U. Wahit, 2014. The Effect of Fabric Weave on Tensile Strength of Woven Kenaf Reinforced Unsaturated Polyester Composite. In the Proceedings of the 2014 International Colloquium in Textile Engineering, Fashion, Apparel and Design, pp: 25-29.
20. Lee, B., K.H. Leong and I. Herszberg, 2001. Effect of Weaving on the Tensile Properties of Carbon Fibre Tows and Woven Composites. Journal of Reinforced Plastics and Composites, 20 (8): 652-670.