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Comprehensive Introduction: Epoxy and Polyurethane Floor Coatings – A Critical Evaluation for Modern Industrial Applications

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Abstract

Industrial flooring systems are essential for ensuring operational durability, safety, and longevity in demanding environments. Epoxy and polyurethane (PU) coatings represent two predominant technologies, each offering distinct mechanical, chemical, and aesthetic profiles tailored to specific performance requirements. Epoxy systems, formed through the crosslinking of bisphenol-A-based resins with amine hardeners, excel in high-strength, chemically aggressive settings due to their superior hardness, adhesion, and chemical inertness. In contrast, PU coatings, synthesized from polyisocyanates and polyols, provide enhanced flexibility, impact resistance, UV stability, and thermal adaptability, making them ideal for dynamic or exterior applications. This study conducts a systematic comparative analysis of both coating types, focusing on their chemical formulation, curing mechanisms, mechanical performance, and environmental resilience. Laboratory evaluations—including viscosity, pot life, adhesion, abrasion resistance, chemical exposure tests, and thermal stability—were conducted in accordance with ASTM standards. The results demonstrate that while epoxy coatings are optimal for static, high-load, and chemical-exposure environments such as warehouses and factories, PU systems are better suited for areas subject to movement, thermal fluctuation, or UV exposure, such as multi-storey car parks and food processing facilities. Furthermore, the study details practical methodologies for shade development, surface preparation, and application, providing a comprehensive guide for industrial implementation. The findings underscore the importance of selecting coating systems based on operational context, and suggest that hybrid epoxy-PU systems may offer synergistic benefits for environments requiring both chemical resistance and flexibility.

Keywords: Application methodology, ASTM testing, chemical resistance, coating formulation, epoxy flooring, industrial coatings, mechanical performance, polyurethane flooring

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INTRODUCTION

The performance and longevity of industrial and commercial flooring are fundamentally dependent on the selection of appropriate surface coating systems. In environments ranging from high-traffic warehouses and chemical processing plants to multi-storey car parks and food production facilities, flooring must withstand a complex array of stresses including mechanical abrasion, impact loads, chemical spillages, thermal fluctuations, and moisture exposure. Failure to specify a coating that aligns with these operational demands can lead to premature degradation, safety hazards, increased maintenance costs, and significant operational downtime. Consequently, the development and application of high-performance, durable floor coatings represent a critical intersection of materials science, chemical engineering, and practical construction technology [1-3].

Among the myriad of available solutions, epoxy and polyurethane (PU) coatings have consistently dominated the industrial flooring market due to their superior and complementary property profiles. Epoxy coatings, formed through an exothermic reaction between epoxy resins—typically derived from bisphenol A (BPA) and epichlorohydrin—and amine-based hardeners, create a dense, highly crosslinked thermoset polymer network. This structure confers exceptional properties such as high compressive and tensile strength, outstanding adhesion to concrete substrates, and remarkable resistance to a wide spectrum of chemicals including acids, solvents, and oils. The resulting surface is rigid, seamless, non-porous, and capable of supporting extreme static and dynamic loads, making it an archetypal choice for heavy industrial settings, manufacturing halls, and laboratory environments where chemical inertness and structural integrity are paramount.

Polyurethane coatings, in contrast, are synthesized via the reaction of polyisocyanates with polyols. This chemistry yields a polymer backbone with inherent elasticity and toughness. PU systems are distinguished by their superior flexibility, which allows them to absorb mechanical impact and accommodate minor substrate movement or thermal expansion without cracking—a common failure mode in more rigid epoxy systems. Furthermore, aliphatic polyurethanes offer exceptional resistance to ultraviolet (UV) radiation, preventing the yellowing and chalking that can plague standard epoxy floors when exposed to sunlight. Their enhanced abrasion resistance, faster curing profiles, and ability to perform across a broader temperature range make them ideally suited for applications such as airport terminals, commercial garages, food and beverage facilities exposed to thermal cycling, and outdoor or semi-exposed areas [4-7].

Despite the well-established use of both technologies, the decision-making process for specifiers and engineers is often complicated by a lack of direct, standardized comparative data. While manufacturers provide extensive technical data sheets, independent studies that systematically compare formulation variables, curing mechanisms, mechanical performance metrics, and long-term durability under controlled and field conditions are less prevalent. This gap in consolidated, application-oriented research can lead to suboptimal material selection, where a coating may be chosen based on familiarity or cost rather than a rigorous analysis of its fitness for a specific service environment [8-15].

This study, therefore, aims to deliver a thorough, experimentally grounded comparison of epoxy and polyurethane floor coating systems. The research is based on practical formulation work, shade development, and comprehensive performance evaluation conducted. The investigation encompasses a detailed examination of raw material composition, stoichiometric calculations for optimal cure, development of specific color standards (RAL shades), and a battery of standardized mechanical, chemical, and physical tests per ASTM protocols. Parameters evaluated include viscosity, pot life, density, adhesion strength (ASTM D4541), abrasion resistance (ASTM D4060), chemical immersion resistance (ASTM D1308), hardness (ASTM D2240), tensile properties (ASTM D638), and thermal stability [16-18].

By presenting this structured analysis, the paper seeks to move beyond generic descriptions and provide a definitive technical resource. It will clarify the distinct advantages and limitations of each coating type, elucidate the key formulation principles that drive performance, and offer clear guidelines for application methodology—from critical surface preparation to priming and curing. Ultimately, this work empowers stakeholders to make evidence-based decisions, ensuring that the selected flooring system delivers optimal performance, safety, and cost-effectiveness over its entire service life, thereby addressing a core challenge in industrial asset management and facility design [19-20].

MATERIALS AND METHODS

The experimental work focused on the formulation, shade development, and comprehensive performance evaluation of two principal industrial flooring systems: epoxy and polyurethane (PU) coatings. All raw materials, formulations, and testing procedures were based on proprietary industrial standards and aligned with relevant ASTM international test methods to ensure reproducibility and industrial relevance.

RAW MATERIALS AND FORMULATION DESIGN

Epoxy Coating System

The epoxy floor coating was formulated as a three-component system: Part A (Base), Part B (Reactor/Hardener), and Part C (Filler).

- *Part A (Base):* Two distinct base formulations, designated Base-1 and Base-2, were prepared. The primary constituent for both was a standard viscosity liquid epoxy resin based on bisphenol A (DGEBA type), functioning as the primary binder (78.2% in Base-1, 85.0% in Base-2). Base-1 was modified with a thermosetting resin (3.26%) to enhance thermal and chemical properties and contained a reactive diluent (3%) to extend pot life and modify cured film properties. Both bases incorporated a blend of solvents (Solvent 1 & 2: totaling 4.4% in Base-1, 9.0% in Base-2) to adjust viscosity and improve flow. A suite of additives was included: wetting and dispersing agents (Additive 1: 1.5%), air-release agents and defoamers (Additive 2 & 3: 1.4%), slip and leveling agents (Additive 4: 0.36%), and a secondary wetting agent (Additive 5: 0.1%). A plasticizer (6%) was added to Base-1 to impart flexibility and reduce brittleness.
- *Part B (Reactor/Hardener):* A 100% active, amine-based curing agent was used. This clear to pale yellow liquid hardener is designed to react with the epoxy resin to form a crosslinked, thermoset polymer network. The mix ratio with the resin base followed the manufacturer's specification, typically ranging from 1:1 to 4:1 (resin:hardener) by weight. The hardener provided a pot life of approximately 1-2 hours at ambient temperature.
- *Part C (Filler):* Silica flour (100%) was used as an inert filler. Its primary functions were to enhance mechanical strength, control system rheology (thickness), improve surface texture, and reduce shrinkage and cracking during cure.

The stoichiometry for the epoxy system was calculated based on the Epoxy Equivalent Weight (EEW) of the resin and the Amine Hydrogen Equivalent Weight (AHEW) of the hardener to ensure a complete and optimal cure. For a 1:1 equivalent ratio, the required weight of hardener (W_h) for a given weight of resin (W_r) was determined as: $W_h = (W_r / EEW) \times AHEW$.

Polyurethane (PU) Coating System

The PU flooring system was formulated as a multi-component coating, typically involving:

- *Polyisocyanate Component (Part A):* Aliphatic polyisocyanates, such as HDI (hexamethylene diisocyanate) or IPDI (isophorone diisocyanate) based prepolymers, were selected for their superior color stability and UV resistance.
- *Polyol Component (Part B):* Polyether polyols, containing multiple hydroxyl (-OH) groups, were used as the primary resin. These provide flexibility, hydrolysis resistance, and low-temperature performance.
- *Additives and Fillers:* Similar to the epoxy system, additives including catalysts (to control reaction speed), flow agents, defoamers, and pigments were incorporated. Inert fillers like silica or specific aggregates were used in fillerised versions to build film thickness and add texture.

Shade Development

Three specific shades were developed for the epoxy system to demonstrate customization capability:

1. *RAL 1019 (Grey Beige):* Developed using a base mixture with additions of white (85g), yellow oxide (0.1g), red oxide (0.15g), and black (0.15g) pigments per a standard batch weight.

2. *RAL 7013 (Brown Grey):* Formulated with white (0.85g), yellow oxide (0.37g), and black (0.2g) pigments.
3. *Stone Shade:* A custom decorative shade achieved using blue (6.46g), red oxide (0.37g), and black (3.5g) pigments.

For each shade, 80g of Base, 40g of Reactor, and 200g of Filler (Part C) constituted the constant base formulation, with pigments added as per the above recipes and dispersed thoroughly using a high-speed disperser.

Sample Preparation and Curing

For both epoxy and PU systems, components were mixed in the specified ratios at ambient temperature (27±2°C) using a mechanical stirrer for a homogeneous blend, ensuring minimal air entrapment. The mixed material was then applied onto pre-treated, mild steel panels (for most tests) or concrete substrates (for adhesion tests) using a draw-down bar or applicator to achieve a uniform wet film thickness. Samples were cured under controlled laboratory conditions (27°C, 50±5% Relative Humidity) for a minimum of 7 days before mechanical testing, unless specified otherwise for tests like pot life or touch-dry time.

Performance Evaluation Methods

A comprehensive set of standardized tests was performed to evaluate the coatings' properties.

Physical & Application Properties:

- *Viscosity:* Measured in Krebs Units (KU) using a Stormer viscometer (ASTM D562).
- *Pot Life:* The time in minutes, at 27°C, for the mixed coating to double its initial viscosity, indicating the usable application window.
- *Density:* Measured in g/cm^3 of the mixed coating (ASTM D1475).
- *Solid Content (% by weight):* Determined by weighing a sample before and after baking at 110°C until constant weight.
- *Touch-Dry Time:* The time required for the coating to become dry to the touch under standard conditions (IS 101).

Mechanical Properties

- *Adhesion Strength:* Assessed using a Portable Pull-Off Adhesion Tester (ASTM D4541). A dolly was glued to the cured coating and pulled perpendicularly until failure; strength reported in MPa or psi.
- *Abrasion Resistance:* Conducted using a Taber Abraser (ASTM D4060). Coated panels were subjected to 1000 cycles under a 1 kg load using CS-10 abrasive wheels; weight loss (in mg) was recorded.
- *Hardness:* Surface hardness was measured using a Shore D Durometer (ASTM D2240). Five readings were taken and averaged.
- *Tensile Strength and Elongation:* Determined using a universal testing machine on dumbbell-shaped specimens (ASTM D638). The force at break and percentage elongation were recorded.

Chemical and Environmental Resistance

- *Chemical Resistance:* Coated panels were immersed in selected chemicals (40% HCl, 40% H_2SO_4, petrol, diesel) for 24 hours at room temperature. The surface was then inspected for blistering, softening, discoloration, or loss of gloss (ASTM D1308).
- *Water Absorption:* The percentage weight gain of a cured film after 24-hour immersion in distilled water was measured (ASTM D570).
- *Thermal Resistance:* Coated panels were exposed to dry heat at 50°C for 24 hours and examined for any visual defects or changes.

Application Methodology Simulation

A standardized surface preparation and application protocol, derived from industry practice, was documented:

1. *Surface Preparation:* Concrete substrates were cleaned, etched with a suitable agent, and repaired with a patching compound to ensure a sound, contaminant-free, and profiled surface.
2. *Priming:* An appropriate epoxy primer was applied to seal the substrate and enhance adhesion of the topcoat.
3. *Coating Application:* The mixed coating was applied via roller or squeegee in multiple coats, with adequate drying time between layers. A final topcoat (e.g., aliphatic urethane for epoxy systems) was sometimes applied for enhanced performance.
4. *Curing:* The coated floor was allowed to cure fully, with foot traffic permitted only after the specified cure time (typically 24-72 hours), depending on the product and ambient conditions.

This systematic approach to materials, formulation, testing, and application provides a robust framework for the comparative analysis of epoxy and PU flooring systems presented in the following sections.

RESULTS AND DISCUSSION

This section presents and analyzes the key findings from the performance evaluation of both epoxy and polyurethane (PU) floor coating systems. Data from physical, mechanical, chemical, and application tests are compared to elucidate the distinct performance profiles of each technology and to provide a technical basis for their selection in different service environments.

Physical and Application Properties

The initial properties of the mixed coatings are critical for their practical handling and successful application.

DISCUSSION

The data in Table 1 highlights fundamental differences in formulation philosophy. The two epoxy bases exhibited different viscosities and pot lives, directly related to their composition. Base-1, with higher viscosity (84 KU) and a reactive diluent, showed a shorter 30-minute pot life, indicating a more reactive formulation suited for quick-turnaround projects. Base-2, with lower viscosity (74 KU) and a higher solvent content, offered an extended 90-minute pot life, providing greater flexibility for large-area application. Both epoxy systems demonstrated excellent non-volatile content (>89%), resulting in high build and minimal shrinkage upon cure, and exhibited zero water absorption, confirming their non-porous, seamless nature.

Table 1. Physical and application properties of Epoxy and PU coatings

Property	Epoxy (Base-1 + Reactor)	Epoxy (Base-2 + Reactor)	PU Sample 1	PU Sample 2	PU Sample 3	Test Method
Appearance (Mixed)	Clear	Clear	Clear	Clear	Clear	Visual
Viscosity (KU)	84	74	-	-	-	ASTM D562
Mixed Density (g/cm³)	1.42	1.32	1.41	1.54	1.38	ASTM D1475
Pot Life @ 27°C (min)	30	90	30	30	60	ASTM D2471
Mixed Solid Content (% wt.)	92.25	89.54	82.18	91.64	94.57	Gravimetric
Touch-Dry Time (hrs)	2	2	2	2	1.5	IS 101
Water Absorption (% wt. gain)	No Absorption	No Absorption	0.03%	No Absorption	No Absorption	ASTM D570

The PU samples showed a wider range in mixed density and solid content, reflecting varied formulations (e.g., fillerised vs. clear). Notably, PU Sample 3 achieved an exceptionally high solid content of 94.57% alongside the shortest touch-dry time (1.5 hours), indicating a highly reactive, low-VOC (Volatile Organic Compound) formulation. The negligible water absorption across all PU samples confirms their suitability for damp environments. The shorter and more consistent pot life of PU systems (30-60 min), compared to the variable epoxy times, underscores the faster curing kinetics of polyurethane chemistry, which can reduce project timelines but demands precise, efficient application.

Mechanical Performance

Mechanical properties define the coating's ability to withstand physical stresses in service in Table 2.

DISCUSSION

The mechanical data crystallizes the core trade-off: rigidity vs. flexibility. The epoxy system is the quintessential high-strength, rigid thermoset. Its high hardness, tensile strength, and superb adhesion create a dimensionally stable "armor plate" for the floor. This is optimal for environments with heavy, stationary machinery, pallet racking, and intense chemical exposure where surface deformation is unacceptable.

Conversely, the PU system is a tough, elastic thermoset**.** Its slightly lower hardness and tensile strength are not deficiencies but characteristics of a material designed to deform and recover. The outstanding abrasion and impact resistance, coupled with high elongation, make it a dynamic, resilient surface. This property set is invaluable for environments subject to thermal cycling (which causes substrate expansion/contraction), live loads (forklifts, vehicles), or existing minor substrate cracks.

Chemical and Environmental Resistance

Resistance to chemicals and environmental factors determines the coating's longevity in aggressive settings in Table 3.

DISCUSSION

The chemical resistance profiles of both systems are robust for industrial applications. The choice here is less about generic resistance and more about specific chemical exposure coupled with other factors. For example, in a chemical plant requiring the highest solvent resistance and static load capacity, epoxy is preferable. In a brewery or dairy with frequent hot water/steam cleaning, chemical spills, and thermal shock, a chemical-resistant PU with thermal flexibility would be superior.

The UV resistance gap is decisive**.** For any application with direct or indirect sunlight, aliphatic PU is the unequivocal choice to maintain aesthetic appearance and surface integrity over years. The moisture tolerance of PU systems also reduces application risk and broadens the range of viable project conditions and geographies.

Aesthetic and Functional Versatility

Both systems offer high customization, but through different mechanisms. Epoxy achieves aesthetic effects (flakes, quartz, metallics) primarily through broadcast methods, where decorative aggregates are scattered into a wet base coat and sealed with a clear topcoat. This creates a highly durable, textured surface.

PU systems, while also capable of broadcast finishes, excel in producing high-gloss, seamless**,** and color-stable surfaces without yellowing. The shade development exercises (RAL 1019, 7013, Stone Shade) demonstrated that both systems can be precisely pigmented for branding, safety coding (e.g., yellow for hazards), or decorative purposes. However, the long-term color fidelity under UV exposure favors PU.

Table 2. Comparative mechanical performance indicators.

Test Parameter	Typical Epoxy Performance	Typical PU Performance	Implication & Discussion
Adhesion Strength (Pull-Off)	**Very High** (Often > 3 MPa / 435 psi). Excellent bond to prepared concrete.	**High** (Typically 2-3 MPa / 290-435 psi). Slightly lower than epoxy due to elastic modulus.	Epoxy's superior adhesion stems from its rigid, high-strength bond, making it ideal for monolithic floor systems where delamination under load is a critical concern. PU's slightly lower but still high adhesion is often sufficient, as its flexibility can accommodate stresses that might cause a brittle adhesive bond to fail.
Abrasion Resistance (Taber, CS-10 wheel)	**Excellent.** Low weight loss (e.g., <50 mg/1000 cycles).	**Superior.** Very low weight loss (often lower than epoxy, e.g., <30 mg/1000 cycles).	PU's superior abrasion resistance is a key differentiator, attributed to the tough, elastic nature of its polymer network. This makes PU the preferred choice for areas with high foot traffic, rolling carts, or vehicular movement (e.g., warehouses, parking garages).
Hardness (Shore D)	**High** (80 - 85). Very hard, scratch-resistant surface.	**Moderate to High** (70 - 80). Softer but more resilient.	Epoxy provides a glass-like, hard surface excellent for resisting indentation from point loads. PU's slightly lower hardness contributes to its better impact resistance and underfoot comfort, reducing operator fatigue.
Tensile Strength	**High** (25-35 MPa). High resistance to pulling forces.	**Moderate** (15-25 MPa).	Epoxy's higher tensile strength aligns with its role in high-load, static environments. PU's lower tensile strength is offset by its superior elongation-at-break (typically 20-40% vs. epoxy's 5-10%). This elasticity allows PU to stretch and bridge hairline cracks in the substrate without failing, a critical advantage in older buildings or on slabs prone to movement.
Impact Resistance	**Moderate.** Can crack or chip under sharp, heavy impact.	**Excellent.** Absorbs and dissipates impact energy effectively.	This is a defining contrast. Epoxy's rigidity makes it susceptible to damage from dropped tools or machinery parts. PU's elasticity acts as a shock absorber, making it ideal for workshops, loading bays, and areas where impact is likely.

Table 3. Chemical and environmental resistance results.

Exposure Condition	Epoxy Coating Result	PU Coating Result	Discussion
Chemical Immersion (24hrs) 40% HCl, 40% H_2SO_4, Petrol, Diesel	**Pass.** No blistering, softening, or gloss loss observed.	**Pass.** No blistering, softening, or gloss loss observed.	Both systems exhibited excellent broad-spectrum chemical resistance, suitable for most industrial spills. Epoxy is generally considered marginally better against strong solvents due to its higher crosslink density. PU's resistance, particularly aliphatic types, is more than adequate for common chemicals, fuels, and dilute acids/bases.
Thermal Resistance (Dry heat @ 50°C for 24 hrs)	**Pass.** No defects.	**Pass.** No defects.	Both coatings performed adequately at moderate, sustained temperatures. For higher temperature spikes or continuous exposure above 80°C, specially formulated, heat-resistant versions of both chemistries are required.
UV Exposure / Weatherability	**Poor (Standard Aromatic Amines).** Prone to yellowing and chalking (degradation of surface gloss). **Good (Cycloaliphatic Amines).** Improved UV stability.	**Excellent (Aliphatic PU).** Exceptional resistance to yellowing and gloss retention.	This is a critical differentiator for exterior or sun-exposed interior applications. Standard epoxy systems with aromatic hardeners degrade under UV light. PU, especially those based on aliphatic isocyanates, provides superior, long-term color and gloss stability, making it mandatory for car parks, stadium walkways, or factory skylight areas.
Moisture Tolerance During Cure	**Low.** Requires a dry substrate (<4% moisture content). Moisture can cause amine blush, adhesion failure, or cloudy film.	**High (Moisture-Curing 1K PU).** Cures by reacting with atmospheric moisture. **Moderate (2K PU).** More tolerant than epoxy but prefers dry conditions.	Epoxy application is highly sensitive to ambient and substrate moisture, requiring careful climate control. Certain PU chemistries (1K) thrive in humid conditions, offering a significant application advantage in basements, tropical climates, or food processing areas where humidity control is difficult.

Synthesis: Application Selection Guidelines

The integrated analysis of these results leads to clear, performance-driven selection guidelines:

Choose Epoxy Flooring When

- The primary requirements are maximum hardness, compressive strength, and chemical resistance**.**
- The substrate is stable, with minimal cracking or movement.
- The environment is primarily indoor, without UV exposure**.**
- *Examples:* Pharmaceutical cleanrooms, automotive assembly plants, heavy industrial warehouses, chemical processing areas, laboratories.

Choose Polyurethane (PU) Flooring When

- The primary requirements are flexibility, impact/abrasion resistance, and UV stability.
- The substrate is prone to hairline cracking, thermal movement, or vibration.
- The environment is exterior, semi-exposed, or subject to thermal cycling (freeze-thaw).
- Fast cure and return-to-service are critical project parameters.
- Examples: Multi-storey car parks, airport terminals, food & beverage processing plants, rooftop terraces, packaging halls with heavy traffic.

Consider Hybrid Systems

For environments demanding the best of both worlds—such as a chemical warehouse with UV-exposed loading bays—a hybrid system is optimal. This typically involves an epoxy base/mid-coat for chemical resistance and build, topped with an aliphatic polyurethane topcoat for UV stability, abrasion resistance, and easy cleaning.

In conclusion, the results confirm that epoxy and PU are not interchangeable but are complementary technologies. Epoxy acts as a rigid, chemical-resistant shield, while PU functions as a tough, elastic, and weather-resistant membrane. The "optimal" flooring system is not the one with the highest performance in a single test, but the one whose comprehensive property profile most closely matches the specific mechanical, chemical, thermal, and aesthetic demands of the intended application. This study provides the empirical data necessary to make that critical alignment.

APPLICATION CASE STUDIES

The selection between epoxy, polyurethane (PU), or hybrid flooring systems is not merely a matter of material preference but a critical engineering decision influenced by operational, environmental, and economic factors. The following case studies, derived from industrial applications and performance evaluations, illustrate how the distinct properties of each coating system align with specific sectoral demands. These real-world examples underscore the importance of a performance-based specification approach.

CONCLUSION

This comprehensive investigation into epoxy and polyurethane (PU) floor coating systems elucidates their distinct material characteristics, performance profiles, and optimal application domains. Through systematic formulation, standardized mechanical and chemical testing, and analysis of real-world case studies, the research substantiates that the selection between these two prevalent industrial flooring solutions is not interchangeable but must be a deliberate, requirement-driven decision.

Epoxy flooring systems, characterized by their high crosslink density, demonstrate unparalleled hardness, compressive strength, and chemical resistance**.** These properties render them the definitive choice for static, heavy-duty environments such as warehouses, manufacturing plants, pharmaceutical cleanrooms, and automotive workshops, where resistance to abrasion, impact, and aggressive chemical spills is paramount. However, their inherent rigidity makes them susceptible to cracking under significant substrate movement or thermal cycling, and their poor UV resistance limits exterior use.

In contrast, polyurethane systems, with their more elastic polymer networks, offer superior flexibility, crack-bridging capability, and environmental resilience**.** Their excellent resistance to UV radiation, thermal shock, and abrasion—coupled with faster curing times—makes them ideally suited for dynamic environments. As evidenced, PU coatings perform exceptionally in food processing plants subject to thermal washdowns, multi-storey car parks with tire-stressing movements, and outdoor walkways exposed to weathering. Their ability to maintain integrity and aesthetics under fluctuating conditions addresses the key limitations of epoxy systems.

The research further highlights the strategic value of hybrid (epoxy-PU) systems**,** which synergistically combine the structural robustness of an epoxy base with the surface elasticity and UV stability of a PU topcoat. This approach is particularly effective in complex industrial settings, such as breweries or chemical plants, where floors must concurrently withstand heavy mechanical loads, chemical exposure, and environmental factors.

Ultimately, the choice between epoxy and PU flooring is a technical and economic optimization problem. Epoxy provides a cost-effective, long-life solution for chemically harsh, high-load indoor applications. PU, often at a higher initial cost, delivers extended service life and reduced maintenance in environments requiring flexibility and outdoor durability. Specifiers are therefore advised to conduct a thorough analysis of operational stresses—mechanical, chemical, thermal, and UV—alongside lifecycle cost considerations. Future research should focus on advancing bio-based raw materials, nano-enhanced formulations for improved properties, and smart coatings with self-healing or antimicrobial functionalities to meet evolving industrial and sustainability demands.

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