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The Development of Composite Materials for Architectural Work Using Oil Palm Frond and Plastic Fishing Net Waste

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Abstract

In southern Thailand, the accumulation of oil palm fronds and plastic waste, particularly discarded fishing nets from local fishery and farming communities, poses significant environmental challenges due to limited large-scale recycling options. This study aims to develop innovative composite materials for architectural applications by utilizing oil palm fronds and plastic fishing net waste, thereby reducing environmental pollution and promoting sustainable waste management. The research employs an experimental approach to fabricate composite panels through a systematic formation process, followed by comprehensive testing of their physical and mechanical properties. Physical properties evaluated include density, thickness swelling, and water absorption, while mechanical properties encompass modulus of rupture (MOR), modulus of elasticity (MOE), and internal bonding strength (IB). The results demonstrate that incorporating plastic fishing net waste significantly enhances the composite's density, flexural strength (MOR), modulus of elasticity (MOE), and tensile strength perpendicular to the surface. Specifically, these properties exhibit a positive correlation with the proportion of plastic fishing net waste in the composite mix, with optimal performance observed at higher plastic ratios. Conversely, thickness swelling decreases as the plastic content increases, indicating improved dimensional stability. All tested composite panel specimens meet or exceed the requirements of the Thai Industrial Standard (TIS) 876-2565 (2022) for particleboards, confirming their suitability for interior architectural applications, such as wall panels and ceiling materials. This research not only provides a sustainable solution to manage agricultural and plastic waste in southern Thailand but also contributes to the development of eco-friendly, high-performance materials for the construction industry, supporting circular economy principles and environmental conservation.

Keywords: composite material; fishing net waste; oil palm frond waste; plastic waste.



Southern Thailand's coastal geography and humid climate make it ideal for oil palm cultivation, establishing it as a cornerstone of the region's economy. In 2022, Thailand's oil palm (see Fig. 1) plantations spanned 10,271.62 km², producing 18,588,120 tons of oil palm, with the southern region accounting for 8,830.96 km² (86%) and 16,764,666 tons (90%) of the national totals (OAE, 2023). However, the expansion of oil palm plantations has led to a significant increase in agricultural biomass waste, including fronds, trunks, leaves, and empty fruit bunches. Oil palm fronds (OPF) constitute over 50% of this biomass, making them the most abundant waste product from the industry (Ooi et al., 2017). While some OPF is repurposed as fertilizer or animal feed, or left to decompose naturally to enrich plantation soils, a substantial portion remains unused, posing challenges for plantation management and contributing to environmental degradation (Wahab et al., 2022). The cellulose-rich composition of OPF, characterized by high strength, hardness, and low density, makes it a promising candidate for fiber-based products, particularly as a reinforcing material in composites (Luangsod et al., 2018; Kusumaningrum et al., 2017; Malti et al., 2023).

Concurrently, southern Thailand faces a critical challenge from marine plastic waste, particularly discarded fishing nets, which threaten marine ecosystems, biodiversity, and local economies. Globally, over 12 million tons of plastic waste enter the oceans annually, with 20% originating from marine activities such as fishing, including over 640,000 tons of fishing nets (Rattanakhot, 2021). In Thailand, the fishing industry generates approximately 700,000 kg of fishing net waste monthly (see Fig. 2), contributing to marine pollution, coral degradation, and mortality of marine species due to ingestion or entanglement (Rattanakhot, 2021). The durability and flexibility of fishing net plastics, typically polyethylene or nylon, make them difficult to dispose of, requiring significant landfill space and costly transportation (Liotta et al., 2024). Recycling and reusing these plastics offer a sustainable solution to mitigate their environmental impact.)

This study addresses the dual environmental challenges of oil palm frond and fishing net waste by developing composite



Fig. 1

Oil palm frond waste found in Tha Sala, Nakhon Si Thammarat



Fig. 2

Fishing net waste in Ban Nai Thung, Tha sala, Nakhon Si Thammarat

materials for architectural applications. By combining the cellulose fibers of OPF, sourced from local plantations in Tha Sala, Nakhon Si Thammarat, with plastic fishing net waste collected from the fishing village of Ban Nai Thung, Tha Sala, this research leverages the complementary properties of these materials OPF's strength and lightweight nature and plastic's flexibility and moldability. The composites were fabricated using a hot-pressing method, with melted fishing net plastic serving as a binder to enhance structural integrity. This approach not only valorizes locally abundant waste materials but also aligns with circular economy principles by reducing waste accumulation and promoting sustainable material use. The research aims to develop and characterize composite panels suitable for interior architectural applications, such as wall and ceiling materials, by evaluating their physical (density, thickness swelling, water absorption) and

mechanical (modulus of rupture, modulus of elasticity, internal bonding strength) properties, with the goal of meeting Thai Industrial Standard (TIS) 876-2565 (2022). By increasing the utilization of oil palm fronds and plastic fishing net waste, this study seeks to mitigate environmental pollution while contributing to the advancement of eco-friendly construction materials.

Oil palm frond as a composite material

Oil palm fronds (OPF), comprising the petiole and leaf of the oil palm, represent a significant portion of agricultural waste in southern Thailand, where oil palm is a major economic crop. Approximately 2.475 million kg/km²/year of OPF is generated and often left on plantations, contributing to environmental challenges such as soil management and waste accumulation (Klumem, 2021). Researchers have explored OPF as a sustainable resource for construction materials due to its abundant availability and favourable properties. Studies have demonstrated its potential in applications such as deck panels (Hashim et al., 2023), sound-absorbing sheets (Khem et al., 2023), and composite wood products (Yunus et al., 2020), highlighting its versatility as a reinforcing fiber in composite materials.

The chemical composition of OPF underpins its suitability for composite applications. As shown in Table 1, OPF consists of 83.5% holocellulose (including 49.8% cellulose and 33.7% hemicellulose), 20.5% lignin, 4.5% extractives, and 2.4% ash (Abdul et al., 2006). Compared to hardwoods, OPF has a lower lignin content, which enhances its flexibility and compatibility with polymer matrices in composites (Kusumaningrum et al., 2017). The high cellulose content provides strength and rigidity, making OPF an ideal natural fiber for reinforcing composite materials used in structural or decorative architectural elements (Wahab et al., 2022; Malti et al., 2023).

Table 1

Chemical composition of oil palm frond

Composition	Chemical composition (%)					
	Extractive	Holocellulose	Cellulose	Hemicelluloses	Lignin	Ash
Oil palm frond	4.5	83.5	49.8	33.7	20.5	2.4

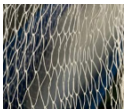
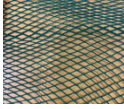
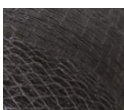
Fishing net waste as a polymer matrix

Marine plastic waste, particularly discarded fishing nets, poses a significant environmental challenge in coastal regions like southern Thailand. Fishing nets, primarily composed of thermoplastics such as polyamide (PA6, nylon), polyethylene (PE), and polypropylene (PP), contribute substantially to marine pollution (Rattanakhhot, 2021; EJF, 2023). Table 2 summarizes the types, usage, and characteristics of fishing nets commonly used in Thailand, as classified by the Environmental Justice Foundation (EJF, 2023). These nets, used in artisanal and commercial fisheries, target species such as crabs, shrimps, and mackerels, with materials like PA6 nylon (monofilament or multifilament) and high-density polyethylene (HDPE) being prevalent due to their durability and flexibility.

This study utilizes knotted nylon multifilament nets, composed of polyamide (PA6), collected from the Ban Nai Thung fishing village in Tha Sala District, Nakhon Si Thammarat, Thailand. PA6 is a thermoplastic polymer with a linear or short-branched structure, offering high strength, toughness, and resistance to tensile and tearing forces (Supasinsathit, 2013). With a melting point of 180–200°C, PA6 can withstand temperatures up to 120°C, making it suitable for hot-pressing processes in composite fabrication (PITH, 2013). Its additional properties include corrosion and abrasion resistance, flexibility, and good barrier properties against fats and oxygen, though it exhibits low moisture resistance and absorbs environmental humidity, which may reduce its gas barrier performance (Pornchaloempong and Rattanapanone, n.d.). PA6’s recyclability, enabled by grinding and remelting without significant degradation of its chemical or physical properties, makes it an ideal binder for composites, enhancing the structural integrity of oil palm frond-based materials.

Table 2

Types of Fishing nets used in Thailand

Type	Usage	Categorized	Color	Plastic Type	Target species
Nylon Monofilament Nets 	Artisanal Fisheries	Gillnets (Entangling Nets)		PA6-Nylon Monofilament	Crabs, Squids, Mulletts, and other small fishes
Knotted Nylon Multifilament Nets 	Artisanal and Commercial Fisheries	Gillnets, Falling Nets, and Lift Nets		PA6-Nylon Multifilament	Indian Mackerels, Snappers, Shrimps, Groupers, Spanish Mackerels
Trammel Nets 	Artisanal Fisheries	Gillnets (Entangling Nets)		Selvedge (red part) - HDPE, White part - PA6 (Nylon Monofilament and/ or Nylon Multifilament)	Shrimps
HDPE Monofilament Nets 	Artisanal and Commercial Fisheries	Push Nets and Falling Nets		HDPE	Krill, Squids, Anchovies
Knotless Nylon Multifilament Nets 	Artisanal and Commercial Fisheries	Surrounding Nets, Falling Nets, and Lift Nets		PA6-Nylon Multifilament	Anchovies, Squids
'Poly' Nets 	Artisanal and Commercial Fisheries	Trawls, Traps, Strow Nets, Floating Baskets		HDPE	Fishes, Squids, Shrimps
Black - Coated Knotted Nylon Multifilament Nets 	Commercial Fisheries	Surrounding Nets		PA6-Nylon Multifilament	Indian Mackerels
Black - Coated Knotless Nylon Multifilament Nets 	Commercial Fisheries	Surrounding Nets		PA6-Nylon Multifilament	Indian Mackerels

Synthesis of oil palm frond and fishing net waste in composites

The combination of OPF's cellulose fibers and recycled fishing net plastics offers a promising approach to developing sustainable composite materials. The high cellulose content of OPF provides mechanical reinforcement, while the thermoplastic properties of PA6 enable effective binding through melting and moulding processes (Wahab et al., 2022). Previous studies have demonstrated the feasibility of using agricultural waste fibers with plastic matrices to produce composites for construction, leveraging the complementary properties of natural fibers and polymers (Malti et al., 2023). This research builds on these findings by integrating locally sourced OPF and fishing net waste, addressing both agricultural and marine waste challenges in southern Thailand while developing eco-friendly materials for architectural applications.

Previous studies on oil palm fiber composites

Oil palm biomass, particularly oil palm fronds (OPF), exhibits excellent specific properties, such as high cellulose content and low density, making it a viable alternative to wood and synthetic fibers in bio-composites, hybrid composites, pulp, and paper industries (Abdul et al., 2012). However, its limitations, including low mechanical strength, environmental sensitivity, and poor moisture resistance, restrict its use in high-performance applications. To address these challenges, researchers have explored hybrid composites by combining OPF with other fibers, such as glass or other natural fibers, to enhance strength and durability (Abdul et al., 2012). These hybrid composites have shown promise for applications in furniture, construction, transportation, and both structural and non-structural components (Ahmad et al., 2022). Additionally, OPF has been identified as a potential raw material for particleboard and fiberboard industries, offering a sustainable alternative to traditional wood in furniture and construction (Ahmad et al., 2022; Saifulazry et al., 2022; Ahmad et al., 2023).

Several studies have investigated the integration of OPF with plastic matrices to develop wood-plastic composites (WPCs) as substitutes for conventional wood products. Rasat et al. (2011) evaluated composite sheets made from OPF using phenol and urea formaldehyde as binders. Their findings indicated that OPF-based composites outperformed those made from oil palm trunks and exhibited mechanical properties comparable to, though slightly inferior to, rubberwood. These results suggest that OPF composites have significant potential to address material shortages in the wood industry (Rasat et al., 2011). Similarly, Thanawattanasirikul et al. (2011) developed WPCs by combining OPF powder with high-density polyethylene (HDPE) from recycled water bottles and maleic anhydride as a coupling agent. The mechanical properties, including tensile and bending strength, improved with higher plastic content and molding temperature, achieving performance comparable to commercial WPCs (Thanawattanasirikul et al., 2011).

Russita and Bahrudin (2018) investigated WPCs produced via twin-screw extrusion, combining OPF with polypropylene, maleated polypropylene (MAPP), and paraffin. The resulting composites met commercial WPC standards, with a maximum tensile strength of 19.2 MPa, bending strength of 43.6 MPa, and water absorption of 0.32% w/w, demonstrating their suitability for industrial applications (Russita and Bahrudin, 2018). Luangsod et al. (2018) explored pseudo-plywood composites made from OPF and polyethylene, finding that lower OPF content (below 65%) resulted in higher density, bending strength, modulus of elasticity, and tensile strength perpendicular to the surface, with reduced water absorption and thickness swelling. These composites met relevant standards, indicating their potential for construction applications (Luangsod et al., 2018).

Asyraf et al. (2022) conducted a comprehensive review of OPF-polymer composites, emphasizing the use of natural fibers and biopolymers to replace synthetic plastics. Their analysis highlighted that OPF enhances mechanical strength but identified research gaps in fiber-matrix adhesion, polymer selection, and fiber size optimization. They proposed guidelines for improving OPF composite performance, particularly for reinforcing applications in sustainable materials (Asyraf et al.,

2022). Collectively, these studies underscore the potential of OPF-plastic composites to address environmental and industrial challenges, providing a foundation for the current research, which uniquely combines OPF with recycled fishing net waste (polyamide, PA6) to develop eco-friendly composite panels for architectural applications.

This experimental study develops composite panels using agricultural waste (oil palm fronds, OPF) from plantations in Tha Sala, Nakhon Si Thammarat, Thailand, and plastic fishing net waste from the fishing village of Ban Nai Thung, Tha Sala. The specimens were fabricated and tested in accordance with the Thai Industrial Standard (TIS 876-2565, 2022) for flat-pressed particleboards to ensure suitability for architectural applications, targeting Thai industrial standards. The methodology encompasses material preparation, composite specimen production, and evaluation of physical and mechanical properties, including density, thickness swelling, modulus of rupture (MOR), modulus of elasticity (MOE), and internal bonding strength (IB).

Material preparation

Oil palm fronds (OPF) were sourced from local plantations in Tha Sala, Nakhon Si Thammarat, and fishing net waste, identified as knotted nylon multifilament nets (polyamide, PA6), was collected from the Ban Nai Thung fishing community. The OPF was sun-dried to remove moisture and deter insect activity, then peeled and cut into 3–5 mm pieces. These pieces were oven-dried at 105°C to further reduce moisture content to below 5% (w/w). Similarly, the fishing net waste was cleaned to remove debris and contaminants, then cut into 3–5 mm pieces to ensure uniform mixing with OPF (as shown in Fig. 3).

Materials and methods



Fig. 3

Raw and Mixed Materials for Composite Fabrication

Specimen fabrication

Composite panels were designed with a thickness of 10 mm, using OPF and PA6 fishing net waste in three mixing ratios by weight: 40:60, 50:50, and 60:40 (fishing net:OPF), as shown in Table 3. The materials were blended using a mechanical mixer to achieve homogeneity. The mixture was then hot-pre ssed at 190°C in a 250 mm × 250 mm × 10 mm mould using a compression machine, with a pressing time sufficient to melt the PA6 and bond the OPF fibers. After pressing, the panels were cooled to stabilize their structure and cut to standard dimensions specified by TIS 876-2565 (2022) for testing as shown in Fig. 4 and 5.

Table 3

The mixing ratio of the specimens

Mixing ratio	Fishing net	Oil palm frond
40:60	40	60
50:50	50	50
60:40	60	40

Fig. 4

Hot-Pressing Process for Composite Panel Fabrication

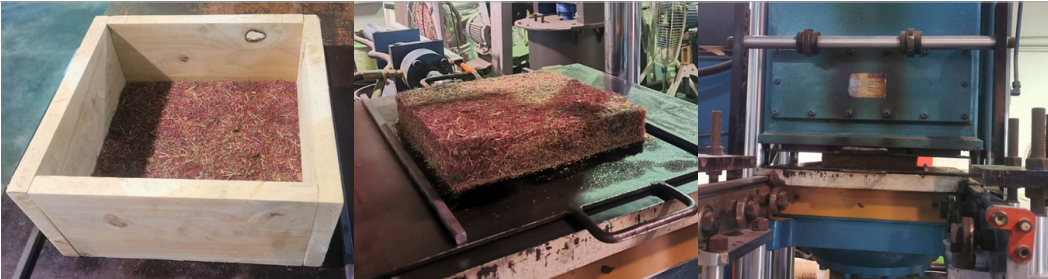
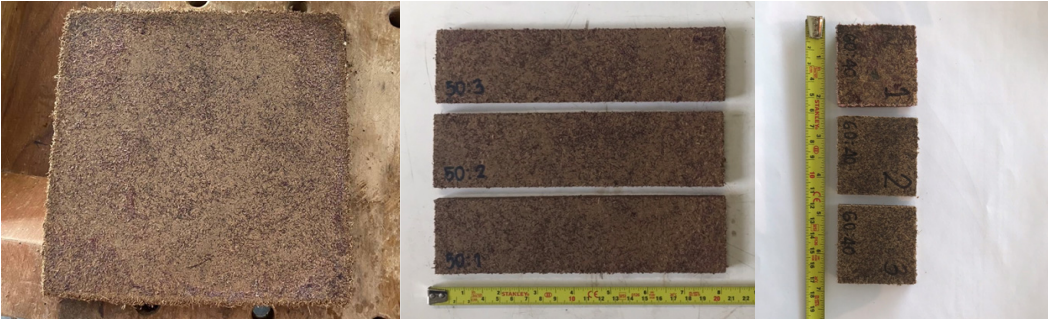


Fig. 5

Prepared Composite Specimens for Testing



Property testing

The physical and mechanical properties of the composite panels were evaluated per TIS 876-2565 (2022) for flat-pressed particleboards. Specimens for thickness swelling, MOR, MOE, and IB tests were conditioned at 20 ± 2°C and 65 ± 5% relative humidity until mass stability was achieved (mass change <0.1% over 24 hours). Density test specimens did not require conditioning.

a Density test

Specimens (50 mm × 50 mm × 10 mm) were prepared per TIS 876-2565 (2022). Mass was measured using a digital scale (0.01 g resolution), and thickness was determined at the specimen center using a micrometer (0.05 mm resolution) with a 6–20 mm diameter measuring plate. Length and width were measured using a sliding caliper (0.1 mm resolution) at a 45° angle to the horizontal plane. Density was calculated as:

$$\rho = \frac{m}{V} \times 10^6 \quad (1)$$

Where; ρ is density in (kg/m^3), m is mass in (g), and V is volume in (mm^3).

b Thickness swelling test

Specimens ($50 \text{ mm} \times 50 \text{ mm} \times 10 \text{ mm}$) were weighed (0.01 g resolution) and their thickness measured at the center (marked for consistency). They were immersed in water at $20 \pm 1^\circ\text{C}$ for 24 hours, with surfaces perpendicular to the water surface, positioned 25 mm below the surface, and separated by at least 10 mm from each other and the container walls. After immersion, specimens were wiped dry, and thickness was remeasured at the marked position. Thickness swelling was calculated as:

$$TS = \frac{t_2 - t_1}{t_1} \times 100 \quad (2)$$

Where: TS = thickness swelling (%), t_1 = thickness of specimen before immersion (mm), t_2 = Thickness of Specimen After Immersion (mm)

c Modulus of rupture and modulus of elasticity test

Specimens ($50 \text{ mm} \times 200 \text{ mm} \times 10 \text{ mm}$) were tested per TIS 876-2565 (2022). Each specimen was placed on support bars spaced at 150 mm (15 times the 10 mm thickness, rounded to the nearest 10 mm), with a 25 mm overhang on each side. A universal testing machine applied a central force at a rate of 10 mm/min, with failure occurring within 30–90 seconds (Fig. 6). The MOR and MOE were calculated as:

$$f_m = \frac{3F_{max} l_1}{2bt^2} \quad (3)$$

$$E_m = \frac{l_1^3 (F_2 - F_1)}{4bt^3 (a_2 - a_1)} \quad (4)$$

Where: f_m is modulus of rupture (MPa), F_{max} is the maximum pressure that the specimen can withstand (N), l_1 is the distance between support bars (mm), b is the width at the midpoint of the long side of the specimen (mm), t is the thickness at the center of the specimen (mm), E_m is modulus of elasticity (MPa), $F_2 - F_1$ is the force increment in the linear region (N), $a_2 - a_1$ is the deflection increment (mm).

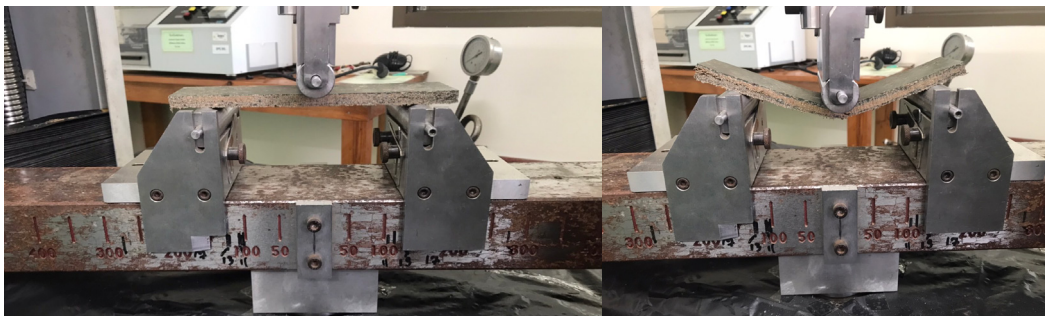


Fig. 6

Setup for Modulus of Rupture and Modulus of Elasticity Testing

d Internal bonding strength test

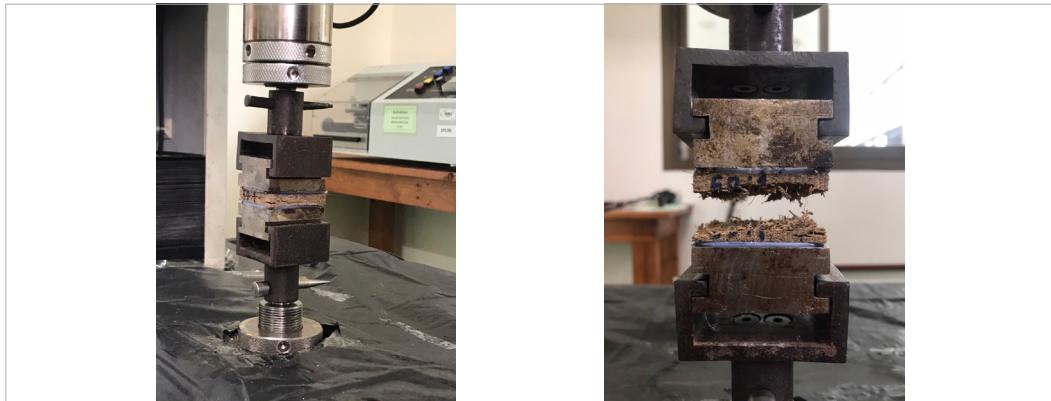
Specimens (50 mm × 50 mm × 10 mm) were bonded to 50 mm × 50 mm metal tensile plates using synthetic adhesive stronger than the specimen's internal bond. A universal testing machine applied tensile force at 2 mm/min until failure (within 30–90 seconds) (see Fig. 7). Internal bonding strength was calculated as:

$$IB = \frac{P'}{b \times L} \quad (5)$$

Where: IB is internal bonding strength (MPa), P' is the maximum tensile force (N), b is the width of specimen (mm), and L is the length (mm).

Fig. 7

Setup for Internal Bonding Strength Testing



Results and discussion

The composite panels, fabricated from oil palm fronds (OPF) and polyamide (PA6) fishing net waste at mixing ratios of 40:60, 50:50, and 60:40 (fishing net:OPF by weight), were evaluated for physical (density, thickness swelling) and mechanical (modulus of rupture, modulus of elasticity, internal bonding strength) properties per the Thai Industrial Standard (TIS 876-2565, 2022) for flat-pressed particleboards. The results demonstrate the influence of the plastic content on composite performance, with trends indicating improved properties with higher PA6 ratios, except for thickness swelling, which decreases. These findings support the potential of OPF-PA6 composites for interior architectural applications, such as wall panels and ceilings.

Physical properties

a Density

The density of the composite panels increased with the proportion of PA6 fishing net waste. The 40:60 (fishing net: OPF) specimens exhibited an average density of $680.50 \pm 24.72 \text{ kg/m}^3$, the 50:50 specimens $700.35 \pm 22.67 \text{ kg/m}^3$, and the 60:40 specimens $735.03 \pm 61.28 \text{ kg/m}^3$ as shown in Fig. 8. The highest density in the 60:40 ratio is attributed to the greater plastic content, which has a higher intrinsic density than OPF (Luangsod et al., 2018). All specimens met the TIS 876-2565 (2022) density requirement of $400\text{--}900 \text{ kg/m}^3$, indicating suitability for particleboard applications (see Fig. 8).

b Thickness swelling

Thickness swelling decreased as the PA6 content increased. The 40:60 specimens showed the highest average swelling at $8.71 \pm 1.06\%$, followed by $5.53 \pm 0.89\%$ for the 60:40 specimens and $4.39 \pm 1.02\%$ for the 50:50 specimens as shown in Fig. 9. The lower swelling in higher PA6

ratios reflects the moisture-resistant properties of PA6 compared to the hygroscopic OPF fibers (Muktana-a-nun et al., 2019). All specimens satisfied the TIS 876-2565 (2022) requirement of less than 12% swelling. The slightly lower swelling in the 50:50 ratio compared to the 60:40 ratio may result from uneven PA6 distribution during fabrication, affecting water ingress pathways.

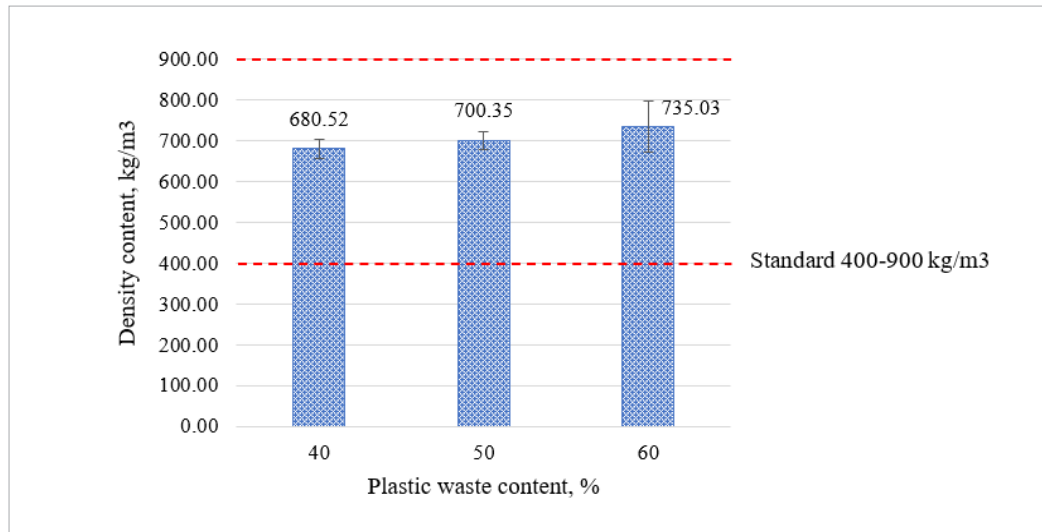


Fig. 8

Density of Composite Panels Across Mixing Ratios

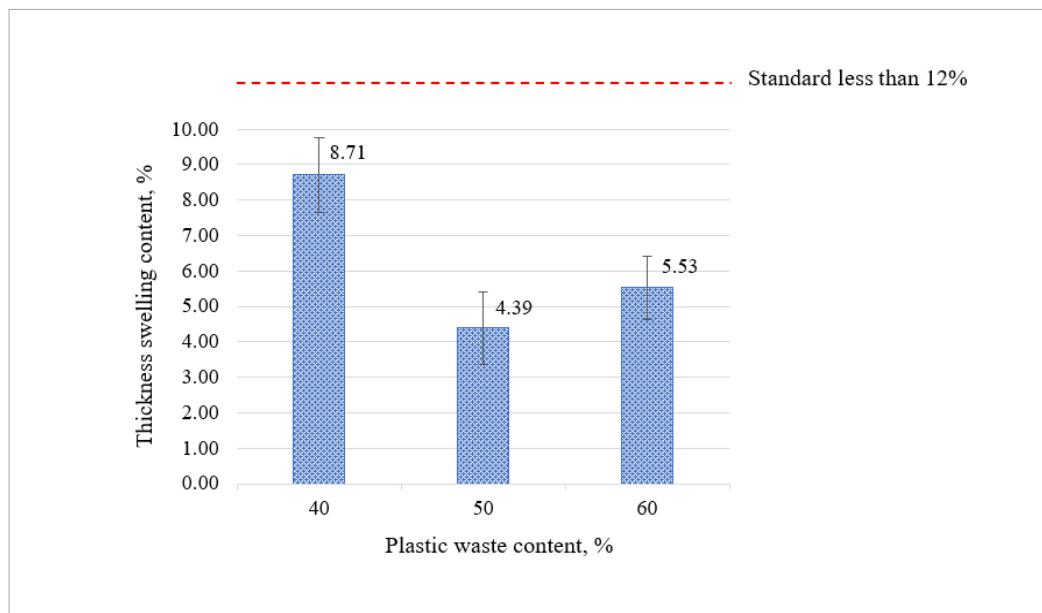


Fig. 9

Thickness Swelling of Composite Panels Across Mixing Ratios

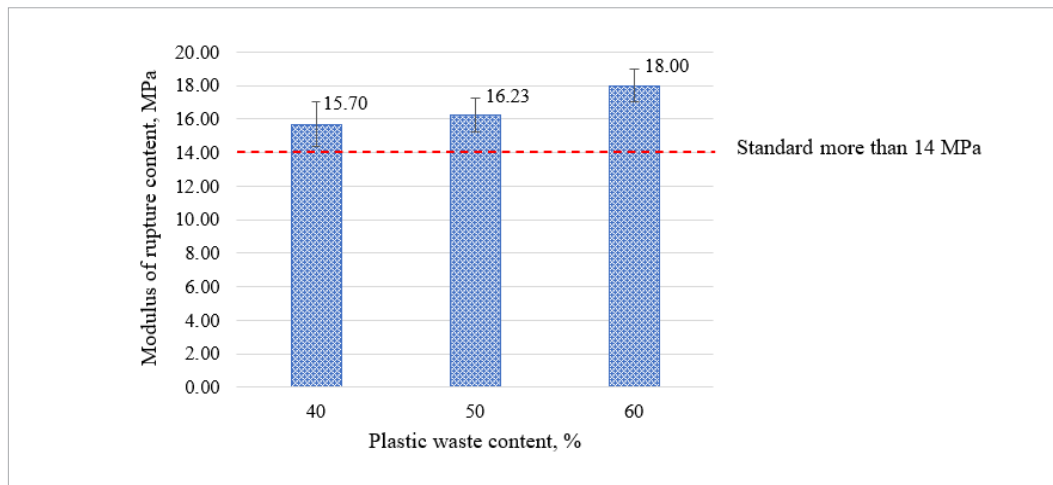
Mechanical properties

a Modulus of rupture (MOR)

The modulus of rupture (MOR), or flexural strength, increased with higher PA6 content. The 40:60 specimens had an average MOR of 15.70 ± 1.31 MPa, the 50:50 specimens 16.23 ± 1.00 MPa, and the 60:40 specimens 18 ± 0.96 MPa. The enhanced flexural strength in the 60:40 ratio is due to the stronger interfacial bonding provided by the melted PA6, which acts as an effective binder (Syamsir et al., 2022). All specimens exceeded the TIS 876-2565 (2022) minimum requirement of 14 MPa, confirming their suitability for structural applications (see Fig. 10).

Fig. 10

Modulus of Rupture of
Composite Panels Across
Mixing Ratios

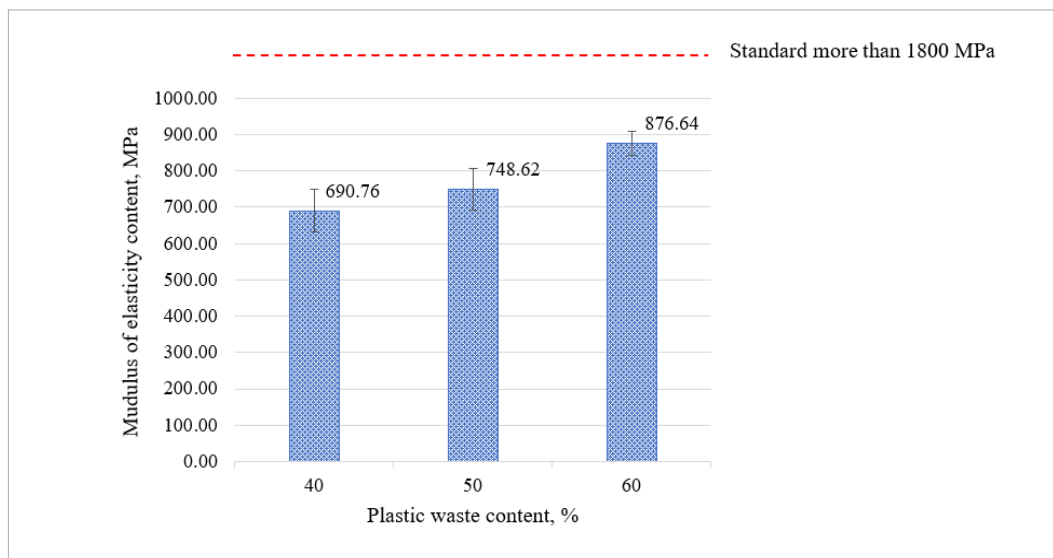


b Modulus of elasticity (MOE)

The modulus of elasticity (MOE) followed a similar trend, with values of 690.76 ± 59.73 MPa for the 40:60 ratio, 748.62 ± 57.11 MPa for the 50:50 ratio, and 876.64 ± 33.49 MPa for the 60:40 ratio (Fig. 11). The increase in MOE with higher PA6 content reflects the plastic's contribution to stiffness, complementing the rigidity of OPF fibers (Russita and Bahrudin, 2018). However, all specimens fell below the TIS 876-2565 (2022) minimum requirement of 1800 MPa, suggesting that further optimization (e.g., additives or fiber treatment) may be needed for applications requiring high stiffness.

Fig. 11

Modulus of Elasticity of
Composite Panels Across
Mixing Ratios



c Internal bonding strength (IB)

Internal bonding strength (IB) also improved with increasing PA6 content, with values of 0.28 ± 0.08 MPa (40:60), 0.30 ± 0.01 MPa (50:50), and 0.50 ± 0.08 MPa (60:40). The 60:40 ratio's superior IB is attributed to the enhanced adhesion provided by the melted PA6, which effectively binds OPF fibers (Muktana-a-nun et al., 2019). Only the 60:40 specimens met the TIS 876-2565 (2022) requirement of ≥ 0.40 MPa, indicating that higher plastic content is critical for achieving adequate internal cohesion (see Fig. 12). This IB value (0.50 MPa) is adequate for non-load-bearing architectural

applications, such as interior wall panels and ceiling tiles, where typical IB requirements range from 0.4–0.6 MPa for particleboards used in dry conditions (EN 312:2010; ANSI A208.1-2016). However, for load-bearing panels (e.g., structural flooring or furniture components), higher IB values (≥ 0.7 MPa) are often required to ensure durability under mechanical stress (Wahab et al., 2022). The 60:40 ratio's IB supports its use in lightweight, decorative applications but may require reinforcement (e.g., additives like maleated polypropylene) or optimized processing to achieve the higher cohesion needed for structural applications.

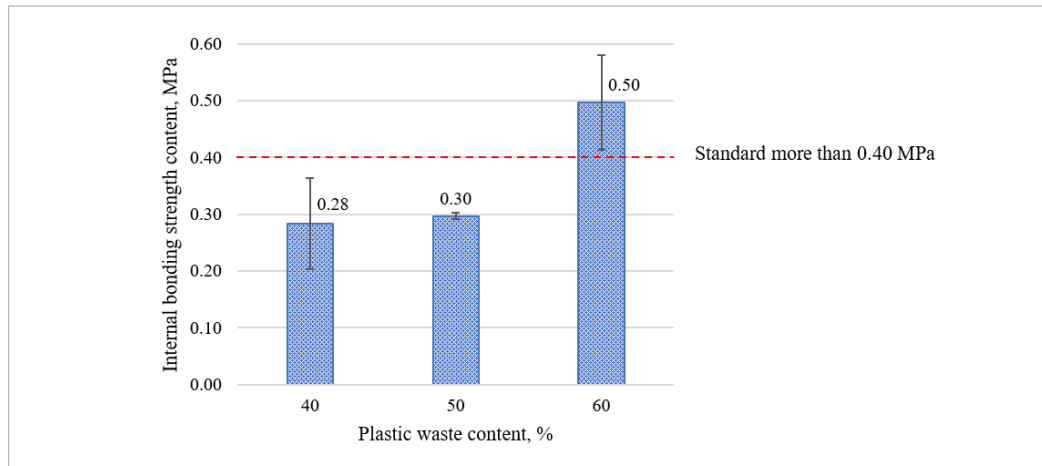


Fig. 12

Internal Bonding Strength of Composite Panels Across Mixing Ratios

Waste utilization

The composite panels effectively utilized significant quantities of waste materials, as shown in Table 4. For a 1 m² panel (10 mm thick), the 40:60 ratio used 2.88 kg of fishing net waste and 4.32 kg of OPF, the 50:50 ratio used 3.60 kg of each, and the 60:40 ratio used 4.32 kg of fishing net waste and 2.88 kg of OPF. These quantities demonstrate the potential to valorize up to 7.2 kg/m² of waste, reducing environmental pollution from both agricultural and marine sources.

Mixing Ratio (Fishing Net: OPF)	Fishing Net (kg)	Oil Palm Frond (kg)
40:60	2.88	4.32
50:50	3.60	3.60
60:40	4.32	2.88

Table 4

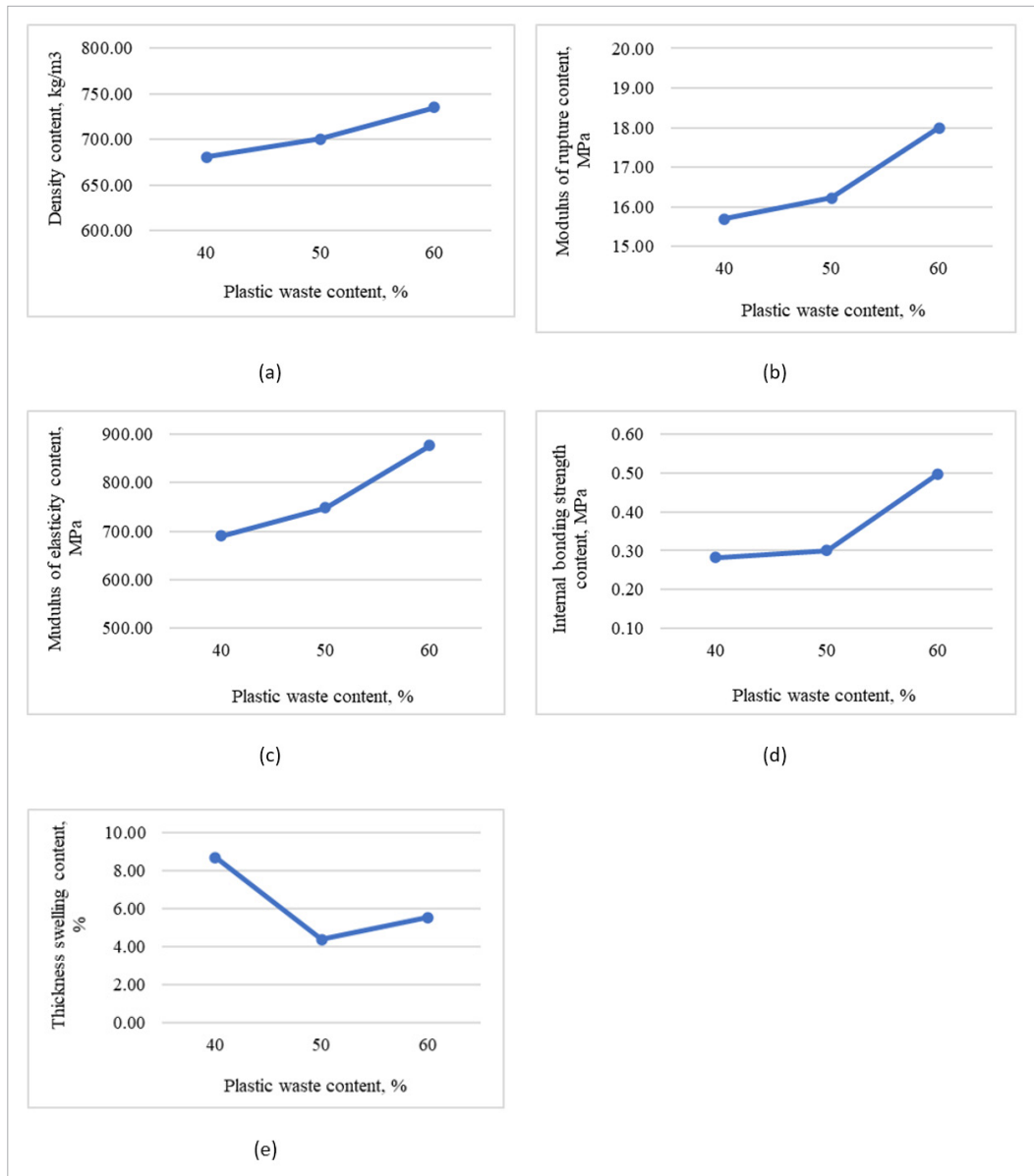
Waste Utilization per 1 m² of Composite Panel

The results (see Fig. 13) confirm that increasing the PA6 fishing net content enhances the density, MOR, MOE, and IB of OPF-based composites, while reducing thickness swelling, consistent with the moisture-resistant properties of thermoplastics (Muktana-a-nun et al., 2019). The 60:40 ratio exhibited the best overall performance, meeting TIS 876-2565 (2022) standards for density, thickness swelling, MOR, and IB, making it suitable for interior architectural applications such as wall panels, ceilings, and furniture. The failure to meet the MOE standard across all ratios suggests limitations in stiffness, possibly due to insufficient fiber-matrix adhesion or the inherent flexibility of PA6 (Asyraf et al., 2022). Uneven PA6 distribution, as observed in the anomalous thickness swelling of the 50:50 ratio, highlights the importance of optimizing the mixing and hot-pressing processes to ensure homogeneity (Muktana-a-nun et al., 2019). These findings align with previous studies on OPF-plastic composites (e.g., Russita and Bahrudin, 2018; Luangsod et al., 2018), but the use of PA6 fishing net waste is novel, offering a sustainable solution to marine and agricultural waste management in southern Thailand.

Discussion

Fig. 13

Trend of Density Across Mixing Ratios (a), Trend of Modulus of Rupture Across Mixing Ratios (b), Trend of Modulus of Elasticity Across Mixing Ratios (c), Trend of Internal Bonding Strength Across Mixing Ratios (d), Trend of Thickness Swelling Across Mixing Ratios (e)



Conclusions

This study develops sustainable composite panels from oil palm frond (OPF) and polyamide (PA6) fishing net waste, addressing environmental challenges in southern Thailand. The panels demonstrate potential for interior architectural applications, such as wall panels and ceilings, by valorizing waste materials. The composite panels, fabricated at mixing ratios of 40:60, 50:50, and 60:40 (fishing net: OPF by weight), were evaluated for physical and mechanical properties per the Thai Industrial Standard (TIS 876-2565, 2022). Statistical analysis ($n = 5$ replicates per ratio) confirmed significant trends ($p < 0.05$, ANOVA) in performance with increasing PA6 content. The key findings are summarized as follows:

- Density: Panels exhibited average densities of $680.50 \pm 24.72 \text{ kg/m}^3$ (40:60), $700.35 \pm 22.67 \text{ kg/m}^3$ (50:50), and $735.03 \pm 61.28 \text{ kg/m}^3$ (60:40), increasing significantly with higher PA6 content ($p < 0.01$). All ratios met the TIS standard of $400\text{--}900 \text{ kg/m}^3$ (Fig. 8).
- Thickness Swelling: Swelling decreased with increasing PA6 content, with average values of $8.71 \pm 1.06\%$ (40:60), $4.39 \pm 1.02\%$ (50:50), and $5.53 \pm 0.89\%$ (60:40). All ratios remained

below the TIS maximum of 12% (Fig. 9). The slightly lower swelling at 50:50 compared to 60:40 suggests uneven PA6 distribution.

- Modulus of Rupture (MOR): Flexural strength improved with more PA6, from 15.70 ± 1.31 MPa (40:60) to 16.23 ± 1.00 MPa (50:50), and 18.00 ± 0.96 MPa (60:40) ($p < 0.01$), all exceeding the TIS minimum of 14 MPa (Fig.10).
- Modulus of Elasticity (MOE): MOE values were 690.76 ± 59.73 MPa (40:60), 748.62 ± 57.11 MPa (50:50), and 876.64 ± 33.49 MPa (60:40), increasing with PA6 but remaining below the TIS minimum of 1800 MPa, indicating insufficient stiffness (Fig. 11).
- Internal Bonding Strength (IB): IB values rose from 0.28 ± 0.08 MPa (40:60), to 0.30 ± 0.01 MPa (50:50), and 0.50 ± 0.08 MPa (60:40) ($p < 0.01$). Only the 60:40 ratio met the TIS requirement of ≥ 0.40 MPa (Fig. 12).
- Waste Utilization: Each 1 m^2 panel (10 mm thick) utilized up to 7.2 kg of waste materials. The 40:60 ratio used 2.88 kg fishing net and 4.32 kg OPF; the 50:50 ratio used 3.60 kg of each; and the 60:40 ratio used 4.32 kg fishing net and 2.88 kg OPF (Table 4).
- Further Work: Optimization is needed for uniform PA6 distribution to enhance MOE and IB. Future work should also investigate thermal insulation, fire resistance, acoustic performance, and conduct life cycle assessments to validate long-term sustainability.

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Abdul, K., Jawaid M., Hassan A., Paridah M. T. & Zaidon, A. (2012). Oil Palm Biomass Fibres and Recent Advancement in Oil Palm Biomass Fibres Based Hybrid Biocomposites. *Composites and Their Applications*, 187-202. <https://doi.org/10.5772/48235>

Abdul, K., M. Siti, A. & A.K. Mohd, O. (2006). Chemical composition, anatomy, lignin distribution, and cell wall structure of Malaysian plant waste fibers. *BioResources*, 1(2), 220-232. <https://doi.org/10.15376/biores.1.2.220-232>

Ahmad, M., Osman, S., Ibrahim, Z., Alias, A. H., Abdul Wahab, N., Ramli, R. & Abdul Hamid, F. (2022). Fiberboard from oil palm biomass. *Oil Palm Biomass for Composite Panels: Fundamentals, Processing, and Applications*. Elsevier (297-319). <https://doi.org/10.1016/B978-0-12-823852-3.00003-9>

Ahmad, N., Jalil, A. M. A., Abdullah, Z. A., Sarmin, S. N. & Razali, A. N. (2023). Effects of Density and Resin Content on Particleboard from Oil Palm Frond (OPF). *Springer Proceedings in Materials*. Springer Nature. https://doi.org/10.1007/978-981-19-6195-3_4

Asyraf, M. R. M., Ishak, M. R., Syamsir, A., Nurazzi, N. M., Sabaruddin, F. A., Shazleen, S. S., & Razman, M. R. (2022). Mechanical properties of oil palm fibre-rein-

forced polymer composites: A review. *Journal of Materials Research and Technology*, 17, 33-65. <https://doi.org/10.1016/j.jmrt.2021.12.122>

EJF, Environmental Justice Foundation. (2023). Fishing Net and Rope Identification Guide: Thailand. <https://ejf-foundation.org/reports/net-free-seas-project>

Hashim, M. M., Marsi, N., Rus, A. Z. M., Sharom, N. S. M., & Said, A. M. (2023). Natural Fiber of Palm Empty Fruit Bunches (PEFB) Reinforced Epoxy Resin as Polymer Composites. In *Structural Integrity and Monitoring for Composite Materials*. Singapore: Springer Nature Singapore (213-242). https://doi.org/10.1007/978-981-19-6282-0_14

Klum-em, K. (2021). Utilization of oil palm for animal husbandry. (Department) Bureau of Animal Nutrition Development.

Khem, S., Sutikno, S., Suwarta, P. & Istana, B. (2023). Experimental Study of Sound Absorption Coefficient Characteristics of Oil Palm Frond Reinforced Composite. *Key Engineering Materials*, 941, 257-263. <https://doi.org/10.4028/p-5t05f8>

Kusumaningrum, W., Syamani, F., Desiana, D., Suryanegara, L. & Subyakto. (2017). Characterization of

References

- acetylated cellulose from OPF fiber (*Elaeis guineensis* Jacq.) for composites application. *Journal of Lignocellulose Technology*, 2(1), 18-23.
- Liotta, I., Avolio, R. Castaldo, R., Gentile, G., Ambrogio, V., Errico, M. E. & Cocca, M., (2024). Mitigation approach of plastic and microplastic pollution through recycling of fishing nets at the end of life. *Process Safety and Environmental Protection* 2024, 182, 1143-1152. <https://doi.org/10.1016/j.psep.2023.12.031>
- Luangsod, S., Khamput, P., Lregpiboon, A. & Pradmal, S. (2018). Production of the pseudo-plywood from polyethylene mixing with oil palm fibers for community enterprise.
- Malti, A., Masri, T., Yagoub, M., Mahbubul, I. M., Ghazali, A. & Benchabane, A. (2023). Manufacturing of Composite Panels from Date Palm Leaflet and Expanded Polystyrene Wastes Using Hot Compression Moulding Process. *Journal of Composite & Advanced Materials/Revue des Composites et des Matériaux Avancés*, 33(3). <https://doi.org/10.18280/rcma.330303>
- Muktana-a-nun, K., Lertwattanaruk, P., Jarusombuti S. & Wongwatcharapaiboon J. (2019). Development of Composite Board made from Agricultural Residues and Plastic Waste for Residential Building Applications. *Built Environment Research Associates Conference, BERAC2019 Faculty of Architecture and Planning, Thammasat University*.
- Nair, S. N., & Dasari, A. (2022). Development and characterization of natural-fiber-based composite panels. *Polymers*, 14(10), 2079. <https://doi.org/10.3390/polym14102079>
- OAE, Office of Agricultural Economics. (2023). Oil Palm: Standing Area, Fruiting Area, Yield and Yield per Rai 2022, Office of Agricultural Economics.
- Ooi, Z. X., Teoh, Y. P., Balakrishnan, K. & Shuit, S. H. (2017). Oil palm frond as a sustainable and promising biomass source in Malaysia: A review. *Environmental Progress and Sustainable Energy*, 36. <https://doi.org/10.1002/ep.12642>
- PITH, Plastics Institute of Thailand. (2013). Plastics knowledge. Plastics Institute of Thailand. Bangkok, Thailand.
- Pornchaloempong, P. & Rattanapanone, N. Nylon or Polyamide.
- Rasat, M. S. M., Wahab, R., Sulaiman, O., Moktar, J., Mohamed, A., Tabet, T. A. & Khalid, I. (2011). Properties of composite boards from oil palm frond agricultural waste. *BioResources*, 6(4), 4389-4403. <https://doi.org/10.15376/biores.6.4.4389-4403>
- Rattanakhot M., (2021). Net Free Seas. *National Geographic Thailand*. <https://ngthai.com/environment/33611/net-free-seas/>
- Russita, M. & Bahrudin. (2018). Production of palm frond based wood plastic composite by using twin screw extruder. *IOP Conference Series: Materials Science and Engineering*, 345, 012039. <https://doi.org/10.1088/1757-899X/345/1/012039>
- Saifulazry, S. O. A., Lee, S. H. & Lum, W. C. (2022). Particleboard from oil palm biomass. *Oil Palm Biomass for Composite Panels: Fundamentals, Processing, and Applications*. Elsevier. <https://doi.org/10.1016/B978-0-12-823852-3.00013-1>
- Supasinsathit, A. (2013). Plastic and the dangers of plastic. *Environmental Journal*, 17(3), 1-20. <https://digital.car.chula.ac.th/cuej/vol17/iss3/2>
- Syamsir, A., Nadhirah, A., & Mohamad, D., Beddu, S., Asyraf, M. R. M., Itam, Z. & Anggraini, V. (2022). Performance Analysis of Full Assembly Glass Fiber- Reinforced Polymer Composite Cross-Arm in Transmission Tower. *Polymers*, 14, 1563. <https://doi.org/10.3390/polym14081563>
- Thanawattanasirikul, N., Ratanawilai, T. & Pochana, K. (2011). (Wood Plastic Composites from Oil Palm Wood and HDPE). *KKU Engineering Journal*, 38, 285-296. <https://doi.org/10.2306/scienceasia1513-1874.2012.38.289>
- TIS, Thai Industrial Standard. (2022). Flat pressed Particleboards, TIS 876-2565. Thai Industrial Standards Institute Ministry of Industry.
- Wahab, R., Sukhairi Mat Rasat, M., Mohd Fauzi, N., Saiful Sulaiman, M., W. Samsi, H., Mokhtar, N., Haziq Razak, M. (2022). Processing and Properties of Oil Palm Fronds Composite Boards from *Elaeis guineensis*. *IntechOpen*. <https://doi.org/10.5772/intechopen.98222>
- Yunus, N. Y. M., Jasmi, N. F., & Rahman, W. M. N. W. A. (2020). Processing and Alkali Treatment Impact Towards Oil Palm Frond Fibers Bulk Density and Wood-Plastic Composite Performance. In *World Conference on Byproducts of Palms and their Applications*. Singapore: Springer Nature Singapore (65-77). https://doi.org/10.1007/978-981-19-6195-3_6

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