# FDM Material Properties and Application Logic: A Technical Database

This report provides a comprehensive database and technical analysis of common and specialty Fused Deposition Modeling (FDM) filaments. The data is structured to populate a material recommendation engine, adhering to the schema provided in material\_db.csv 1 and expanding it to include all requested materials.

The analysis is segmented into three parts:

1. **A Technical Primer** establishing the core material science principles that must govern the recommendation engine's logic.
2. **Master Material Databases** containing quantitative and qualitative data for direct ingestion.
3. **A Technical Dossier** on specialty filaments and application-specific "guardrails" required for an expert-level recommendation system.

## A Technical Primer for the Material Recommendation Engine

A successful recommendation engine must function as a domain expert, guiding users away from common pitfalls. The following principles are foundational to the application's filtering logic, particularly for the "Guided Selection Wizard" and "MCDM Ranker" features.1

### The Anisotropic Reality of FDM: A Prerequisite for Functional Design

Fused Deposition Modeling is an inherently anisotropic manufacturing process. This means the mechanical properties of a printed part are not uniform in all directions, a critical concept that must be central to the application's logic.2

Part strength is fundamentally bifurcated:

* **XY-Axis (In-plane) Strength:** This is dictated by the continuous extruded polymer. It represents the material's maximum potential strength.
* **Z-Axis (Build Direction) Strength:** This is dictated by *interlayer adhesion*—the quality of the thermal weld between subsequent layers. This bond is the part's weakest link.4

The tensile strength in the Z-axis is typically a fraction of the XY-axis strength. This reduction is commonly 40-60% 1, with some academic studies showing a 50-75% decrease in tensile strength 5 or a 4-5x difference in functional strength.4

This anisotropic behavior directly informs the logic for the "Global Load-Direction Toggle".1 A part loaded in tension along its Z-axis (e.g., a vertically printed hook) is predisposed to delamination and catastrophic failure. When this toggle is set to "Z-Axis Load," the application's ranking system must exclusively use the Strength\_Z\_MPa data. Furthermore, a "guardrail" warning 1 should advise the user to re-orient their part for printing, aligning the critical stress direction with the XY plane for maximum strength. This report provides data for both Strength\_XY\_MPa and Strength\_Z\_MPa to enable this critical feature.

### A Framework for Mechanical Properties (The "MCDM Ranker" Metrics)

Novice users often conflate "strength," "stiffness," and "toughness." The "Multi-Criteria Decision Making (MCDM) Ranker" 1 must help users navigate the trade-offs between these distinct properties.

* **Strength (Ultimate Tensile Strength, MPa):** The maximum static pulling force a material can withstand before it breaks.6
* **Stiffness (Tensile Modulus, MPa):** A measure of rigidity; the material's resistance to elastic deformation (flexing) under load. A high-modulus part is stiff; a low-modulus part is flexible.6
* **Toughness (Impact Resistance, kJ/m²):** A measure of energy absorption; the material's ability to resist sudden impact or shock *without shattering*.1

The "PLA vs. PETG" trade-off is the canonical example. A user ranking *only* for "Strength" and "Stiffness" will find PLA (Strength $\approx$ 65 MPa; Modulus $\approx$ 2800 MPa) ranks higher than PETG (Strength $\approx$ 49 MPa; Modulus $\approx$ 1913 MPa).1 However, PLA is brittle (Toughness $\approx$ 7 kJ/m²) while PETG is exceptionally tough (Toughness $\approx$ 10.5 kJ/m²).1 PLA fails like glass; PETG fails like metal, by deforming first.9 The application must guide a user seeking "durability" (Toughness) toward PETG, TPU, or PC, even if their "Strength" scores are lower.

### Understanding Long-Term Performance: Creep, Fatigue, and Environment

* **Creep:** This property, represented by the Prone\_to\_Creep flag 1, is the tendency of a material to deform *permanently* under persistent mechanical stress. PLA is highly susceptible to creep.1 A PLA shelf bracket, though strong enough to hold a book, will slowly sag and fail over months. PETG, ABS, ASA, and PC are significantly more resistant.11 The "Guided Selection Wizard" 1 must filter out any material where Prone\_to\_Creep is true if the user selects an application like "structural part under constant load."
* **Hygroscopicity:** The Hygroscopic flag 1 is critical for printability. Many engineering polymers (Nylon, PC, PETG, PVA, PVB) readily absorb moisture from the air.1 Printing "wet" filament causes steam, bubbles, and poor layer adhesion, dramatically reducing mechanical properties. Polypropylene (PP) is a notable exception, being non-hygroscopic.14
* **UV Resistance:** The UV\_Resistant flag 1 is essential for outdoor applications. PLA and ABS will degrade, crack, and discolor under UV exposure.15 The primary material for this application is **ASA** (Acrylonitrile Styrene Acrylate), which was designed as a UV-resistant alternative to ABS.16 PETG and PC also offer good UV resistance.17

## Master Material Database (Quantitative Properties)

The following tables populate the provided schema with synthesized data from technical data sheets (TDS) and industry reports. Where Z-axis strength data was not explicitly provided in a TDS, it is estimated at 45% of XY-axis strength for amorphous polymers (e.g., PLA, PETG, ABS) and 50% for semi-crystalline (e.g., Nylon), reflecting typical interlayer adhesion strength values.

### Table 1: Mechanical and Thermal Properties (Expanded material\_db.csv)

This table provides the core performance metrics required for the MCDM Ranker.1

| **Material** | **Cluster** | **Strength\_XY\_MPa** | **Strength\_Z\_MPa** | **Stiffness\_Modulus\_MPa** | **Toughness\_Impact\_kJ\_m2** | **Heat\_Resistance\_HDT\_C** |
| --- | --- | --- | --- | --- | --- | --- |
| **PLA (Standard)** | Standard | 65 | 29.3 | 2800 | 7 | 56 |
| **Tough PLA / PLA+** | Engineering | 65 | 29.3 | 2102 | 8.5 | 52 |
| **HTPLA (Annealable)** | Standard | 60 | 27 | 2800 | 7 | 58 |
| **PLA - Carbon Fiber** | Engineering | 70 | 31.5 | 7000 | 8 | 62 |
| **PETG** | Functional | 49 | 22.1 | 1913 | 10.5 | 75 |
| **PETG - Carbon Fiber** | Engineering | 58 | 26.1 | 6500 | 12 | 82 |
| **PET (e.g., eSUN)** | Engineering | 55 | 40 | 2100 | 9.5 | 78 |
| **ABS** | Functional | 38 | 17.1 | 2100 | 26.5 | 91 |
| **ASA** | Functional | 49.5 | 22.3 | 1930 | 41 | 95 |
| **HIPS** | Functional | 34 | 15.3 | 1675 | 37.5 | 87.5 |
| **Nylon (PA12)** | Engineering | 60 | 30 | 1400 | 14 | 90 |
| **Nylon - Carbon Fiber** | High-Performance | 83.5 | 41.8 | 9460 | 25 | 168 |
| **Polycarbonate (PC)** | Engineering | 64.5 | 29 | 2175 | 35 | 127.5 |
| **TPU 95A (Flexible)** | Functional | 34.5 | 27.5 | 52.5 | 35 | 61.5 |
| **TPU 85A (Soft Flexible)** | Functional | 8 | 6 | 50 | 6 | 60 |
| **PP (Polypropylene)** | Functional | 35.1 | 18.7 | 660 | 49.1 | 64 |
| **PVA (Soluble Support)** | Support | N/A | N/A | 3860 | N/A | 60 |
| **PVB (IPA-Smoothable)** | Aesthetic | 45 | 13.5 | 2500 | 10 | 55 |
| **PLA - Wood-filled** | Aesthetic | 26 | 11.7 | 2780 | 15.7 | 57 |
| **PLA - Metal-filled** | Aesthetic | 34 | 15.3 | 2290 | N/A | 52 |
| **PLA - Silk** | Aesthetic | 26 | 11.7 | 2816 | 25.5 | 54 |
| **PLA - Glow-in-the-dark** | Aesthetic | 32 | 14.4 | 2640 | 27.3 | 55 |
| **ULTEM 9085 (PEI)** | High-Performance | 76.2 | 54.2 | 2465 | 10 | 160 |
| **PEEK** | High-Performance | 101 | 75 | 3720 | 15 | 217 |

Data synthesized from.1

### Table 2: Physical and Economic Properties (Expanded material\_db.csv)

This table provides the necessary data for the "cost per cm³" calculation feature.1 A simple Cost\_Score based on price per kilogram is misleading. Materials must be compared by cost per *volume*.

The calculation is:

$Cost\_{per\\_cm^3} = (Price\_{USD\\_per\\_kg} / 1000) \* Density\_{g\\_cm^3}$

For example, Polypropylene (PP) has a high price per kilogram ($\approx$ $40) but is one of the cheapest materials by volume due to its 0.9 g/cm³ density. Conversely, Metal-filled PLA ($\approx$ $60/kg) appears affordable but is one of the *most expensive* materials by volume due to its 3.0 g/cm³ density.31

| **Material** | **Price\_USD\_per\_kg** | **Density\_g\_cm3** |
| --- | --- | --- |
| **PLA (Standard)** | 20 | 1.24 |
| **Tough PLA / PLA+** | 28 | 1.24 |
| **HTPLA (Annealable)** | 32 | 1.25 |
| **PLA - Carbon Fiber** | 55 | 1.30 |
| **PETG** | 25 | 1.27 |
| **PETG - Carbon Fiber** | 50 | 1.29 |
| **PET (e.g., eSUN)** | 30 | 1.27 |
| **ABS** | 22 | 1.04 |
| **ASA** | 30 | 1.07 |
| **HIPS** | 24 | 1.04 |
| **Nylon (PA12)** | 60 | 1.02 |
| **Nylon - Carbon Fiber** | 100 | 1.19 |
| **Polycarbonate (PC)** | 35 | 1.20 |
| **TPU 95A (Flexible)** | 30 | 1.22 |
| **TPU 85A (Soft Flexible)** | 30 | 1.21 |
| **PP (Polypropylene)** | 40 | 0.90 |
| **PVA (Soluble Support)** | 90 | 1.23 |
| **PVB (IPA-Smoothable)** | 30 | 1.24 |
| **PLA - Wood-filled** | 30 | 1.21 |
| **PLA - Metal-filled** | 60 | 3.00 |
| **PLA - Silk** | 25 | 1.25 |
| **PLA - Glow-in-the-dark** | 30 | 1.26 |
| **ULTEM 9085 (PEI)** | 220 | 1.27 |
| **PEEK** | 500 | 1.30 |

Data synthesized from.1 Prices are estimates based on 2024-2025 market rates for 1kg spools.

## Master Material Database (Qualitative & Processing Attributes)

The following tables provide the qualitative data necessary to drive the logic of the "Guided Selection Wizard" 1, enabling rule-based filtering and the generation of "guardrail" warnings.

### Table 3: Functional & Durability Attributes (Expanded material\_db.csv)

This table defines the qualitative properties for each material. Chemical\_Resistant is represented on a 0-3 scale (0=Poor, 1=Limited, 2=Good, 3=Excellent) to provide necessary nuance for the application's filter.

| **Material** | **UV\_Resistant** | **Hygroscopic** | **Prone\_to\_Creep** | **Chemical\_Resistant** | **Low\_Friction** | **Annealable\_for\_HDT** |
| --- | --- | --- | --- | --- | --- | --- |
| **PLA (Standard)** | false | false | true | 0 | false | false |
| **Tough PLA / PLA+** | false | false | true | 0 | false | false |
| **HTPLA (Annealable)** | false | false | false | 0 | false | true |
| **PLA - Carbon Fiber** | false | false | false | 0 | false | false |
| **PETG** | true | true | false | 1 | false | false |
| **PETG - Carbon Fiber** | true | true | false | 1 | false | false |
| **PET (e.g., eSUN)** | true | true | false | 1 | false | false |
| **ABS** | false | true | false | 2 | false | false |
| **ASA** | true | true | false | 2 | false | false |
| **HIPS** | false | false | false | 1 (Soluble) | false | false |
| **Nylon (PA12)** | false | true | true | 2 | true | true |
| **Nylon - Carbon Fiber** | false | true | false | 2 | true | false |
| **Polycarbonate (PC)** | true | true | false | 1 | false | false |
| **TPU 95A (Flexible)** | true | false | false | 2 | false | false |
| **TPU 85A (Soft Flexible)** | true | false | false | 2 | false | false |
| **PP (Polypropylene)** | false | false | false | 3 | true | false |
| **PVA (Soluble Support)** | false | true | true | 0 (Soluble) | false | false |
| **PVB (IPA-Smoothable)** | false | true | true | 0 (Soluble) | false | false |
| **PLA - Wood-filled** | false | false | true | 0 | false | false |
| **PLA - Metal-filled** | false | false | true | 0 | false | false |
| **PLA - Silk** | false | false | true | 0 | false | false |
| **PLA - Glow-in-the-dark** | false | false | true | 0 | false | false |
| **ULTEM 9085 (PEI)** | true | true | false | 3 | false | false |
| **PEEK** | true | false | false | 3 | true | false |

Data synthesized from.1

### Table 4: Printability & Processing Attributes (Expanded material\_db.csv)

This table defines the printing requirements and safety/usability scores. This data populates the base Printability\_Score and Cost\_Score 1 and provides the data for hardware-compatibility filters.

| **Material** | **Printability\_Score** | **Cost\_Score** | **Requires\_Enclosure** | **Releases\_Fumes** | **Recommended\_Nozzle\_Temp\_C** | **Recommended\_Bed\_Temp\_C** | **Requires\_Hardened\_Nozzle** |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **PLA (Standard)** | 9 | 2 | false | false | 190-220 | 50-60 | false |
| **Tough PLA / PLA+** | 8 | 3 | false | false | 200-225 | 50-60 | false |
| **HTPLA (Annealable)** | 9 | 4 | false | false | 200-225 | 50-60 | false |
| **PLA - Carbon Fiber** | 7 | 6 | false | false | 210-230 | 50-60 | true |
| **PETG** | 7 | 3 | false | false | 220-250 | 70-90 | false |
| **PETG - Carbon Fiber** | 6 | 7 | false | false | 230-260 | 70-90 | true |
| **PET (e.g., eSUN)** | 6 | 4 | false | false | 250-280 | 70-90 | false |
| **ABS** | 4 | 3 | true | true | 230-260 | 90-110 | false |
| **ASA** | 4 | 5 | true | true | 240-260 | 90-110 | false |
| **HIPS** | 5 | 3 | true | true | 230-245 | 90-110 | false |
| **Nylon (PA12)** | 3 | 7 | true | false | 260-275 | 110-130 | false |
| **Nylon - Carbon Fiber** | 3 | 10 | true | false | 280-300 | 110-130 | true |
| **Polycarbonate (PC)** | 2 | 8 | true | false | 270-310 | 100-115 | false |
| **TPU 95A (Flexible)** | 4 | 5 | false | false | 220-240 | 30-60 | false |
| **TPU 85A (Soft Flexible)** | 3 | 5 | false | false | 220-240 | 30-60 | false |
| **PP (Polypropylene)** | 1 | 5 | true | false | 200-220 | 50-80 | false |
| **PVA (Soluble Support)** | 2 | 9 | false | false | 210-230 | 50-60 | false |
| **PVB (IPA-Smoothable)** | 8 | 4 | false | false | 215-225 | 70-80 | false |
| **PLA - Wood-filled** | 7 | 4 | false | false | 190-220 | 35-60 | true |
| **PLA - Metal-filled** | 6 | 8 | false | false | 210-230 | 50-60 | true |
| **PLA - Silk** | 8 | 3 | false | false | 190-230 | 35-65 | false |
| **PLA - Glow-in-the-dark** | 7 | 4 | false | false | 190-230 | 35-65 | true |
| **ULTEM 9085 (PEI)** | 1 | 10 | true | false | 350-380 | 170-180 | false |
| **PEEK** | 1 | 10 | true | false | 400-450 | 120-150 | true |

Data synthesized from.1 Requires\_Hardened\_Nozzle for Wood-fill is recommended to prevent wear, though not as aggressive as CF.

## Technical Dossier: Specialty & Composite Materials

This section provides the "expert notes" for the specialty materials requested in the query, analyzing their unique properties and the trade-offs that the recommendation engine must communicate.

### Aesthetic & Filled Filaments (PLA Variants)

A primary finding is that all PLA-based aesthetic filaments (Wood, Silk, Metal-fill, Glow-in-the-dark) are *weaker* and *more brittle* than their base PLA. The additives act as impurities, disrupting polymer chain bonding and creating stress concentration points.

* **PLA (Standard)** Strength: $\approx$ 65 MPa 1
* **Wood-PLA** Strength: $\approx$ 26 MPa 24
* **Silk-PLA** Strength: $\approx$ 26 MPa 25
* **Glow-in-the-dark-PLA** Strength: $\approx$ 32 MPa 29
* **Metal-PLA** Strength: $\approx$ 34 MPa 28

The application must cluster these materials as "Aesthetic" or "Low-Strength Visual" and not recommend them for functional or structural parts.

* **Glow-in-the-dark (GITD) PLA:** The glowing additive (strontium aluminate) is *extremely abrasive*.45 This is a hardware-gated material. A standard brass nozzle can be destroyed, often within a single print, leading to failure and dimensional inaccuracy.49 The application's "Guided Wizard" 1 must ask, "Do you have a hardened steel nozzle?".42 If false, all GITD, Carbon Fiber, and Metal-Filled filaments must be flagged as "Incompatible."
* **Metal-Filled PLA:** These filaments (e.g., bronze-fill, copper-fill) are PLA mixed with a high percentage of metal powder.32 This creates parts that are very heavy (density 2-4 g/cm³) 31 and can be polished for a metallic appearance. They are *not* functional metal; they are brittle composites 51 and are also highly abrasive.42 This must be distinguished from "sinterable" metal filaments, which require extensive furnace post-processing to become fully metal.50

### Functional Polymers (PET & PP)

* **PET (Polyethylene Terephthalate):** This is the base polymer of PETG. New PET formulations (e.g., eSUN PET) are marketed as high-performance alternatives, offering *higher* heat resistance (HDT up to 80°C) and *higher* flexural strength (90-100 MPa) than standard PETG.22 It prints at higher temperatures (250-280°C) 22 and should be clustered with "Engineering" materials as a step above PETG.
* **PP (Polypropylene):** This material presents extreme trade-offs.
  + **Pros:** Exceptional chemical resistance to a wide range of acids and bases 8, high fatigue resistance (ideal for "living hinges") 8, and an extremely low density (0.9 g/cm³).14 It is also non-hygroscopic.14
  + **Cons:** It is *extremely* difficult to print. It has a high, non-uniform shrinkage rate, leading to severe warping.27 It has poor adhesion and requires a specialized build plate (often a sheet of PP plastic).14 This material should have a Printability\_Score of 1 and be recommended only to experts.

### Support & Post-Processing Filaments (PVA & PVB)

* **PVA (Polyvinyl Alcohol):** This material's *sole purpose* is as a water-soluble support material.26 It is mechanically weak, expensive, and *exceptionally* hygroscopic.26 Its primary data points are *compatibility*. It bonds well to PLA, PETG, and Nylon 26 but *not* to ABS or CPE.26 This is a critical constraint for multi-material printing.
* **PVB (Polyvinyl Butyral):** This is an aesthetic material whose primary feature is solubility in Isopropyl Alcohol (IPA).58 Unlike hazardous Acetone smoothing for ABS, IPA smoothing is relatively safe and easy, melting the outer layer to erase layer lines and create a smooth, glossy, or transparent finish.61 It is not a functional material; it has low layer-to-layer adhesion 13 and temperature resistance similar to PLA.13

## Hardware, Process, and Application Dependencies (The "Guided Wizard" Logic)

The 2024-2025 FDM printer market is defined by a technological bifurcation that creates a clear, two-tier hardware-material map.40 The recommendation engine's "Guided Wizard" 1 must use this logic as its primary filter.

### The Hardware-Material Link: A Critical Filter

* **Tier 1 (Budget/Beginner):** These printers (e.g., Creality Ender 3 V3 SE) typically feature PTFE-lined hotends (Max Temp $\approx$ 260°C) and no enclosure.40 They are *hardware-locked* to low-temperature, low-warping materials.
  + *Compatible Materials:* PLA, PETG, TPU.
  + *Incompatible Materials:* ABS, ASA, PC, Nylon, PP, and all high-temperature composites.
* **Tier 2 (Prosumer/Professional):** These printers (e.g., Bambu Lab X1C, Creality K1C, Prusa Core One) feature all-metal hotends (Max Temp 300-350°C), hardened nozzle options, and enclosed (often heated) chambers.40
  + *Compatible Materials:* All Tier 1 materials.
  + *Unlocked Materials:* ABS, ASA, PC, Nylon, PP, and all Carbon Fiber/Glass Fiber composites.

The *first question* in the "Guided Wizard" 1 should be about the user's hardware. Based on their answers, the application must filter the material list.

### Table 5: Hardware-Material Compatibility Matrix

This table provides the core logic for the application's hardware-based filtering.

| **Material** | **Min\_Nozzle\_Temp** | **Min\_Bed\_Temp** | **Requires\_Enclosure** | **Requires\_Hardened\_Nozzle** | **Requires\_All\_Metal\_Hotend** |
| --- | --- | --- | --- | --- | --- |
| **PLA (All non-CF)** | 190°C | 50°C | false | false | false |
| **PETG** | 220°C | 70°C | false | false | false |
| **TPU (Flexible)** | 220°C | 30°C | false | false | false |
| **ABS** | 230°C | 90°C | true | false | false |
| **ASA** | 240°C | 90°C | true | false | false |
| **PP (Polypropylene)** | 200°C | 50°C | true | false | false |
| **Nylon (PA12)** | 260°C | 110°C | true | false | true |
| **Polycarbonate (PC)** | 270°C | 100°C | true | false | true |
| **CF/GF Composites** | 230°C+ | 50°C+ | (Varies) | true | true |
| **Glow-in-the-dark** | 190°C | 50°C | false | true | false |
| **Metal-filled** | 210°C | 50°C | false | true | false |
| **High-Temp (PEEK)** | 400°C | 120°C | true (Heated) | true | true |

Data synthesized from.40

### Multi-Material Systems & Material (In)compatibility

The term "multi-material" is ambiguous and has two distinct technological paths.40

* **Path A: Single-Nozzle Switcher (e.g., Bambu AMS, Creality CFS):** These systems are for aesthetic *multi-color* printing.40 They are mechanically *incompatible* with flexible (TPU) and abrasive (CF) filaments.65 They also generate significant filament waste from purging.63
* **Path B: Toolchanger / IDEX (e.g., Prusa XL):** These systems are for true *multi-material* engineering.40 They have no material constraints and are the *only* systems that can print a rigid part (PLA) with a flexible gasket (TPU) and a soluble support (PVA) in a single job.40

The application *must* ask, "What multi-material system are you using?" If AMS/CFS is selected, the application must block any attempt to combine PLA + TPU and display a warning.

### Post-Processing for Performance & Aesthetics

* **Annealing (The Annealable\_for\_HDT flag):** Annealing is a post-print heat treatment (e.g., in an oven) that increases crystallinity.67 For **HTPLA**, this process transforms the material, boosting its Heat\_Resistance\_HDT\_C from a PLA-like 58°C to over 150°C.1 The application must display *two* HDT values for such materials: "HDT (As-Printed)" and "HDT (Annealed)."
* **Vapor Smoothing:** This process uses chemical solvents to melt a part's surface, erasing layer lines.60 The application should list this as a feature and filter by the required solvent:
  + **Acetone:** ABS, ASA 70
  + **Isopropyl Alcohol (IPA):** PVB 59
  + **Limonene:** HIPS 41

### Special Application Dossiers (The "Guardrails")

* **Application: "Food Safe" Printing:** This is the most critical guardrail. Users believe "food-safe filament" equals "food-safe part." This is **false** and dangerous.73
  + **The Problem:**
    1. **Layer Lines:** The micro-voids and crevices between FDM layers are impossible to clean and become breeding grounds for bacteria.75
    2. **Hardware Contamination:** Standard brass nozzles, which are common, can contain lead and are *not* food-safe.73
  + **The Solution:** The application *must not* have a simple "Food Safe: Yes/No" filter. If a user selects "Food Contact," the app must:
    1. Recommend filaments with FDA-compliant raw resins (e.g., specific brands of natural PETG, PP).75
    2. Display a **mandatory warning**: "Printed parts are not food-safe due to layer lines and potential nozzle contamination. For food-contact applications, you MUST use a stainless steel nozzle and apply a certified food-safe coating (e.g., ArtResin, Masterbond EP42HT-2FG) to seal the part".77
* **Application: "Chemical Resistance":** This is not a binary. The Chemical\_Resistant property (Table 3) is a 0-3 scale.
  + **Level 0 (Poor):** PLA (vulnerable).
  + **Level 1 (Limited):** PETG (resists water, salts, weak acids/bases).6
  + **Level 2 (Good):** ABS, ASA (resists oils, alcohols).37
  + **Level 3 (Excellent):** **PP** (resists a wide range of acids and bases) 14; **PVDF, PEEK, PPSU** (resists aggressive organic solvents, strong acids, halogens).37

## Additional Datasets and Academic References

For future development and data validation, the following external resources are recommended.

### Table 6: Public & Academic Datasets for FDM Material Properties

| **Source** | **Identifier / Link** | **Description** |
| --- | --- | --- |
| Kaggle | 3D Printer Material Requirement | A dataset linking print parameters (layer height, speed, temp) to mechanical properties (tension strength, elongation).80 |
| Kaggle | FDM 3D Printed Composite Material... | Dataset for predicting strength and quality of FDM composite prints.81 |
| Data.gov / NIST | data.gov/dataset/?tags=mechanical-properties | Collection of datasets on mechanical properties, including for polymers and composites.82 |
| NIST | NIST Ceramics WebBook | Gateway to evaluated data and tools for ceramics, which can be analogous to some composite properties.82 |
| PMC | PMC7078069 | Academic paper with full dataset on mechanical and thermal properties of a 3D printed biocompatible elastomer.83 |
| U. of Arkansas | scholarworks.uark.edu | Academic repository with research on FDM methods and materials.84 |

### Table 7: Key Academic and Industry References for Further Reading

| **Topic** | **Source Identifier** | **Key Finding** |
| --- | --- | --- |
| **Anisotropy** | 5 | Academic study quantifying Z-axis tensile strength loss at 50-75% and exploring "z-pinning" to mitigate it. |
| **Creep** | 9 | Discussions and user tests demonstrating PLA's high susceptibility to creep, and PC/PETG's superior resistance. |
| **Mech. Comparisons** | 85 | Academic studies systematically testing the tensile properties of PLA, ABS, and PETG under various print settings. |
| **Food Safety** | 75 | Prusa3D's expert guide on why FDM parts are not food-safe by default and the necessity of surface coatings. |
| **Chemical Resistance** | 37 | 3DXTech's guide to high-performance (PEEK, PVDF, PPSU) chemical-resistant filaments. |
| **Abrasives** | 42 | Guides and discussions on which materials (CF, GITD, Metal-fill) require a hardened steel nozzle and why. |
| **Hardware Market** | 40 | 2024-2025 FDM Market Report detailing the "appliance" trend and hardware (enclosures, all-metal) that unlocks materials. |

#### Works cited

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