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Investigation of Differences in Light Transmission in Translucent Materials Used in Additive Manufacturing

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***Abstract*— The present study investigates the impact of filament colour and specimen thickness on overall light transmittance in fused deposition modelling printed transparent PETG. Flat specimens were prepared in six transparent colour variants (transparent, blue, neon green, orange, red, and yellow) and in thicknesses ranging from 1.0 to 3.5 mm. The measurements were conducted within a custom-built enclosed laboratory stand, thereby ensuring the elimination of ambient light interference. In order to verify the result stability, the transmitted light was measured at four nominal source power levels (200, 2600, 6600, and 10600 lx) and evaluated as normalized transmittance. For all of the materials that were analysed, there was a decrease in transmittance as specimen thickness increased. Transparent PETG demonstrated the highest transmittance from 1.0 to 2.5 mm, while yellow PETG exhibited the highest values at 3.0 and 3.5 mm. In the present study, the lowest transmittance was exhibited by blue PETG at all thickness levels, with the approach of complete attenuation being observed in thicker specimens. Neon green exhibited an intermediate level of transmission, while orange and red demonstrated comparatively reduced transmission following a notable decline between 1.0 and 1.5 mm. The normalized values were found to be consistent across the higher source power settings, thereby supporting the reliability of the measured attenuation trends. The findings of this study demonstrate that transparent tinted PETG filaments cannot be regarded as optically equivalent, and that specimen thickness is a significant factor in determining attenuation in printed components.**

Keywords*— *additive manufacturing, attenuation, fused deposition modeling, PETG, light transmittance, translucent materials

I. INTRODUCTION

Additive manufacturing is increasingly utilised for the fabrication of polymer components that are expected to transmit visible light, including lamp covers, optical housings, façade elements, and microfluidic devices [1, 2, 3, 4]. In such instances, the optical performance is not solely governed by the polymer type. The quantity of light that traverses a printed element is contingent on the material itself, the optical path length through the component, and the internal structure that is formed by filament deposition and layer stacking [1, 2, 5, 6]. In the context of translucent FDM materials, it is imperative to acknowledge that both specimen thickness and filament colour can exert a substantial influence on the ultimate attenuation.

In the realm of FDM materials, PETG stands out as a particularly noteworthy contender. This is due to its unique amalgamation of printability, impact resistance, and a notable degree of transparency, as evidenced by numerous studies [1, 3, 7]. This renders it particularly appealing for applications where light transmission is of paramount importance. Recent research in the field of PETG has provided evidence that specimens produced by the FDM method can exhibit high levels of transparency, provided

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that the manufacturing conditions are suitably optimised [1, 3, 5, 7]. However, it is evident that the printed state deviates from the bulk material. The phenomenon of light transmission is influenced by the geometry of deposited roads, layer interfaces, and internal scattering that is introduced during the FDM process [1, 2, 5]. Consequently, it is imperative that transmittance and attenuation are evaluated on printed specimens, as opposed to being assumed from nominal filament properties alone.

The extant PETG literature is characterised by a lack of uniformity in scope. The majority of extant studies concentrate on the manner in which printing conditions can be optimised to maximise transparency or image visibility [1, 3, 5, 7]. The significance of this work lies in its demonstration of the profound impact of processing on optical performance. However, it provides less direct evidence for a related inquiry: namely, how the transmission of light is influenced by variations in specimen thickness and filament colour when these factors are manipulated as the primary variables. In the context of PETG, there is a notable absence of controlled comparisons of transparent coloured filaments tested across a thickness series. Instead, greater emphasis is placed on process optimisation, post-treatment, and application-specific transparency, with the result that the subject is much better documented [1, 5, 7].

Research consistently indicates that thickness is the most supported optical factor across the relevant literature. The findings of PETG-specific studies suggest that an increase in the optical path results in a decrease in transparency. This is due to the fact that high transmission is only maintained under print conditions that are meticulously controlled and under relatively favourable specimen formation [1, 3, 5]. Broader FDM literature elucidates this effect. Hamp et al. conducted a study in which they measured the transmittance of printed samples of varying thicknesses. Their findings indicated that the level of transmission was predominantly influenced by the thickness and colour of the samples [6]. As demonstrated by related studies on translucent PLA, an increase in thickness has been shown to result in a reduction in transmitted light [8, 9]. These results provide substantial support for the hypothesis that, in PETG, the attenuation of specimens will be greater the thicker they are.

The impact of colour is less thoroughly documented in the context of PETG, though it is improbable that its effect is negligible. The most robust PETG papers are those which focus on transparent materials, and they do not make a comparison between several transparent tinted PETG filaments within a single measurement protocol [1, 3, 5, 7]. Evidence pertaining to the broader field of FDM indicates that this is not merely a minor omission, but rather a significant gap. As demonstrated by Hamp et al., colour was identified as a primary factor contributing to disparities in transmittance observed in printed materials [6]. Research conducted on translucent FDM filaments has demonstrated that pigments and additives have the capacity to modify the absorption, scattering, and the spectral character of transmitted light. This effect has been observed to intensify in proportion to the optical path length [8, 10, 11]. It is important to note that even when the polymer family remains constant, the transparent blue, red, yellow, orange, and neon green materials should not be assumed to attenuate light in the same manner.

As indicated by the extant literature, the attenuation of FDM-printed polymers is not always adequately described by a simple homogeneous slab model. As Hamp et al. reported, the application of a simple exponential relation between thickness and transmission was limited by multiple scattering [6]. The hypothesis that light loss in FDM parts is attributable to both absorption and structure-dependent scattering is corroborated by related research on printed translucent materials and appearance modelling [2, 10]. This is a salient consideration in experimental design, as it underscores the significance of practical measurements of overall transmittance, even in circumstances where the underlying optical behaviour exhibits greater complexity than that of pure bulk absorption.

The extant literature on measurement supports the use of controlled specimen series and shielded test arrangements. It is evident that a number of the most prominent publications employ flat samples of defined thickness, stable illumination, and a controlled light path to facilitate a comparison of the transmitted light between specimens [1, 6, 9, 12]. Despite the variation in instrumentation across studies, the fundamental logic remains constant. The reliability of direct comparison is enhanced when the environment is fixed and only one variable is modified at a time [1, 6, 12]. This is particularly pertinent in the context of brief experimental studies, where methodological consistency can serve as a compensatory mechanism for the absence of comprehensive optical characterisation.

A comprehensive review of the extant literature indicates that PETG is a promising transmissive FDM material. However, the current evidence base remains limited in terms of systematic comparisons focused on colour and specimen thickness. A review of extant PETG studies reveals a predominant focus on enhancing transparency through process optimisation. Conversely, a survey of broader FDM studies suggests that both thickness and color can significantly affect the transmission of light [1, 5, 6, 8]. It is evident that there is a clear necessity for comparative data acquired on printed PETG specimens of varying colours and thicknesses under a single stable measurement method. The analysis of such data can facilitate a more comprehensive understanding of the attenuation behaviour exhibited by transparent PETG filaments. Furthermore, it has the potential to broaden the existing literature by expanding its scope beyond the current emphasis on either clear specimens or processing parameters alone.

In this context, the present study investigates overall light transmittance in FDM-printed transparent PETG specimens as a function of colour and thickness. The samples were prepared in six transparent colour variants — transparent, blue, orange, neon green, yellow, and red —

and in thicknesses of 1.0, 1.5, 2.0, 2.5, 3.0, and 3.5 mm. The objective of the study is twofold: firstly, to generate directly comparable attenuation data by testing all specimens on the same closed laboratory stand; and secondly, to address the lack of systematic evidence for transparent coloured PETG in the current FDM optics literature.

II. Materials and Methods

A. Materials

The study is carried out using transparent PETG filament materials intended for FDM printing. Six transparent colour variants are selected: transparent, blue, orange, neon green, yellow and red. Using one polymer family with several transparent colour variants makes it possible to examine the effect of colour while limiting the influence of large differences in base chemistry. This approach is consistent with previous work on FDM optics showing that colour can significantly impact transmitted light, even when the underlying printing process remains the same [1, 3, 5]. The main factors and used levels are showed in table 1. All used filaments are with a diameter of 1.75 mm, kept in zip-tie bag with silica gel to avoid additional moisture. The materials utilised in the production process are sourced from a variety of manufacturers, primarily due to the fact that not all manufacturers offer the complete range of semi-transparent colours.

Table 1 Factors and Levels

№	Influencing factors and levels used	
	Factors	*Levels used*
1	Material	PETG
2	Printing technology	FDM
3	Colours	Transparent, blue, orange, neon green, yellow, red
4	Nominal thickness	1.0, 1.5, 2.0, 2.5, 3.0, 3.5 mm
5	Nominal source power levels	200, 2600, 6600, 10600 lx.

Flat specimens with constant nominal thickness were prepared for optical testing. A thickness series is commonly used in transmission studies of printed polymers because it allows direct comparison of attenuation as the optical path increases [1, 2, 3]. Each specimen group differed only in colour and nominal thickness, while the remaining design features were kept constant. Table 2 shows the main parameters and factors and variables used in specimen design and fabrication. Figure 1 shows the geometry of the tested specimens.

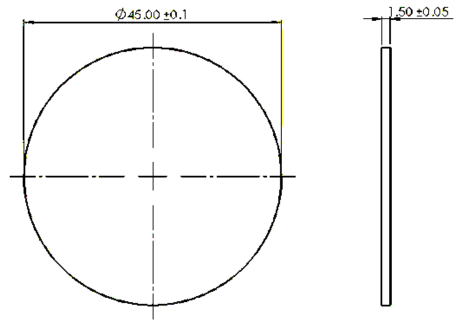

Fig 1. Test specimen Ø45 mm; thickness – 1.5 mm.

Table 2 Parameters and Draft Description

№	Specimen parameters and draft description	
	Factors	*Levels used*
1	Specimen geometry	Flat plate specimens
2	Thickness	1.0 to 3.5 mm in 0.5mm steps
3	Variable factors	Colour and thickness
4	Verification factor	Nominal source power
5	Fixed factors	All remaining print settings held constants for all samples

Specimens were manufactured by FDM printing on a Prusa Mk4S using a 0.4 mm nozzle. Printing is performed with fixed settings for nozzle temperature, bed temperature, layer height, print speed, cooling, extrusion multiplier, infill strategy, and print orientation. These parameters should be reported explicitly because PETG transparency is known to depend on print formation conditions [3, 5, 6]. For the present study, however, such parameters were held constant so that the primary comparison remained centered on color and specimen thickness. Printing conditions are shown in table 3.

TABLE I. Printing Parameters

№	Specimen parameters and draft description	
	Parameters	*Levels used*
1	Printer	Prusa Mk4S
2	Slicer	Prusa SlicerR 2.9.4
3	Nozzle temperature	245 °C
4	Bed temperature	85 °C
5	Layer height	0.15 mm
6	Print speed	Up to 200 mm/s
7	Infill	15 %
8	Infill pattern	Grid
9	Cooling setting	Basic

Overall light transmittance is measured using a laboratory stand designed and manufactured before the present study. The stand is largely 3D printed and fully enclosed, so that environmental light does not affect the measurement. A closed optical path is appropriate for comparative transmittance testing because it improves repeatability and reduces uncontrolled variation from ambient light [1, 2]. Figure 2 shows the used stand. The test samples are then placed in the holders (8), which have been specially designed for this purpose. The holders are then placed in the test stand (3). The lid (4) is then closed, and the measurement process begins. Sensors (6) are employed to monitor both the ambient temperature and the temperature of the light source. The measuring sensor is located in cover 2; 1 is the test stand; 5 is the cooling element; and 7 is a fan that activates when additional cooling is required.

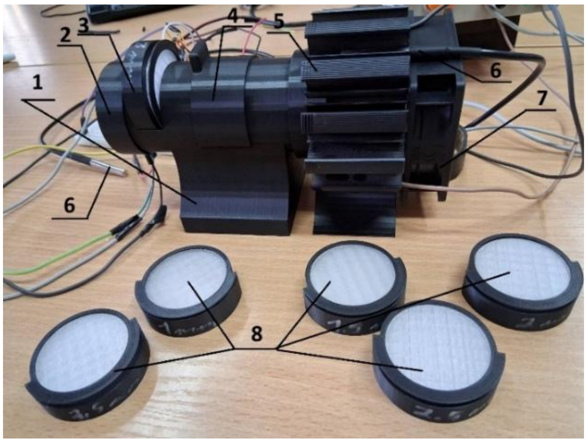

Fig 2. Laboratory stand.

Before specimen testing, the stand should be allowed to reach stable operating conditions. For each measurement series, the nominal light source power was first set to one of four levels: 200, 2600, 6600, or 10600 lx. A reference measurement without a specimen in the optical path was then recorded for that source setting. Each printed sample was placed in the same position inside the stand and measured under identical geometric conditions.

This procedure was repeated for all specimens at all four nominal source-power levels. The source-power series was not treated as a primary experimental factor, but as a consistency check to verify whether attenuation trends remained stable under different illumination intensities.

A practical procedure is given below.

1. Stabilize the light source for a fixed warm-up time.
2. Set the nominal source power to 200, 2600, 6600, or 10600 lx.
3. Record the reference signal with no specimen in the optical path.
4. Insert the specimen into the holder in a repeatable orientation.
5. Record the transmitted-light signal.
6. Repeat the measurement for all source-power levels and all specimen groups.

B. Methods

Calculation of transmittance and attenuation

Because the raw transmitted-light values scaled with source intensity, the comparative optical results should be reported as normalized transmittance. For each specimen and source-power level, transmittance is expressed as the ratio of transmitted intensity to the corresponding reference intensity:

$$T = \frac{I}{I_0} \quad (1)$$

Where I is the measured transmitted-light intensity for the specimen and I_0 is the reference intensity at the same nominal source-power setting. If reported as a percentage:

$$T_{\%} = 100.\frac{I}{I_0} \quad (2)$$

Attenuation may be expressed as:

$$A = 1 - \frac{I}{I_0} \quad (3)$$

or, in percentage form:

$$A_{\%} = 100 - T_{\%} \quad (4)$$

Because FDM printed translucent materials often show scattering in addition to absorption, the measured attenuation should be interpreted as an effective result of the printed material and structure rather than as pure bulk absorption alone [1, 7].

The method is designed to isolate the two variables of main interest: filament color and specimen thickness. This choice reflects a clear gap in the current literature. PETG studies mainly emphasize how process parameters affect transparency [3, 5, 6], whereas broader FDM studies show that thickness and color are strong optical drivers in their own right [1, 7]. By holding print settings constant and using one enclosed measurement stand for all specimens, the experiment is positioned to deliver directly comparable overall transmittance data for transparent colored PETG samples.

III. Results and Discussion

The dataset covered six PETG colour variants and six specimen thicknesses, with measurements performed at four nominal light source power levels of 200, 2600, 6600, and 10600 lx. Because the transmitted-light readings scaled with source intensity, the comparative results are reported below as normalized transmittance percentages, obtained from the ratio of transmitted light to the nominal source level. For each colour-thickness combination, the table values represent the mean normalized transmittance across the four source settings. The main trend was clear. Overall light transmittance decreased with increasing specimen thickness, and the magnitude of transmission depended strongly on filament colour. The mean normalized transmittance is shown in table 4.

TABLE II. MEAN NORMALIZED TRANSMITTANCE

Colour	**Mean transmittance, %**					
	1.0 mm	***1.5 mm***	***2.0 mm***	***2.5 mm***	***3.0 mm***	***3.5 mm***
Transparent	44.22	41.00	30.18	28.03	25.47	24.19
Blue	1.53	0.71	0.24	0.21	0.19	0.18
Neon green	37.08	35.46	23.21	22.20	20.35	19.90
Orange	24.82	13.14	9.71	9.73	9.21	8.40
Red	25.80	15.17	9.31	10.29	9.06	8.40
Yellow	39.91	38.83	26.29	26.45	26.23	25.45

Transparent PETG showed the highest mean transmittance at 1.0 to 2.5 mm, while yellow PETG is highest at 3.0 and 3.5 mm. Blue PETG showed by far the lowest transmittance at all thickness levels. At 1.0 mm, the difference between the highest and lowest transmitting materials is 42.69 percentage points, while at 3.5 mm the difference is 25.27 percentage points. Mean attenuation is presented in table 5.

TABLE III. MEAN ATTENUATION

Colour	**Mean attenuation, %**					
	1.0 mm	***1.5 mm***	***2.0 mm***	***2.5 mm***	***3.0 mm***	***3.5 mm***
Transparent	55.78	59.00	69.82	71.97	74.53	75.81
Blue	98.47	99.29	99.76	99.79	99.81	99.82
Neon green	62.92	64.54	76.79	77.80	79.65	80.10
Orange	75.18	86.86	90.29	90.27	90.79	91.98
Red	74.20	84.83	90.69	89.71	90.94	91.60
Yellow	60.09	61.17	73.71	73.55	73.77	74.55

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The attenuation data follow the inverse pattern of transmittance. For all tested materials, attenuation is high and generally increased with thickness. The strongest attenuation is observed for blue PETG across the full thickness range, whereas transparent and yellow PETG retained the highest transmitted-light fraction.

Thickness effect

For every tested colour, normalized transmittance was lower at greater specimen thickness. The most pronounced decrease is observed between 1.5 and 2.0 mm for transparent, neon green, and yellow specimens. Transparent PETG decreased from 44.22% at 1.0 mm to 24.19% at 3.5 mm, corresponding to a reduction of 20.03 percentage points. Neon green PETG decreased from 37.08% to 19.90%, and yellow PETG from 39.91% to 25.45%. For orange and red specimens, the dominant drop occurred between 1.0 and 1.5 mm, after which the transmittance values remained in a relatively narrow low range near 8% to 15%. Blue PETG showed extremely low transmittance already at 1.0 mm and approached zero transmission at higher thicknesses. Table 6 shows the effect of the colour at fixed thicknesses.

TABLE IV. COLOUR EFFECT AT FIXED THICKNESS

Thickness	**Colour effect at fixed thickness**	
	Highest transmittance	***Lowest Transmittance***
1.0 mm	Transparent	Blue
1.5 mm	Transparent	Blue
2.0 mm	Transparent	Blue
2.5 mm	Transparent	Blue
3.0 mm	Yellow	Blue
3.5 mm	Yellow	Blue

When thickness held constant, the optical effect of colour remained clear. Transparent and yellow PETG consistently transmitted the most light, with neon green forming an intermediate group. Orange and red transmitted substantially less light, while blue is distinctly lower than all other colours at every thickness. This shows that transparent tinted PETG filaments cannot be treated as optically equivalent within one material family.

The four source settings were used as a robustness check rather than as a primary experimental factor. For moderate and high-transmittance specimens, the normalized transmittance values were generally consistent across 2600, 6600, and 10600 lx, which supports the stability of the attenuation trend. The 200 lx condition showed larger deviations for very low-transmittance specimens, especially blue samples at 2.0 mm and above, where the transmitted signal approached the lower resolution limit of the setup.

This pattern suggests that the main conclusions about colour and thickness are stable, while the lowest source-power condition is less informative for heavily attenuating samples.

According to the data shown above a summary of the main findings is presented:

- Overall light transmittance decreased with increasing specimen thickness.
- Colour had a strong effect on transmitted light even within one PETG family.

- Transparent and yellow specimens showed the highest transmittance.
- Blue specimens showed the highest attenuation at all thickness levels.
- Neon green formed an intermediate transmission group.
- Orange and red showed low transmission after a marked drop at small thickness.
- The normalized results were broadly consistent across the higher source-power settings.

IV. Conclusions

The study examined the influence of filament colour and specimen thickness on overall light transmittance in FDM printed transparent PETG. Based on the obtained results, the following conclusions can be drawn.

- Both specimen thickness and filament color significantly affected transmitted light.
- For all tested PETG variants, transmittance decreased as thickness increased and attenuation increased accordingly.
- Transparent and yellow PETG showed the highest transmittance in the tested set, while blue PETG showed the strongest attenuation at all thickness levels.
- Neon green formed an intermediate optical group, whereas orange and red exhibited lower transmission after a pronounced drop at small thickness.
- The normalized results were broadly consistent across the higher nominal source-power levels, which supports the robustness of the observed attenuation trends.
- Transparent tinted PETG filaments cannot be considered optically equivalent within one material family.

Overall, the work fills a gap in the current literature by providing comparative transmittance data for several transparent coloured PETG specimens tested across a defined thickness range using one enclosed measurement setup. The results can support material selection and design decisions for FDM printed parts in which visible-light transmission is functionally important.

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