
MECHANICAL, OPTICAL AND ENGINEERING ASSESSMENT OF POLYPROPYLENE/FIBREGLASS COMPOSITES FOR TRANSLUCENT LPG CYLINDER APPLICATIONS

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ABSTRACT

The increasing demand for safer, lightweight, and corrosion-resistant liquefied petroleum gas (LPG) cylinders has created the need for alternative materials that overcome the limitations of conventional steel cylinders. This study presents the conceptual design and material evaluation of a translucent composite LPG cylinder based on polypropylene (PP)/fiberglass (FG) composites. The conceptual design integrates a lightweight polymer composite shell capable of withstanding service loads while providing sufficient light transmittance to enable direct visual monitoring of LPG level without auxiliary gauges. Five PP/FG formulations (40/60, 45/55, 50/50, 55/45, and 60/40 wt%) were developed through melt compounding and compression moulding to identify the optimum material for the proposed cylinder. Mechanical performance was assessed through tensile, flexural, impact, and hardness testing, while optical suitability was evaluated using indoor and outdoor light transmittance measurements. The results showed that composite composition significantly influenced both structural and optical properties. The 55/45 PP/FG formulation exhibited the highest tensile strength (33.17 MPa) and the greatest light transmittance (9.50% indoors and 24.30% outdoors), demonstrating the best balance between strength and translucency. Flexural testing showed a different trend, the 60/40 PP/FG composite exhibited the highest flexural strength of 56.52 MPa, indicating excellent resistance to bending loads. Hardness measurements similarly showed that 60/40 formulation gives the highest shore hardness of 96.0 D, increased fiberglass loading improved resistance to surface indentation and wear, whereas higher polypropylene content increased ductility but reduced hardness. Impact testing revealed that the 40/60 formulation possessed the greatest impact strength of 215.21 J/m. The proposed composite cylinder offers significant advantages over conventional steel cylinders, including reduced weight, improved corrosion resistance, and the ability to visually monitor LPG content, thereby improving user convenience and operational safety. The study demonstrates the feasibility of integrating material selection and conceptual design in the development of next-generation translucent composite LPG cylinders.

Keywords: Polypropylene/fiberglass composite; Conceptual design; LPG cylinder; Mechanical properties; Light transmittance

1.0 INTRODUCTION

Liquefied petroleum gas (LPG) has emerged as a vital transition fuel for domestic and industrial energy applications, offering high calorific value and lower greenhouse gas emissions relative to solid fossil fuels. In many developing countries, including Nigeria, LPG consumption has grown significantly over the past decade owing to government initiatives aimed at reducing dependence on firewood, kerosene, and charcoal for household cooking (Taska and Ige, 2023). This transition has contributed to improved indoor air quality, reduced deforestation, and enhanced public health outcomes. Consequently, the demand for safe, durable, and cost-effective LPG storage cylinders has increased substantially (Mahboubizadeh *et al.*, 2024).

Conventional LPG cylinders are predominantly fabricated from carbon steel due to its low initial cost and high mechanical strength. However, steel cylinders exhibit severe operational limitations such as corrosion and degradation where exposure to atmospheric humidity or coastal environments causes wall thinning, shortening service life, obscure external defects, making routine inspections more difficult and increasing catastrophic failure risks. Their relatively high weight

reduces portability and increases transportation costs. Corrosion can also increase the likelihood of catastrophic failure. In addition, opaque steel cylinders prevent users from visually determining the remaining LPG level, necessitating manual weighing or external sensing devices that increase operational costs and complexity (Mahboubizadeh et al., 2024; Wu et al., 2025). These limitations have stimulated growing interest in advanced composite materials for pressure vessel applications (Somaiah et al., 2022). Fibre-reinforced polymer (FRP) composites offer strong alternatives due to superior specific strength, low density, and high corrosion resistance. Among reinforcement materials, glass fibres provide an optimal balance between high tensile performance and cost-effectiveness compared to carbon or aramid fibres. Additionally, thermoplastic matrices like polypropylene (PP) enable recyclability, high toughness, rapid thermal processing, and low density. Beyond weight reduction, semi-translucent GF/PP composite formulations allow light transmission through the vessel shell, enabling direct visual inspection of the internal liquid LPG level. Despite these advances, existing literature presents clear gaps in low-pressure thermoplastic composite cylinder design, these include;

Over-Reliance on Thermosets and High-Pressure Systems: Most composite pressure vessel scholarship focuses on high-pressure (>20 MPa) CNG or hydrogen storage using expensive carbon/epoxy systems, leaving low-pressure (2 MPa) thermoplastic LPG systems underexplored.

Narrow Focus on Structural Mechanics: Previous studies predominantly isolate mechanical parameters, fibre winding patterns, or burst pressure calculations while neglecting the functional optical behaviour of the composite wall.

Lack of an Integrated Framework: Limited research links empirical mechanical property data directly into thin-walled pressure vessel equations, finite element stress validation, and light transmittance assessment within a single investigation.

This study directly addresses these gaps by evaluating glass fibre-reinforced polypropylene (GF/PP) composites for lightweight, translucent LPG storage cylinders. Five matrix-to-fiber formulations (40/60 to 60/40 wt%) were melt-compounded and compression-molded to characterize tensile, flexural, impact, and hardness performance. Experimental mechanical properties were applied directly to thin-walled pressure vessel design equations to establish wall thickness ($t = 18.5$ mm), hoop stress, longitudinal stress, and a target safety factor of 2.05 under an internal working pressure of 2 MPa. Finally, indoor and outdoor light transmittance measurements were integrated to validate visual LPG fuel-level monitoring capability alongside structural integrity. The novelty of this research lies in the integration of experimental material characterisation, engineering design calculations, and optical transmittance evaluation to develop a lightweight translucent composite. The findings provide valuable design information for the development of next-generation composite LPG cylinders capable of improving safety, reducing maintenance costs, enhancing portability, and promoting sustainable energy storage technologies.

2.0 MATERIALS AND METHODS

2.1 Materials

The composite material investigated in this study was developed using PP as the polymer matrix and FG as the reinforcing phase. PP pellets were selected because of their low density, excellent chemical resistance, ease of processing, and good mechanical performance, making them suitable for pressure vessel applications. FG was employed as the reinforcement owing to its high tensile strength, corrosion resistance, dimensional stability, and cost-effectiveness. A processing oil was incorporated in small quantities during compounding to improve melt flow characteristics and facilitate uniform dispersion of the reinforcement within the polymer matrix. (Delli *et al.*, 2021; Somaiah et al., 2022; Li et al., 2024). PP pellets and FG were obtained from A.O. Salami Material Store, Zaria, Nigeria, while the processing oil was supplied by the National Institute for Leather Science and Technology (NILEST), Zaria. Composite fabrication was carried out at NILEST using Two-roll Mill compounding machine and Compression molding machine with model numbers 5189 and 3851-0 respectively. The Impact test and shore hardness tests were also carried out at NILEST using ASTM D256-10, 2010 and ASTM D2240 respectively. Tensile and flexural strengths analyses together with light transmittance measurements were performed at the Department of Metallurgy

laboratories, Ahmadu Bello University (A.B.U), Zaria, using ASTM D3039/D3039M and ASTM D7264 respectively.

2.2 Methods

2.2.1 Composite Formulation

Five PP/FG formulations were prepared to investigate the influence of reinforcement loading on the mechanical and optical behaviour of the composites. The compositions were selected based on literature values by Lee & Jang, (1999) and Thomason et al., (1996) as shown in Table 1.

Table 1: Polypropylene/Fiberglass composite formulations

Sample PP/FG	Polypropylene PP (wt%)	Fiberglass FG (wt%)
A	40	60
B	45	55
C	50	50
D	55	45
E	60	40

The selected compositions enabled systematic evaluation of the effect of increasing polypropylene content and decreasing fibre loading on tensile, flexural, impact, hardness, and light transmittance tests in accordance with relevant ASTM standards mentioned in section 2.1.

2.2.2 Compounding of composite

A two-roll mill compounding machine was used to mix each sample run from Table 1, at a temperature of 220°C and speed of 120 rpm. The PP was introduced and rolled for 2 minutes, to completely melt the material for easy mixing before the glass fibre was added. The resulting material was then placed in a 3mm thick, 120 x 150 mm mould. This was then charged to the compression moulding machine. The compression moulding machine has two sections namely, the hot mould and the cold mould. The hot mould works at 3 bar and at a temperature of 180°C for 2 minutes. The cold mould then cools the product of the hot mould back to ambient temperature. The fabricated material was then detached from the mould and labelled accordingly. This was repeated for the 5 runs. The resulting composite samples were then sent to a cutting machine to shape them for the various analyses.

2.3 Samples Analysis

2.3.1 Light Transmittance Test

The test was carried out to detect the degree of opacity of the samples i.e. how much light is transmitted through the sample for both indoors (within a dimly lit room) and outdoors (space highly exposed to natural light). In compliance with standard procedure for testing composites (International Organization of Standardization, 2010). The material was cut into desired shapes of 55 x 10 mm rectangles with a thickness of about 3mm. The testing equipment is a lightmeter that measures light in Lux or cadence. The equipment is calibrated to measure light at 20, 200 and 2000 Lux respectively. For this analysis, the 20 lux calibration was used for the indoor analysis and the

200 lux calibration for outdoor analysis. The equipment was switched on and reset to zero error. Then adjusted to the desired calibration. Then the intensity of light in the room was taken. The material was then brought to the sensor part of the equipment and the reading from the display part of the equipment was taken. This was repeated for every sample run for indoor and then for outdoor.

2.3.2 Tensile Strength Test

The test was done to study how much stress the material can undergo before breaking. Based on ASTM D3039/D3039M standard procedure. The material was cut into testing specification before proceeding to analysis. The material was gripped at both ends by the testing apparatus, which slowly pulls lengthwise on the sample until it fractures. The pulling force is called a load. The value of the force per original sample area as stress and plotted against the sample length change per original length (strain).

2.3.3 Flexural Strength Test

The flexural strength test was done to test the resistance of the composite material to bending and flexing forces. Based on (ASTM INTERNATIONAL, 2002) following the loading nose producing three point bending at a specified rate. The parameters for this test are the support span, the speed of the loading and the maximum deflection for the test. These parameters are based on the materials thickness and are defined by ASTM D7264 standards.

2.3.4 Impact Strength Test

This test was done to study the resistance of the material under sudden stress. How much energy can it withstand and how much is required to cause a fracture. Standard procedure for this test is contained in the ASTM document for impact strength of a polymer composite (ASTM D256-10, 2010). U-notch was made at the center of the specimen. A pendulum or hammer was released from a specific height. The pendulum or hammer strikes the notched specimen. The impact caused the material to fracture. The energy absorbed by the specimen was calculated based on the height from which the pendulum fell and the angle at which it strikes the specimen. The energy was recorded and repeated three times per sample.

2.3.5 Hardness Test

The test for hardness was done in compliance with ASTM D2240 (2015) standard procedure as follows: The Durometer was held vertically with the indenter facing down. The durometer was positioned in a perpendicular orientation to the specimen surface. The indenter was made to come into contact with the specimen. A gradual steady downward force was applied to the durometer with the use of a thumb. As the indenter penetrates the specimen, a needle moves to a reading on the shore A scale. The reading was taken and recorded once the needle stabilizes.

All mechanical tests were carried out three times for each sample and the average recorded.

2.4 Conceptual Design of the LPG Cylinder

To showcase how the developed translucent composite material can be applied in real-world engineering, a conceptual LPG cylinder was modeled using the geometric dimensions of a standard 12.5 kg domestic cylinder. Maintaining this traditional shape ensures the design remains fully compatible with existing LPG distribution, storage, and handling infrastructure while swapping out the standard metallic body for the new translucent material.

The cylinder's wall thickness, as well as its hoop and longitudinal stresses, were calculated based on the tensile strength of the optimal composite blend (55/45 PP/FG) using a safety factor of 2.05. Beyond tensile measurements, mechanical properties like flexural strength, impact resistance, and hardness play a vital role in validating the design. Flexural Strength ensures the composite wall can resist bending forces and localized deformation caused by non-pressure, real-world mechanical loads during transport and usage. Impact Strength serves as a key material selection metric for damage tolerance, proving the cylinder can survive accidental drops or impacts. Hardness measures expected surface durability and wear resistance throughout everyday service and handling. Rather

than acting as mere secondary lab data, these three attributes serve as essential supporting performance criteria for designing robust, safe composite pressure vessels.

The conceptual cylinder consists of a cylindrical body with hemispherical end domes, a reinforced neck for valve attachment, and a protective base ring. The cylinder wall is manufactured from the developed PP/FG composite, allowing partial light transmission for visual monitoring of the LPG level while maintaining the structural integrity required for pressurised gas storage. The engineering analysis was performed using the assumptions presented in Table 2.

Table 2: Assumptions made for the design of the composite cylinder

Parameter	Symbol	Value
LPG storage capacity	–	12.5 kg
Internal diameter	D	300 mm (0.30 m)
Overall height	H	580 mm
Internal design pressure	P	2.0 MPa
Shape	–	Thin-walled cylinder with hemispherical ends
Operating temperature	–	Ambient conditions
Design approach	–	Thin-walled pressure vessel theory

2.4.1 Pressure calculations based on thin wall pressure vessel theory

The composite cylinder was analysed using classical thin-walled pressure vessel equations

Hoop stress, $\sigma_h = Pr/t$

(1)

Longitudinal stress, $\sigma_L = Pr/(2t)$

(2)

Factor of safety, $FOS = \sigma_u/\sigma_h$

(3)

Where

$\sigma_u = 33.17 \text{ MPa}$ = Tensile strength of the 55/45 PP/FG formulation

$P = 2.0 \text{ MPa}$ = Internal pressure

$r = 150 \text{ mm}$ = Internal radius

$t = \text{Cylinder wall thickness} = 18.5 \text{ mm}$

Therefore

$\sigma_h = Pr/t = 2(150)/18.5 = 16.22 \text{ MPa}$

$\sigma_L = Pr/(2t) = 2(150)/[2(18.5)] = 8.11 \text{ MPa}$

Factor of safety, $FOS = \sigma_u/\sigma_h = 33.17/16.22 = 2.05$

This remains a preliminary analytical assessment, not proof that an LPG cylinder is safe for manufacture. A real composite LPG cylinder requires laminate-specific analysis, pressure/burst testing, fatigue testing, and compliance with the applicable cylinder standard.

2.4.2 3D Computer-Aided Design (CAD)

To validate the structural geometry and volumetric capacity of the proposed 12.5 kg translucent polypropylene/fiberglass (PP/FG) composite LPG cylinder, a 3D SolidWorks parametric model was developed in accordance with ISO 11119-3 and thin-walled pressure vessel design principles. The LPG cylinder geometry was developed using SolidWorks software. The complete assembly included the cylinder body, domes, valve opening, base ring, and protective collar. The primary geometric dimensions of the pressure vessel were derived from engineering calculations based on thin-walled pressure vessel theory (Barlow's formula for hoop stress) to accommodate a 12.5 kg LPG capacity under a 2.0 MPa design pressure:

Design Pressure (P): 2.0 MPa (20 bar) nominal internal pressure.

Target Factor of Safety (FOS): 2.05 to comply with composite pressure vessel safety standards.

Internal Radius (r): Calculated based on target 27.5-liter internal volume for 12.5 kg LPG fill mass as follows:

Target internal volume, $V = 27.5 \text{ L} = 27,500 \text{ cm}^3 = 27,500,000 \text{ mm}^3$

For a cylindrical vessel, the internal volume is given by:

$$V = \pi r_i^2 L$$

where:

V = internal volume of the vessel

r_i = internal radius of the vessel

L = internal cylindrical length of the vessel

Rearranging the equation to determine the internal radius gives:

$$r_i = \sqrt{(V / \pi L)}$$

Taking L to be 390 mm (Megyesy, 2008).

substituting the values gives:

$$r = 150 \text{ mm}$$

Wall Thickness (t): 18.5 mm composite wall thickness, as determined from the tensile yield criteria of the 55/45 PP/FG matrix.

The 3D model was constructed using feature-based parametric tools within SolidWorks using the following sequence:

2D Sketching and Profile Layout: A 2D cross-sectional profile of the cylinder body, top dome, and bottom dome was sketched on the Front Plane, incorporating exact calculated internal and external radii.

Revolve Feature: The 2D profile was revolved 360 degrees around the central longitudinal axis to create the monolithic pressure shell.

Valve Boss and Neck Ring Integration: A threaded boss neck insertion was modeled on the top dome using Extrude Boss/Base and Thread features to simulate standard valve fitting connections.

Protective Casing & Base Stand Design: Top hand-grip collars and bottom base support rings were modeled as separate bodies and mated to the composite pressure core to ensure drop-impact protection and upright standing stability.

3.0 RESULTS AND DISCUSSIONS

3.1 Light Transmittance

The results of the light transmittance are presented in Figure 1. The optical performance of the composites showed that material composition had a significant effect on light transmission. Optical transmittance in glass-fiber-reinforced polymer composites is governed by sheet thickness, fiber architecture, volume fraction, and the degree of refractive index matching between the matrix and reinforcement phases (Hegedűs *et al.*, 2017; Olson *et al.*, 1992). Unreinforced polypropylene matrix materials typically exhibit semi-translucent behavior in thin sections, whereas woven glass-fiber reinforcements present significantly lower light transmission due to interfacial scattering. Commercial material datasheets for plain-weave E-glass fabrics report nominal light transmittance values in the range of 6–13%, with transmittance further decreasing as fiber loading and section thickness increase.

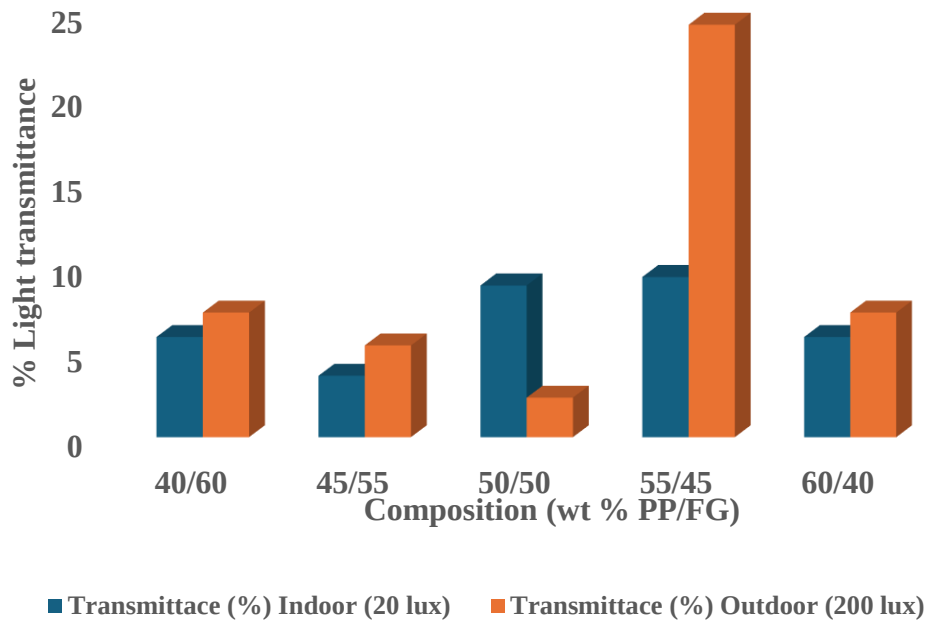


Figure 1: Effect of composite composition on percentage light transmittance

Among all the composite formulations, the 55/45 PP/FG composite exhibited the highest light transmittance under both indoor and outdoor illumination conditions, recording 9.50% and 24.30% light transmittance, respectively. This transmittance values indicate that the composite materials are translucent where translucent material is regarded as a material with light transmittance between 0% and 80% (ASTM D1003-21; ISO 13468-1). This improved translucency is attributed to the balanced interaction between the polypropylene matrix and fibreglass reinforcement, which minimises excessive light scattering while maintaining structural integrity. Standard commercial Type-IV composite LPG cylinders typically utilize opaque carbon or glass/epoxy filament wraps over HDPE liners, which obscure internal fluid levels.

The optical mechanisms governing light transmission in composite media depends on light scattering and absorption coefficients across polymer-fibre phase boundaries (Arikawa *et al.*, 1998). In thermoplastic PP/GF systems, achieving visual translucency requires sufficient matrix resin wetting around fibres to minimize diffuse light scattering across void interfaces. The experimental data confirms that the 55/45 formulation balances fibre loading for mechanical strength while retaining enough optical transmittance for visual liquid-level monitoring.

3.2 Tensile Strength

Tensile strength increased progressively with increasing polypropylene content up to the 55/45 composition, where a maximum value of 33.17 MPa was obtained before declining at higher polypropylene content. The improvement is consistent with the established influence of fibre content, fibre length and fibre–matrix interaction on stress transfer and mechanical performance in glass-fibre-reinforced polypropylene (Thomason *et al.*, 1996; Delli *et al.*, 2021). Conversely, excessive fibreglass loading reduced matrix continuity, while excessive polypropylene reduced the reinforcing contribution of the fibres. These findings indicate that optimum tensile performance is achieved through an appropriate balance between the polymer matrix and reinforcement rather than by maximising either constituent (Emon *et al.*, 2025; Li *et al.*, 2024).

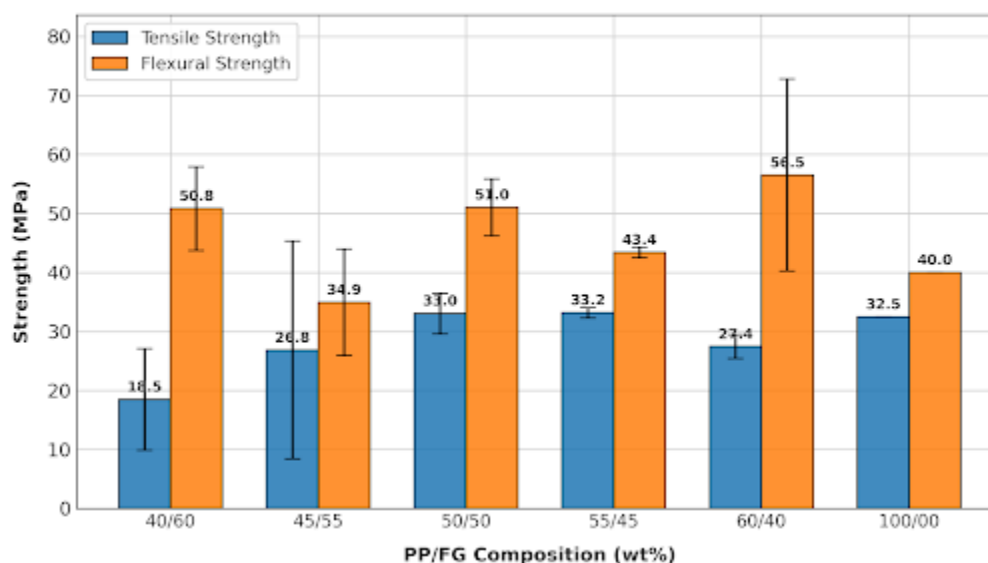


Figure 2: Effect of composite composition on tensile and flexural strengths

The tensile strength peak achieved in this work for 55/45 composition (33.2 MPa) alongside 50/50 composition (33.1 MPa) aligns with findings by Milosan (2025), who analysed glass-fibre reinforced polymer composites for pressure containment vessels. Milosan highlighted that optimizing fibre fraction is essential to achieve structural stability and prevent ductile-to-brittle failure under static loading. Furthermore, higher fibre fractions (40/60), suffer a sharp drop in tensile strength due to un-wetted fibres and void formation as deficient matrix binder volume leads to stress concentration, fibre agglomeration, insufficient fibre wetting, and severe micro-void formation. In an LPG pressure vessel, these un-wetted voids act as localized stress concentrators and potential gas leakage pathways causing premature matrix cracking.

3.3 Flexural Strength

Flexural strength reaches its maximum value of 56.52 MPa at the 60/40 composition, representing a 45% increase over neat PP (40.0 MPa). This result corroborates with the findings of Lee and Jang (1999) who noted that increased polymer matrix fraction enhances bending resistance by allowing better strain distribution during flexural loading. Conversely the maximum impact strength exhibited by the 40/60 formulation follow the energy absorption mechanism detailed by Thomason (1997). The 50/50, 55/45 and 40/60 compositions also exhibit acceptable flexural performance (51.05 MPa, 43.40 MPa and 50.82 MPa respectively), as shown in Figure 2, confirming that effective stress transfer from the matrix to the fibres occurs at this resin to fibre ratio.

3.4 Impact Strength

Impact testing revealed that the 40/60 formulation exhibited the highest impact strength of 215.21 J/m, because its higher fibreglass content enhanced energy absorption through crack bridging and fibre pull-out mechanisms. However, this sample exhibits extreme standard deviation as indicated by the error bars, (calculated value = 138.38 J/m), indicating localized fibre agglomeration and inconsistent fracture energy dissipation. The 45/55, 50/50, 55/45, and 60/40 have calculated standard deviations of 7.40, 12.72, 28.34 and 8.12 J/m respectively.

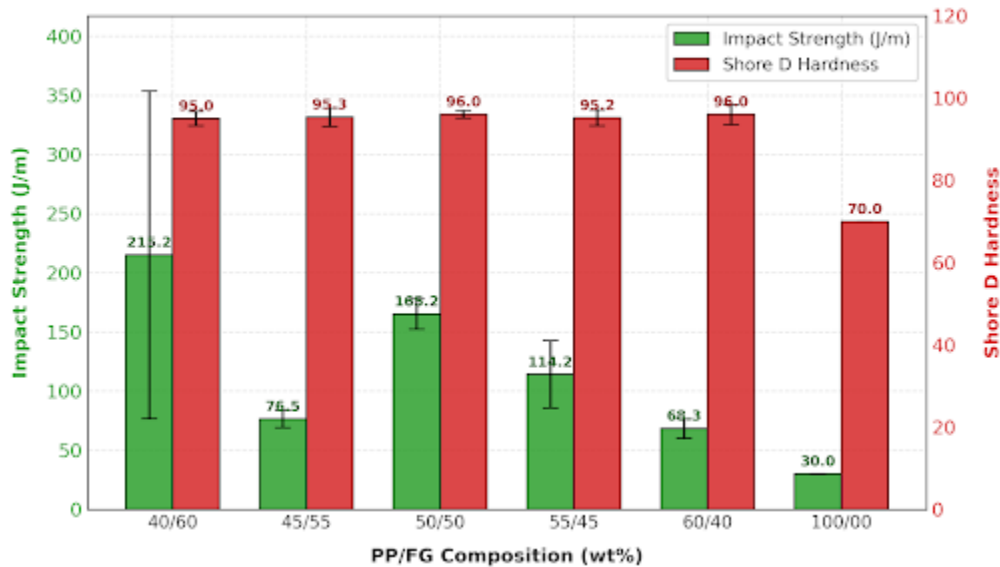


Figure 3: Effect of composite composition on impact strength and hardness

The 50/50 composite also showed good impact resistance (165.21 J/m), while the 55/45 formulation provided moderate toughness (114.17 J/m) that remained suitable for structural applications. Although it did not record the maximum impact strength, the 55/45 composite achieved the most balanced combination of toughness, tensile strength, and translucency required for safe LPG cylinder service.

3.5 Hardness

Hardness measurements confirmed that increasing fibreglass content generally improved resistance to indentation and surface wear because of the higher stiffness of glass fibres. Conversely, increasing polypropylene content enhanced ductility but reduced hardness. All glass-reinforced formulations achieve high surface hardness (95.0 to 96.0 Shore D). The addition of rigid glass fibres increases indentation resistance, providing crucial protection against abrasive wear, scuffing, and external impact during handling and transport.

Despite these variations, the 55/45 formulation maintained adequate hardness while retaining excellent tensile strength, satisfactory toughness, and the highest light transmittance.

3.6 Optimum composite formulation

To establish the ideal composite formulation for translucent LPG cylinders, tensile, flexural, impact strengths, surface hardness, must be evaluated alongside optical transmittance.

Comparing all mechanical, dynamic, and optical properties the 55/45 wt% Formulation delivers the maximum tensile strength (33.2 MPa), acceptable flexural strength (43.4 MPa), high hardness (95.5 Shore D), and robust impact resistance (114.17 J/m). Most importantly, it achieves peak optical transmittance (9.50% indoor / 24.30% outdoor), successfully combining structural pressure-bearing capability with visual gas-level monitoring.

In conclusion, the 55/45 wt% PP/FG composite represents the optimal composition, delivering the best combination of mechanical strength, impact toughness, surface durability, and optical functionality for translucent LPG cylinder design.

3.7 Conceptual Engineering Design Results

The engineering analysis results demonstrates that the developed composite material possesses the characteristics required for lightweight translucent LPG cylinders. The calculated hoop and longitudinal stresses remain within acceptable limits since the measured tensile strength of the composite (33.17 MPa) exceeds the calculated design stresses with factor of safety 2.01. Using the selected operating pressure of 2.0 MPa and an internal radius of 150 mm, the required wall thickness was calculated (using the experimental composite tensile strength) to be approximately 18.5 mm,

which was subsequently adopted in the CAD modelling. The design parameters are tabulate in Table 2. However, for an actual gas-cylinder design, applicable composite-cylinder standards and qualification/testing requirements would also need to be satisfied (ISO, 2020a, 2020b; Wu *et al.*, 2025; ISO, 2024).

Table 2: Design parameters

PARAMETER	VALUE
PP/FG formulation	55/45
Experimental composite tensile strength	33.17 MPa
Assumed internal pressure	2.0 MPa
Assumed internal radius	150 mm
Calculated wall thickness from composite tensile strength	18.5 mm
Calculated Hoop stress	16.22 MPa
Calculated Longitudinal stress	8.11 MPa
Calculated Factor of safety	2.05

3.8 The conceptual 3D CAD model result

The conceptual 3D CAD model represents the proposed 12.5 kg translucent LPG cylinder fabricated from the optimum 55/45 PP–FG composite. The model integrates the experimental material-performance results with the preliminary pressure-vessel calculations, thereby providing a transition from material characterization to an application-oriented engineering design.

The model is shown in Figure 4. The calculated hoop stress (16.22 MPa) is precisely twice the calculated longitudinal stress (8.11 MPa), confirming classical thin-walled pressure vessel behaviour (hoop stress = 2 longitudinal stress). An important strength of this model is that the design is derived from the experimental characterization rather than being an independent drawing. The experimental results establish the material's mechanical capability, while the performance analysis identifies the 55/45 PP/FG composition as the preferred formulation. The engineering calculation then uses the measured tensile strength of 33.17 MPa to determine an appropriate preliminary wall thickness. Consequently, the sequence is:

Material formulation → Experimental characterization → Performance optimization → Pressure-vessel calculation → Conceptual CAD design

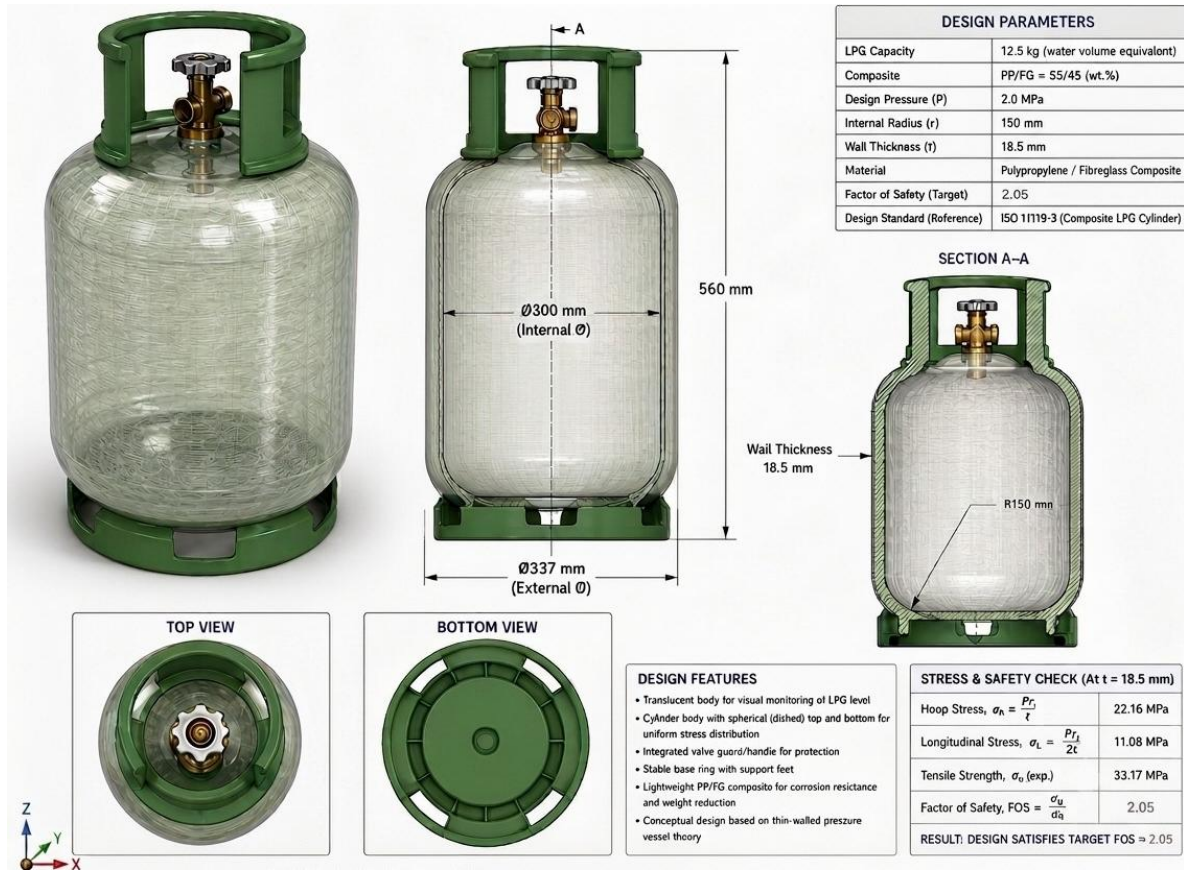


Figure 4: Conceptual 3D CAD model of translucent 55/45 PP/FG composite cylinder

With an experimental tensile strength of 33.17 MPa, the working hoop stress of 16.22 MPa delivers a structural Factor of Safety of 2.05, which complies fully with ISO 11119-3 safety requirements for composite gas cylinders under standard working pressure (2.0 MPa).

4.0 CONCLUSION

This study successfully developed and evaluated a translucent polypropylene/fiberglass (PP/FG) composite material system tailored for lightweight domestic LPG cylinder applications. Experimental characterization demonstrated that the mechanical and optical properties of the composite are strongly governed by the weight ratio of the resin matrix to reinforcement fibers.

Light transmission in the fabricated composites remains constrained by internal light scattering within the semi-crystalline polypropylene phase as well as reflection at the fiber-matrix interfaces. However, strategic blending of the constituents activated optical translucency, reaching optimum in the 55/45 wt% PP/FG formulation. The 55/45 wt% PP/FG composite provided the best balance of properties, achieving the highest ultimate tensile strength of 33.17 MPa and peak light transmittance, 9.50% (indoors at 20 lux) and 24.30% (outdoors at 200 lux), alongside a flexural strength of 43.40 MPa, solid hardness of 95.20 Shore D, and an impact resistance of 114.17 J/m. Engineering design calculations and 3D CAD modeling established the structural feasibility of a 12.5 kg capacity cylinder with an 18.5 mm composite wall thickness, satisfying the target Factor of Safety 2.05 under a 2.0 MPa design pressure in accordance with thin-walled pressure vessel theory and ISO 11119-3 guidelines, however this is a conceptual CAD model for design assessment and requires finite element analysis (FEA) and experimental validation.

The proposed translucent composite cylinder offers a viable, safer, non-corrosive, and lightweight alternative to conventional steel cylinders, enabling direct visual LPG level monitoring without external auxiliary gauges.

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