



Original Article

Effect of Fiber Volume Fraction on the Mechanical Behavior and Failure Characteristics of Ramie/E-Glass Hybrid Composites



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ABSTRACT

Hybrid natural–synthetic fiber composites have gained increasing attention as lightweight and sustainable materials for structural applications. This study investigated the mechanical properties of hybrid composites reinforced with natural ramie fiber and synthetic E-glass fiber as potential materials for helmets that comply with the Indonesian National Standard (SNI) requirements. The composites were fabricated using the hand lay-up method with different fiber volume fraction ratios: A (20% ramie: 10% E-glass), B (10% ramie: 20% E-glass), C (15% ramie: 15% E-glass), and D (25% ramie: 5% E-glass), while maintaining a constant total fiber content of 30% and 70% epoxy matrix. Prior to fabrication, the ramie fibers were treated with a 5% NaOH alkali solution to enhance the fiber–matrix interfacial bonding. Mechanical characterization was conducted through tensile and flexural tests based on the ASTM D638 and ASTM D790 standards, respectively. The results showed that Specimen B exhibited the highest tensile strength and elastic modulus, reaching 104.38 MPa and 5063.02 MPa, respectively. Meanwhile, the highest flexural strength was obtained for Specimen A, with a value of 41.11 MPa and a flexural modulus of 635.89 MPa. All composite configurations satisfied the minimum strength requirement for SNI-standard helmets (33.93 MPa). However, several defects, such as voids, fiber pull-out, and delamination, were observed, which were mainly attributed to incomplete resin infiltration during the hand lay-up process. Therefore, the application of vacuum bagging or other assisted molding techniques is recommended for future studies to reduce internal defects and improve the quality of composites.

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1. Introduction

In an era of rapid technological development, industries increasingly require advanced materials that exhibit superior mechanical performance and lightweight characteristics. Composite materials have become one of the most widely utilized engineering materials owing to their ability to combine the advantageous properties of different materials. A composite is generally defined as a material system composed of two or more distinct components that remain separate at the macroscopic level but act together to provide improved mechanical properties [1-3]. Composites generally consist of two main elements: a binder or matrix and a reinforcing or filler material [1, 4].

Reinforcement materials are commonly fibers with high strength and stiffness. Fibers used in

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composite structures are generally synthetic or natural [5]. Both types function as reinforcing phases, whereas the matrix serves as a binding medium that transfers external loads to the reinforcement fibers [5, 6]. The matrix, usually composed of polymer-based materials, protects the fibers from environmental damage and maintains the structural integrity of the composite. The selection of matrix materials is typically based on their mechanical properties, thermal resistance, and durability [7, 8].

In recent years, natural fibers have attracted increasing attention as environmentally friendly alternatives to synthetic reinforcements in composites. Ramie (*Boehmeria nivea*), a bast fiber-producing plant, is one promising natural fiber that is widely cultivated in Indonesia. The abundant availability of ramie fibers in Indonesia provides significant potential for their utilization in engineering materials [9-11]. Ramie fibers exhibit several advantageous properties, including high tensile strength, low density, and resistance to biological degradation by fungi and bacteria. In addition, ramie fibers demonstrate good thermal stability, enabling them to maintain their mechanical performance under varying environmental conditions [11, 12].

Ramie plants grow well in warm, humid climates with relatively uniform rainfall distribution. They can be efficiently propagated using both seed and vegetative methods, such as stem and root cuttings [13]. Ramie fibers have a density of approximately 1.5 g/cm³ and a tensile strength ranging from 220 to 938 MPa [14]. Their flexural strength has been reported to be approximately 53 MPa [15]. In comparison, E-glass fiber, a commonly used synthetic reinforcement, exhibits a higher density ranging from 2.55 to 2.76 g/cm³ and provides excellent mechanical performance in composite structures [16].

Several previous studies have reported that increasing the fiber volume fraction in composite materials can significantly improve their tensile strength, elastic modulus, and flexural strength [3, 4, 17]. Furthermore, fiber orientation influences the mechanical behavior of composite materials [10, 15]. However, studies specifically addressing hybrid composites combining natural ramie fibers and synthetic E-glass fibers, particularly with systematically varied fiber volume fractions for helmet applications, remain limited. This gap necessitates further investigation into the optimization of such hybrid systems to meet structural and safety performance requirements.

Therefore, this study aimed to investigate the effect of the fiber volume fraction on the mechanical properties of hybrid composites reinforced with ramie and E-glass fibers for potential helmet applications in accordance with Indonesian National Standard (SNI) requirements. The composites were fabricated using the hand lay-up method with a constant total fiber content while varying the ratio of ramie and E-glass fibers. Prior to fabrication, the ramie fibers were treated with a 5% NaOH solution to enhance fiber-matrix interfacial bonding. Mechanical characterization was conducted through tensile and flexural tests based on the ASTM standards to evaluate the suitability of the developed hybrid composites for protective applications.

2. Methods

2.1. Materials and specimen preparation

Hybrid composite laminates were fabricated using the hand lay-up method, a widely adopted technique for composite fabrication because of its simplicity, cost-effectiveness, and suitability for producing prototypes with uniform fiber distributions [18]. This method allows for careful control of fiber orientation and resin impregnation, which is critical for evaluating the effect of the fiber volume fraction on the mechanical properties.

The composite system comprised ramie fibers as the natural reinforcement, woven E-glass fibers as the synthetic reinforcement, and epoxy resin as the matrix. The total fiber content was fixed at 30% with an epoxy matrix content of 70% to maintain a balance between mechanical performance and workability, as supported by prior hybrid composite studies [19-21]. Four configurations were prepared to investigate the

influence of fiber volume fraction variations between ramie and E-glass fibers on the tensile and flexural performances (Table 1) Table 1.

Table 1 Fiber volume fraction composition of hybrid composites

Specimen	Ramie Fiber (%)	E-glass Fiber (%)	Total Fiber (%)
A	20	10	30
B	10	20	30
C	15	15	30
D	25	5	30

The ratios (ramie/E-glass: 20/10, 10/20, 15/15, and 25/5) were selected based on the literature, which shows that hybridization of natural and synthetic fibers at these proportions optimizes load transfer, interfacial bonding, and overall mechanical performance [22-24]. Prior to composite fabrication, the ramie fibers were subjected to alkali treatment using a 5 wt% NaOH solution to enhance fiber–matrix interfacial bonding. The fibers were immersed in the solution for 6 h, rinsed with distilled water, and dried prior to use.

The epoxy matrix was prepared by mixing epoxy resin and a hardener in a ratio of 2:1. The mixture was carefully stirred to minimize the formation of air bubbles. The mold surface was coated with wax and a peel ply prior to fiber placement. Ramie and E-glass fibers were arranged according to the specified volume fraction variations, followed by resin impregnation using a brush to ensure uniform distribution across the fiber layers.

The composite laminate was cured at room temperature for 24 h under a uniform load to ensure proper consolidation. After curing, the laminates were removed from the mold and cut into test specimens according to ASTM standards. The geometries of the tensile and flexural specimens are shown in Figure 1.

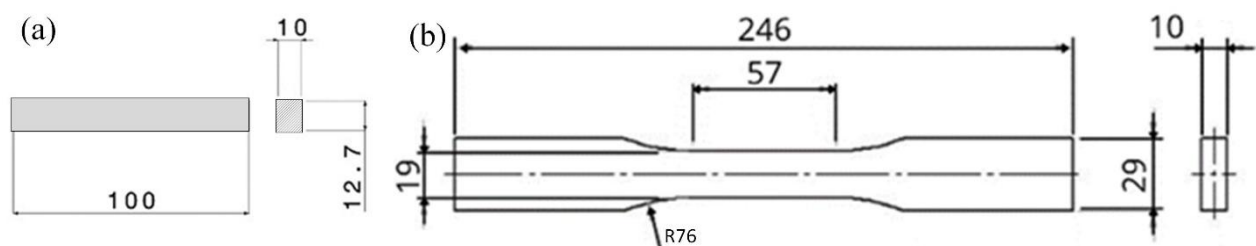


Figure 1. Geometry of the test specimens: (a) bending test specimen and (b) tensile test specimen.

Mechanical testing was conducted in accordance with the ASTM D638 and ASTM D790 standards for tensile and flexural testing, respectively. These tests were performed to determine the tensile strength, elastic modulus, and flexural strength of the hybrid composites.

2.2. Mechanical testing

The mechanical characterization of the hybrid composites was conducted using tensile and flexural tests. Tensile tests were performed in accordance with ASTM D638 to determine the tensile strength and modulus of elasticity. The tests were conducted using a universal testing machine at a constant crosshead speed. During the test, the specimens were subjected to axial tensile loading until failure. The tensile strength was calculated based on the maximum load applied to the specimen using the following equation:

$$\sigma_t = \frac{F}{A} \quad (1)$$

where σ_t is the tensile strength (MPa), F is the maximum applied load (N), and A is the cross-sectional area of the specimen (mm^2).

Flexural testing was conducted in accordance with ASTM D790 using the three-point bending method to evaluate the flexural strength and stiffness of the composite materials. The specimens were placed on two supports and loaded at the midpoint until fracture. The span length and loading rate were determined according to ASTM D790. The flexural strength was determined using the following equation:

$$\sigma_f = \frac{3PL}{2b \cdot d^2} \quad (2)$$

where σ_f is the flexural strength (MPa), P is the maximum applied load (N), L is the support span length (mm), b is the specimen width (mm), and d is the specimen thickness (mm).

For each composite configuration, several specimens were tested to ensure the reliability and repeatability of the results. The obtained mechanical properties were subsequently analyzed to evaluate the effect of the fiber volume fraction on the tensile and flexural performances of the ramie/E-glass hybrid composites.

2.3. Fracture surface analysis

Fracture surface observations were conducted to investigate the failure mechanisms of the hybrid composites following mechanical testing. The fractured specimens obtained from the tensile and flexural tests were examined to identify damage features, such as fiber pullout, void formation, matrix cracking, and interfacial debonding between the fibers and the epoxy matrix.

The fracture surfaces were visually inspected and documented to analyze the interactions between the ramie and E-glass fibers and the epoxy matrix. Particular attention was given to the quality of the fiber–matrix interfacial bonding and the presence of defects that may influence the mechanical performance of the composites. These observations support the interpretation of the mechanical test results.

3. Results and Discussions

3.1. Tensile properties of ramie/e-glass hybrid composites

Figure 2a illustrates the effect of fiber composition on the tensile strength of the ramie/E-glass hybrid composites. The tensile strength values were calculated based on the maximum load obtained during the tensile test using Eq. (1). Specimen B, which comprised 10% ramie and 20% E-glass fibers, exhibited the highest tensile strength among all the tested specimens. In contrast, the lowest tensile strength was observed for Specimen D, which contained 25% ramie and 5% E-glass fibers. This trend indicates that increasing the proportion of E-glass fibers significantly enhanced the tensile performance of the composites. These findings are consistent with those of previous studies, which reported that E-glass fibers possess higher tensile strength and stiffness, thereby improving the load-bearing capability of hybrid composite materials [3, 19].

Furthermore, the tensile strength values obtained in this study exceeded the minimum strength requirement for helmet materials (33.93 MPa). Therefore, the developed hybrid composite demonstrated promising potential as an alternative material for helmet manufacturing and complied with the Indonesian National Standards [20].

Figure 2b shows the load–displacement behavior of the tested specimens. Specimen B exhibited the highest load capacity (2283 kgf), which corresponded to approximately 22386 N. Based on Eq. (1), this load corresponds to a tensile strength of approximately 33.9 MPa, indicating the highest load-bearing capability among the tested composite configurations. This behavior indicates a more efficient stress transfer within the composite structure. This behavior indicates a more efficient stress transfer within the composite structure. The improved mechanical response can be attributed to the hybridization

effect between the natural ramie fibers and synthetic E-glass fibers, which provides a balanced combination of strength and stiffness. Consequently, specimen B exhibited the most favorable tensile performance among the investigated hybrid composite configurations.

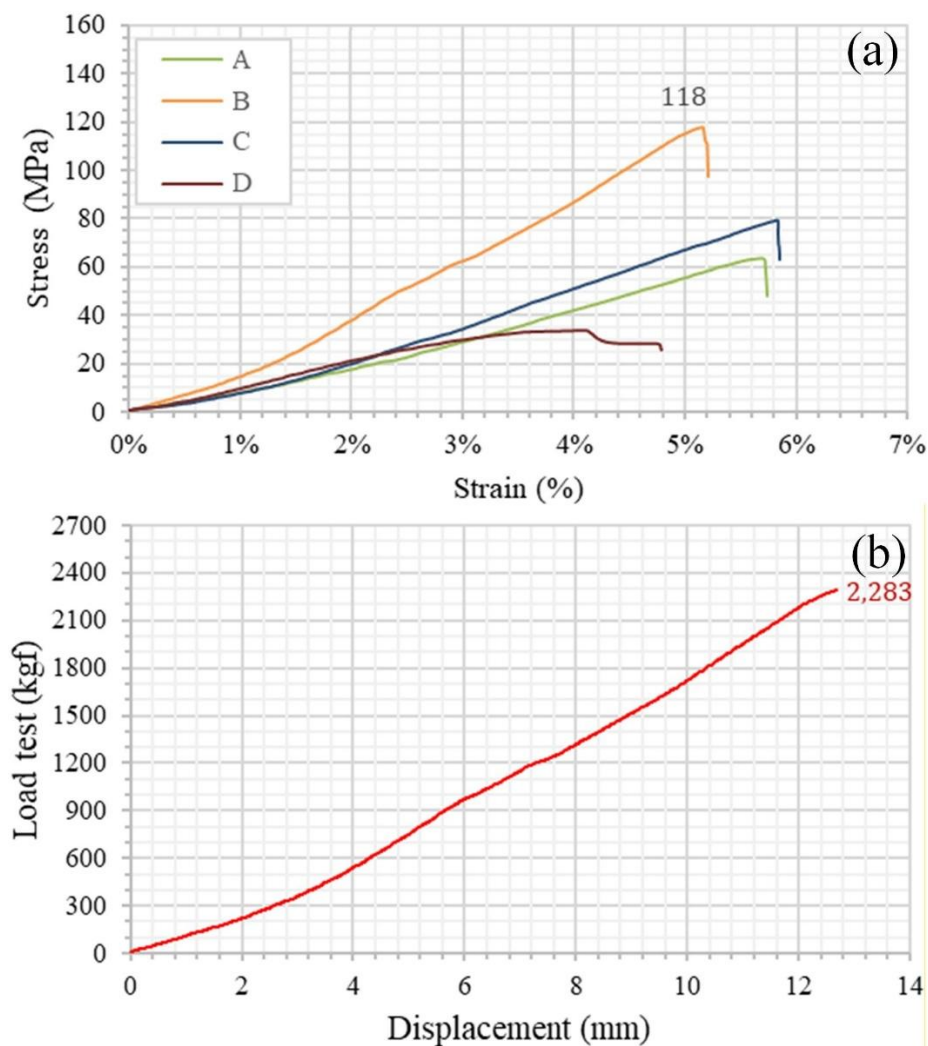


Figure 2. Mechanical test results of the ramie/E-glass hybrid composites: (a) stress–strain curves obtained from tensile testing; (b) specimen B with the highest tensile load.

3.2. Flexural properties of ramie/e-glass hybrid composites

The flexural properties of the ramie/E-glass hybrid composites were evaluated using a three-point bending test in accordance with ASTM D790. The flexural strength values were calculated using Eq. (2), as described in the mechanical testing procedure.

Figure 3a shows the average flexural strength for different fiber compositions. Specimen A (20% ramie, 10% E-glass) exhibited the highest flexural strength of 41.11 MPa, whereas Specimen C (15% ramie, 15% E-glass) had the lowest at 17.15 MPa. Specimens B (10% ramie, 20% E-glass) and D (25% ramie, 5% E-glass) showed flexural strengths of 19.49 MPa and 37.43 MPa, respectively. These results indicate that fiber composition, distribution, and orientation strongly affect bending resistance. Excessively high ramie content, as in Specimen D, can slightly reduce flexural strength owing to weaker fiber–matrix bonding [21].

Figure 3b presents the flexural modulus (ME), showing significant variations among the specimens: A (635.89 MPa) > D (329.92 MPa) > C (183.66 MPa) > B (141.93 MPa). The superior stiffness of Specimen A is attributed to the enhanced fiber–matrix interfacial bonding, facilitated by the alkalization treatment of

ramie fibers, which increases the surface roughness and removes impurities, promoting mechanical interlocking with the epoxy matrix [22, 23]. This improved interfacial shear strength results in more efficient load transfer, higher modulus, and better resistance to bending deformation. Consequently, the interfacial shear strength improved, leading to a higher flexural modulus. Previous studies have reported that such surface modifications significantly enhance interfacial adhesion and flexural stiffness [17, 24].

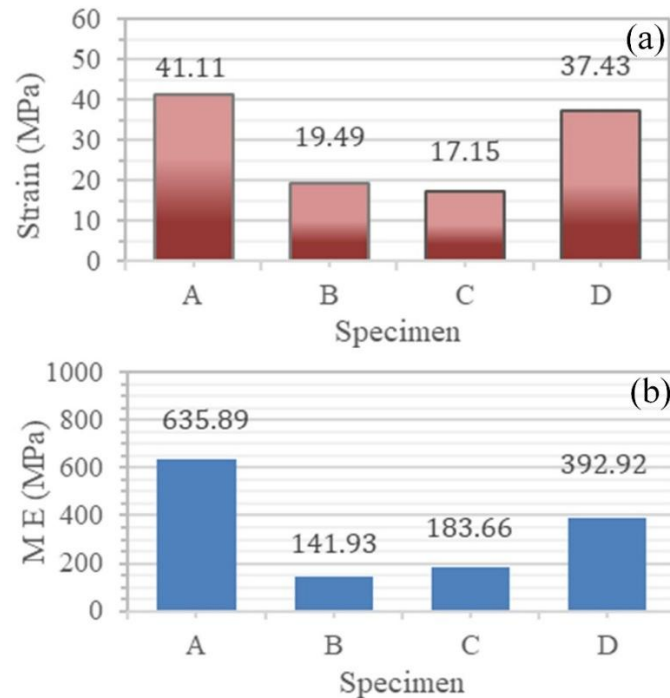


Figure 3. Average flexural properties of ramie/E-glass hybrid composites obtained from three-point bending test: (a) flexural strength and (b) flexural modulus.

Lower modulus values in Specimens B and C suggest less effective interfacial bonding, possibly due to suboptimal fiber distribution, insufficient wetting, or residual surface impurities, thereby reducing the stress-transfer efficiency and causing premature deformation [25]. These observations align with previous studies showing that poorly bonded natural fibers compromise composite stiffness [23, 26].

The high flexural performance of Specimen A also reflects the intrinsic mechanical properties of ramie fibers (tensile strength of ~627 MPa and Young's modulus of ~31.8 GPa) when combined with E-glass fibers and proper surface treatment [12, 27]. Therefore, improving the fiber-matrix adhesion via alkalization or other surface treatments can substantially enhance the modulus of elasticity in flexural testing, as observed for Specimen A [22].

Figure 4 further illustrates the bending behavior of the composite specimens based on the load-displacement response and post-test deformation. Specimen A exhibited the most favorable flexural performance, as indicated by its higher load-carrying capacity and stable deformation behavior before failure. This response suggests a more effective stress distribution and improved resistance to damage under bending loads. The gradual increase in the load with displacement also indicates an enhanced energy absorption capability, reflecting the better toughness of the composite. Therefore, Specimen A demonstrated superior flexural characteristics compared with the other hybrid composite configurations.

3.3. Failure mechanism of ramie/e-glass hybrid composites

The failure mechanisms of the ramie/E-glass hybrid composites were analyzed based on the mechanical test results and post-fracture observations, as shown in Figure 5. These observations provide critical insights into the stress transfer behavior and interfacial integrity under tensile and flexural loading

conditions.

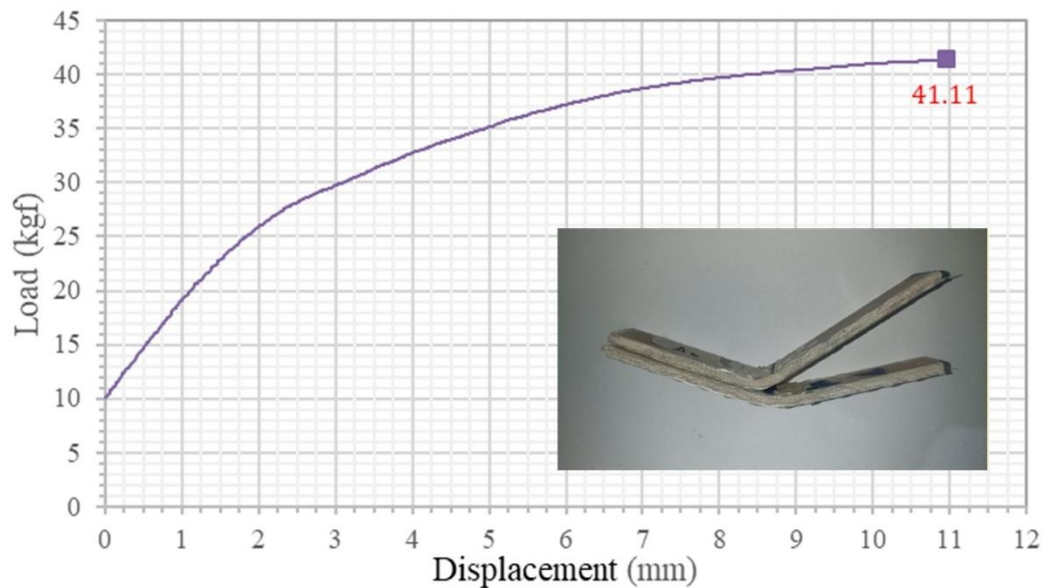


Figure 4. Load–displacement curve and post-test deformation of the ramie/E-glass hybrid composite under flexural loading; the curve indicates the bending response, and the inset shows the deformed specimen after testing.

Under tensile loading, failure is initiated by matrix cracking, followed by fiber–matrix interfacial debonding and subsequent fiber pullout. Specimens with a higher proportion of E-glass fibers, particularly Specimen B, exhibited superior tensile performance owing to the higher stiffness and strength of the glass fibers, which enhanced the load-transfer efficiency and delayed crack propagation. In contrast, specimens with higher ramie fiber content tended to fail earlier, primarily because of the weaker interfacial bonding and lower intrinsic strength of the natural fibers.

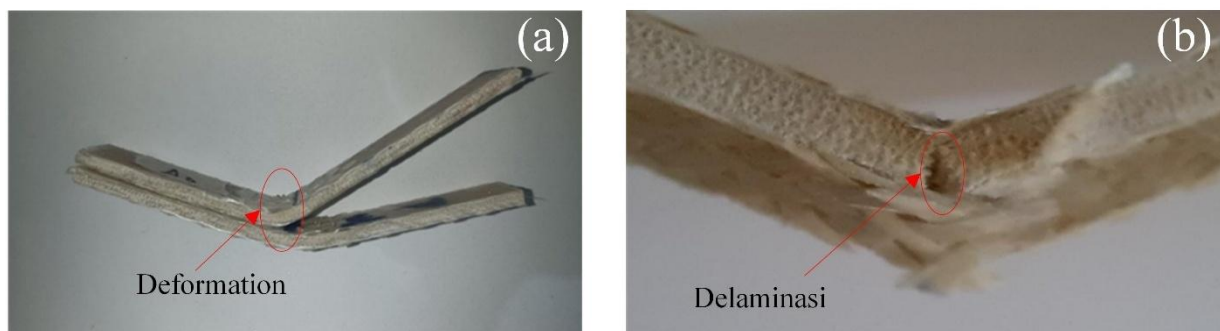


Figure 5. Bending behavior and failure response of ramie/E-glass hybrid composites: (a) deformation behavior under flexural loading and (b) delamination indicating interlaminar failure.

Under flexural loading, failure resulted from the combined effect of tensile stress on the lower surface and compressive stress on the upper surface of the specimen. On the compression side, fiber kinking is the dominant failure mechanism, initiating damage at intermediate load levels and propagating progressively through the laminate. On the tensile side, fiber breakage occurs near the bottom ply and is typically associated with the final failure. In addition, matrix cracking and interlaminar delamination contribute significantly to damage evolution by facilitating crack initiation and propagation along the laminate interfaces [28].

The deformation behavior observed in Figure 5a indicates that the composite can sustain a progressive load prior to failure, reflecting a relatively high fracture energy and improved toughness. This behavior is consistent with the load–displacement response discussed in Section 3.2, wherein a gradual increase in the load signified effective energy absorption and delayed crack propagation. At the microstructural level, toughening mechanisms such as fiber bridging, crack deflection, microcracking, and controlled fiber–matrix

debonding contribute to energy dissipation and enhance fracture resistance [29-31].

As shown in Figure 5b, delamination is a critical interlaminar failure mode that occurs when the interlaminar shear stress (ILSS) exceeds the interfacial bonding strength between the adjacent layers. This failure is primarily associated with manufacturing-induced defects, including voids, non-uniform resin distribution, and insufficient consolidation. These defects degrade interfacial adhesion and create stress concentration sites that accelerate crack initiation and interlaminar propagation [27, 32-35]. Consequently, the structural stiffness and load-bearing capacity of the composites were significantly reduced.

From a fracture mechanics perspective, delamination propagation is governed by the interaction between the fracture energy and interlaminar shear strength. Crack growth is controlled by mixed-mode fracture behavior (Mode I/II), which is influenced by factors such as fiber orientation, ply thickness, and defect size [36]. The coexistence of progressive deformation and interfacial delamination suggests that the overall mechanical performance is determined by the balance between the energy absorption capacity and resistance to interlaminar shear failure.

Furthermore, alkalization treatment of ramie fibers enhances interfacial adhesion by removing surface impurities, such as lignin and hemicellulose, thereby improving the load transfer efficiency and reducing interfacial debonding. This improvement contributed to a more stable and progressive failure mechanism, particularly for the optimal specimen.

Overall, the failure behavior of the hybrid composites was strongly governed by the fiber composition, interfacial bonding quality, and hybridization effects. The optimal configuration demonstrated improved resistance to interlaminar failure, characterized by enhanced energy absorption and controlled crack propagation, confirming its superior mechanical performance.

4. Conclusions

In this study, the effect of the fiber mass fraction on the mechanical behavior and failure characteristics of ramie/E-glass hybrid composites under tensile and flexural loading was systematically evaluated. The key findings are summarized as follows:

- The fiber mass fraction significantly influenced the mechanical performance of the ramie/E-glass hybrid composites, with distinct responses observed under tensile and flexural loading conditions.
- Specimen B (10% ramie/20% E-glass) exhibited the highest tensile strength (104.38 MPa) and elastic modulus (5063.02 MPa), indicating the dominant role of E-glass fibers in enhancing tensile resistance.
- Specimen A (20% ramie/10% E-glass) exhibited the optimal flexural performance, with a flexural strength of 41.11 MPa and modulus of 635.89 MPa, suggesting that balanced hybridization improves bending resistance and stress distribution.
- Failure analysis revealed that voids (v), fiber pullout, and delamination were the primary defects governing the mechanical degradation of the composites.
- Voids act as critical stress concentration sites, reducing the interfacial bonding quality, weakening the load transfer efficiency, and significantly decreasing the interlaminar shear strength (ILSS), thereby promoting premature crack initiation and propagation.
- The presence of manufacturing-induced defects is strongly associated with incomplete resin impregnation and nonuniform matrix distribution, resulting in poor fiber–matrix adhesion.
- Although the composite configurations contained defects, they satisfied the SNI helmet standard requirements, indicating their feasibility for lightweight protective applications.
- The implementation of improved fabrication techniques, such as vacuum bagging, is essential to minimize void content, enhance interfacial bonding, and improve the overall mechanical performance.

This study provides a systematic evaluation of hybrid natural/synthetic fiber ratios and their impact

on mechanical performance, highlighting a design strategy that balances tensile and flexural properties. The findings directly support the development of lightweight helmet materials and offer a novel pathway to optimize hybrid composites for advanced protective applications.

Author's Declaration

Authors' contributions and responsibilities

Muhammad Irfa Nurul Islam contributed to conceptualization, methodology, formal analysis, and writing—original draft preparation. **Hendrix Noviyanto Firmansyah** was responsible for the experimental design, instrumentation, and data visualization of the study. **Shafira Nur Permata** contributed to supervision, project administration, funding acquisition, and writing—review and editing. **Indra Maulana** contributed to investigation, data curation, validation, data processing, statistical analysis, and writing—review and editing.

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Availability of data and materials

All data supporting the findings of this study are available from the corresponding author upon reasonable request.

Competing interests

The authors declare no conflicts of interest related to this study.

References

- [1] M. Yani and F. Lubis, "PEMBUATAN DAN PENYELIDIKAN PERILAKU MEKANIK KOMPOSIT DIPERKUAT SERAT LIMBAH PLASTIK AKIBAT BEBAN LENDUTAN," *MEKANIK: Jurnal Ilmiah Teknik Mesin*, no. Vol 4 No 2 (2018): November 2018, 2018.
- [2] S. B. Setiajit, I. Permana, and M. Ikhsan, "Studi Variasi Fraksi Berat Terhadap Kekuatan Tarik Glass Fiber Reinforced Polymer Hybrid Sabut Kelapa," *Teknika*, vol. 9, no. 1, pp. 96-103, 2024. doi: <https://doi.org/10.52561/teknika.v9i1.296>
- [3] V. Jaiganesh, K. Senthilnathan, T. Kumarasan, R. Saravanan, S. Nanthakumar, and R. Girimurugan, "Influence of fibre on mechanical behavior of Ramie fibre /polystyrene hybrid composite," *Materials Today: Proceedings*, 2023/05/23/ 2023. doi: <https://doi.org/10.1016/j.matpr.2023.05.267>
- [4] J. Yang, Y. Guo, L. Yao, Q. Ni, and Y. Qiu, "Effects of Kevlar volume fraction and fabric structures on the mechanical properties of 3D orthogonal woven ramie/Kevlar reinforced poly (lactic acid) composites," *Journal of Industrial Textiles*, vol. 47, no. 8, pp. 2074-2091, 2018/05/01 2018. doi: <https://doi.org/10.1177/1528083717720204>
- [5] M. H. Shakir and A. K. Singh, "Ramie fiber and its composites: A review," *Polymer Composites*, vol. 46, no. 8, pp. 6813-6841, 2025/06/10 2025. doi: <https://doi.org/10.1002/pc.29417>
- [6] H. Harsi, N. H. Sari, and S. Sinarep, "KARAKTERISTIK KEKUATAN BENDING DAN KEKUATAN TEKAN KOMPOSIT SERAT HYBRID KAPAS/GELAS SEBAGAI PENGGANTI PRODUK KAYU," *Dinamika Teknik Mesin: Jurnal Keilmuan dan Terapan Teknik Mesin*, no. Vol 5, No 2 (2015): Dinamika Teknik Mesin: Jurnal Keilmuan dan Terapan Teknik Mesin, 2015.
- [7] R. Alfiansyah, F. Majedi, and K. N. Faizin, "Analisis Pengujian Bending Komposit Serat Sabut Kelapa (Cocos Nucifera) Dengan Matriks Polyester Sebagai Bahan Cover Intake Manifold,"

- JEECAE (Journal of Electrical, Electronics, Control, and Automotive Engineering)*, no. Vol. 9 No. 1 (2024), pp. 12-15, 2024.
- [8] G. Gugun, A. R. Ramadhan, and A. Wagiman, "Pengaruh Ukuran Serbuk Sabut Kelapa Bermatrix Polyester Terhadap Uji Bending dan Uji Scanning Electron Microscopy (SEM)," *Rekayasa Energi Manufaktur*, vol. 8, no. 1, pp. 21-28, 2023. doi: <http://doi.org/10.21070/rem.v8i1.1658>
- [9] H. F. Annisa and A. Mahyudin, "Pengaruh Fraksi Volume Serat Pinang dan Serat Rami Terhadap Sifat Fisis dan Mekanik Komposit Hibrid Sebagai Bahan Dasar Dashboard Mobil," *Jurnal Fisika Unand*, vol. 14, no. 1, pp. 68-74, 01/29 2025. doi: <https://doi.org/10.25077/jfu.14.1.68-74.2025>
- [10] Y. Du, N. Yan, and M. T. Kortschot, "The use of ramie fibers as reinforcements in composites," in *Biofiber Reinforcements in Composite Materials*, O. Faruk and M. Sain, Eds.: Woodhead Publishing, 2015, pp. 104-137.
- [11] M. Ismayati, M. A. R. Lubis, W. Fatriasari, Sudarmanto, F. P. Sari, F. Falah, N. N. Solihat, A. Karimah, A. P. Wulandari, A. Rahman, J. Kusmoro, B. Irawan, and Suryana, "Chemical and Thermal Properties of Different Type of Indonesian Ramie Fibers," in *Proceedings of the 10th International Symposium for Sustainable Humanosphere*, Singapore, 2025, pp. 79-92: Springer Nature Singapore. doi: https://doi.org/10.1007/978-981-19-1422-5_6
- [12] H. Pratiwi, Kusmono, and M. W. Wildan, "Enhancing properties of unidirectional ramie fibers-reinforced polyester composites via alkali and oxalic acid treatments," *Results in Engineering*, vol. 25, p. 104164, 2025/03/01/ 2025. doi: <https://doi.org/10.1016/j.rineng.2025.104164>
- [13] M. M. Ilham and H. Istiqlaliyah, "Pemanfaatan Serat Rami (Boehmeria Nivea) Sebagai Bahan Komposit Bermatrik Polimer," *Jurnal Mesin Nusantara*, vol. 2, no. 2, pp. 34-41, 2019. doi: <https://doi.org/10.29407/jmn.v2i1.13125>
- [14] B. Koohestani, A. K. Darban, P. Mokhtari, E. Yilmaz, and E. Darezereshki, "Comparison of different natural fiber treatments: a literature review," *International Journal of Environmental Science and Technology*, vol. 16, no. 1, pp. 629-642, 2019/01/01 2019. doi: 10.1007/s13762-018-1890-9
- [15] R. Prasetyo and M. A. Irfai, "PENGARUH KONSENTRASI LARUTAN KOH DAN ARAH ORIENTASI SERAT RAMI TERHADAP KEKUATAN BENDING KOMPOSIT DENGAN Matrik POLYESTER," *Jurnal Teknik Mesin*, vol. 9, pp. 75-80, 2021.
- [16] A. P. Irawan, P. T. Anggarina, D. W. Utama, N. Najid, M. Z. Abdullah, J. P. Siregar, T. Cionita, D. F. Fitriyana, J. Jaafar, A. E. Hadi, and T. Rihayat, "An Experimental Investigation into Mechanical and Thermal Properties of Hybrid Woven Rattan/Glass-Fiber-Reinforced Epoxy Composites," *Polymers*, vol. 14, no. 24, p. 5562. doi: <https://doi.org/10.3390/polym14245562>
- [17] M. B. N. RAHMAN and B. P. KAMIEL, "Pengaruh Fraksi Volume Serat terhadap Sifat-sifat Tarik Komposit Diperkuat Unidirectional Serat Tebu dengan Matrik Poliester," *JURNAL ILMIAH SEMESTA TEKNIKA*, vol. 14, pp. 133-138, 2011. doi: <https://doi.org/10.18196/st.v14i2.542>
- [18] K. Nicolaus Ardi, S. Ferry, and S. Edi, "PENGUJIAN TARIK KOMPOSIT SPESIMEN CAMPURAN SERAT PISANG ALUR DIAGONAL DAN PASIR BESI DENGAN Matrik RESIN POLYESTER DENGAN METODE HAND LAY-UP," *Teknika STTKD: : Jurnal Teknik, Elektronik, Engine*, no. Vol 8 No 2 (2022): TEKNIKA STTKD: JURNAL TEKNIK, ELEKTRONIK, ENGINE, pp. 281-288, 2022. doi: <https://doi.org/10.56521/teknika.v8i2.657>
- [19] L. Banowati, M. Yudhistira, and H. Hartopo, "Analisis Perbandingan Kekuatan Komposit Hybrid Sandwich Serat Rami-E-Glass/Epoxy Berdasarkan Variasi Ketebalan Core Kayu Balsa Terhadap Kemampuan Uji Bending," in *Prosiding Seminar Nasional Teknologi Informasi dan Kedirgantaraan 2022*, pp. 69-78. doi: <http://dx.doi.org/10.28989/senatik.v7i0.465>
- [20] G. W. Samsarga, S. D. Sudarsa, A. L. Suyata, and K. H. Parikesit, "Importance of Indonesian National Standard (SNI) Helmet Usage in Preventing Maxillofacial Injury among Motorbike Drivers in Indonesia: A review," *Intisari Sains Medis*, vol. 15, no. 2, pp. 544-546, 2024. doi: <https://doi.org/10.15562/ism.v15i2.2028>

- [21] F. F. Nurdiansyah, S. Sulardjaka, and N. Iskandar, "PENGARUH FRAKSI MASSA DAN ARAH ORIENTASI SERAT TERHADAP KEKUATAN TEGANGAN GESER KOMPOSIT BERPENGUAT SERAT RAMI DENGAN MATRIKS GONDORUKEM," *JURNAL TEKNIK MESIN*, arah orientasi serat; fraksi massa; gondorukem; greencomposite; serat rami vol. 9, no. 1, pp. 81-90, 2021-01-10 2021.
- [22] Y. Feng, Y. Hu, G. Zhao, J. Yin, and W. Jiang, "Preparation and mechanical properties of high-performance short ramie fiber-reinforced polypropylene composites," *Journal of Applied Polymer Science*, vol. 122, no. 3, pp. 1564-1571, 2011/05/26/ 2011. doi: <https://doi.org/10.1002/app.34281>
- [23] F. M. Margem, S. N. Monteiro, J. Bravo Neto, R. J. S. Rodriguez, and B. G. Soares, "The dynamic-mechanical behavior of epoxy matrix composites reinforced with ramie fibers," *Matéria (Rio de Janeiro)*, vol. 15, no. 2, pp. 164-171, 2010/01/01/ 2010. doi: <https://doi.org/10.1590/S1517-70762010000200012>
- [24] E. Widodo, Mulyadi, A. K. Garside, W. A. Wirawan, and N. H. M. Yaakob@Ariffin, "Enhancing adhesivity and mechanical performance of sansevieria fiber-reinforced composites through alkali treatment," *South African Journal of Chemical Engineering*, vol. 54, pp. 167-178, 2025/10/01/ 2025. doi: <https://doi.org/10.1016/j.sajce.2025.07.007>
- [25] P. K. Kushwaha and R. Kumar, "Effect of Silanes on Mechanical Properties of Bamboo Fiber-epoxy Composites," *Journal of Reinforced Plastics and Composites*, vol. 29, no. 5, pp. 718-724, 2009/02/13/ 2009. doi: <https://doi.org/10.1177/0731684408100691>
- [26] V. Mohanavel, T. Raja, A. Yadav, M. Ravichandran, and J. Winczek, "Evaluation of Mechanical and Thermal Properties of Jute and Ramie Reinforced Epoxy-based Hybrid Composites," *Journal of Natural Fibers*, vol. 19, no. 14, pp. 8022-8032, 2021/08/13/ 2021. doi: <https://doi.org/10.1080/15440478.2021.1958432>
- [27] S. S. Salins, S. Shetty, and H. K. Sachidananda, "Investigating energy absorption and crack propagation in natural rubber-epoxy composites: design, fabrication, and fracture analysis," *Polymer Bulletin*, vol. 82, no. 11, pp. 5463-5491, 2025/04/03/ 2025. doi: <https://doi.org/10.1007/s00289-025-05738-y>
- [28] I. R. Chowdhury, N. H. Nash, A. Portela, N. P. O'Dowd, and A. J. Comer, "Analysis of failure modes for a non-crimp basalt fiber reinforced epoxy composite under flexural and interlaminar shear loading," *Composite Structures*, vol. 245, p. 112317, 2020/04/03/ 2020. doi: <https://doi.org/10.1016/j.compstruct.2020.112317>
- [29] A. Riccio, A. Russo, A. Sellitto, C. Toscano, D. Alfano, and M. Zarrelli, "Experimental and Numerical Assessment of Fibre Bridging Toughening Effects on the Compressive Behaviour of Delaminated Composite Plates," *Polymers*, vol. 12, no. 3, p. 554, 2020/03/03/ 2020. doi: <https://doi.org/10.3390/polym12030554>
- [30] A. Siddique, S. Abid, F. Shafiq, Y. Nawab, H. Wang, B. Shi, S. Saleemi, and B. Sun, "Mode I fracture toughness of fiber-reinforced polymer composites: A review," *Journal of Industrial Textiles*, vol. 50, no. 8, pp. 1165-1192, 2019/06/24/ 2019. doi: <https://doi.org/10.1177/1528083719858767>
- [31] S. Kamat, X. Su, R. Ballarini, and A. H. Heuer, "Structural basis for the fracture toughness of the shell of the conch *Strombus gigas*," *Nature*, vol. 405, no. 6790, pp. 1036-1040, 2000/06/01/ 2000. doi: <https://doi.org/10.1038/35016535>
- [32] X. Han, H. Cai, J. Sun, Z. Wei, Y. Huang, L. Meng, and A. Wang, "Numerical investigation on behaviors of composite laminates with initial delamination defects under impact and compression after impact," *Polymer Composites*, vol. 44, no. 1, pp. 413-431, 2022/10/17/ 2022. doi: <https://doi.org/10.1002/pc.27106>
- [33] M. Yu, H. Liu, R. Xiao, X. Liu, W. Xie, L. Ge, L. Fang, M. Ren, and J. Sun, "Residual strength and failure mechanism of <sc>CF</sc>/<sc>PPS</sc> composites with delamination damage," *Polymer Composites*, vol. 45, no. 13, pp. 12391-12404, 2024/06/11/ 2024. doi:

- <https://doi.org/10.1002/pc.28643>
- [34] D. Liu, L. Xu, and X. Lu, "Stress analysis of imperfect composite laminates with an interlaminar bonding theory," *International Journal for Numerical Methods in Engineering*, vol. 37, no. 16, pp. 2819-2839, 1994/08/30/ 1994. doi: <https://doi.org/10.1002/nme.1620371608>
- [35] S. J. Deteresa, D. C. Freeman, and S. E. Groves, "The Effects of Through-thickness Compression on the Interlaminar Shear Response of Laminated Fiber Composites," *Journal of Composite Materials*, vol. 38, no. 8, pp. 681-697, 2004/04/01/ 2004. doi: <https://doi.org/10.1177/0021998304042401>
- [36] S. S. Wang, "Fracture Mechanics for Delamination Problems in Composite Materials," *Journal of Composite Materials*, vol. 17, no. 3, pp. 210-223, 1983/05/01/ 1983. doi: <https://doi.org/10.1177/002199838301700302>