Technical Report

Application of IR-1000 in Colored Architectural Coatings

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Version 1.0

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This report focuses on the formulation use, reflection performance, and validation methods of IR-1000 in colored architectural coatings.

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Reading Note All performance data are from specific formulations, film thicknesses, substrates, and test conditions. They are intended only for R&D screening and technical communication and do not constitute a performance guarantee for final coatings.

1. Executive Summary and Key Conclusions

IR-1000 is a near-infrared reflective rutile titanium dioxide designed for colored and wide-color-gamut systems. Its value is not simply to increase whiteness or hiding power. Instead, it uses a high refractive index and an approximately 1 μm particle-size distribution to enhance scattering and reflection in the 780-2500 nm range, allowing colored architectural coatings to reduce solar heat absorption while maintaining the target visible color.

Key Conclusion

In typical waterborne exterior wall formulations such as grey, yellow, blue, brown, and green, the IR-1000 formulation increased NIR by approximately 0.07-0.35 compared with standard pigmentary TiO2 formulations. In specific temperature-rise tests, endpoint temperature difference was reduced by 5.0-8.0°C. The performance gain is especially significant in dark-color systems, low-reflectance substrates, and high-transmission pigment systems, giving it higher application value.

The best use of IR-1000 is not direct one-for-one replacement. It should be co-optimized with color pigments, PVC, film thickness, and substrate.

Grey and dark-color systems should avoid carbon black or iron black for lowering lightness. A compound black can be built from iron red, iron yellow, and phthalocyanine blue, with IR-1000 used to establish the NIR scattering framework.

Architectural coating evaluation must be conducted under the same color, dry-film thickness, and substrate conditions. Both high-reflectance and low-reflectance substrates are recommended to identify the effect of substrate-assisted reflection through transmission.

In colored systems, priority should be given to real NIR performance on low-reflectance substrates, color consistency, and temperature-rise changes, rather than only reviewing results on high-reflectance substrates.

IR-1000 should not be treated as a simple equivalent substitute for standard TiO2. Addition level, dispersion, pigment package, and weatherability must be optimized as a complete coating system.

2. Technical Basis and Product Positioning

2.1 Spectral Logic of Solar Heat Management

The solar spectrum is mainly composed of ultraviolet, visible, and near-infrared bands. Visible light controls the color appearance of a coating, while the near-infrared band is a major source of solar heat input. The core technical objective of colored architectural coatings is not simply to make colors lighter, but to maximize NIR reflectance and minimize NIR absorption while strictly maintaining the target L*a*b* color coordinates. This helps control heat transmitted to the substrate and improve thermal insulation performance.

2.2 Product Characteristics of IR-1000

Item	Typical / Specification Information	Meaning for Architectural Coatings
Product type	NIR-reflective rutile TiO2	For colored and wide-color-gamut solar heat management
TiO2 content	≥90%	Builds a stable high-refractive-index inorganic framework
Particle size D50	Approx. 1000 nm	More oriented toward NIR scattering than pigmentary TiO2
Refractive index	Approx. 2.7	Creates a large refractive-index contrast with acrylic and other resins
Inorganic treatment	SiO2 / Al2O3	Improves weatherability, dispersion, and system compatibility
Oil absorption	≤19 g/100 g	Affects wetting, viscosity, and formulation solids
Dispersion in oil	≤15 μm	Dispersion process still needs confirmation in the actual waterborne coating system

Data note: Basic product data are from the Final IR Series Technical White Paper_CN and are typical values or technical communication values.

2.3 Functional Difference from Standard Pigmentary TiO2

Standard pigmentary TiO2 is mainly optimized for hiding power, whiteness, and tinting strength in the visible-light range. IR-1000, by contrast, uses controlled particle size and distribution to better match NIR scattering mechanisms. It can significantly improve NIR reflectance in colored systems while reducing tinting strength. Therefore, IR-1000 is positioned

closer to a NIR functional filler than to a general TiO2 grade that can be directly substituted at equal dosage in all formulations.

3. Functional Mechanism of IR-1000 in Colored Coatings

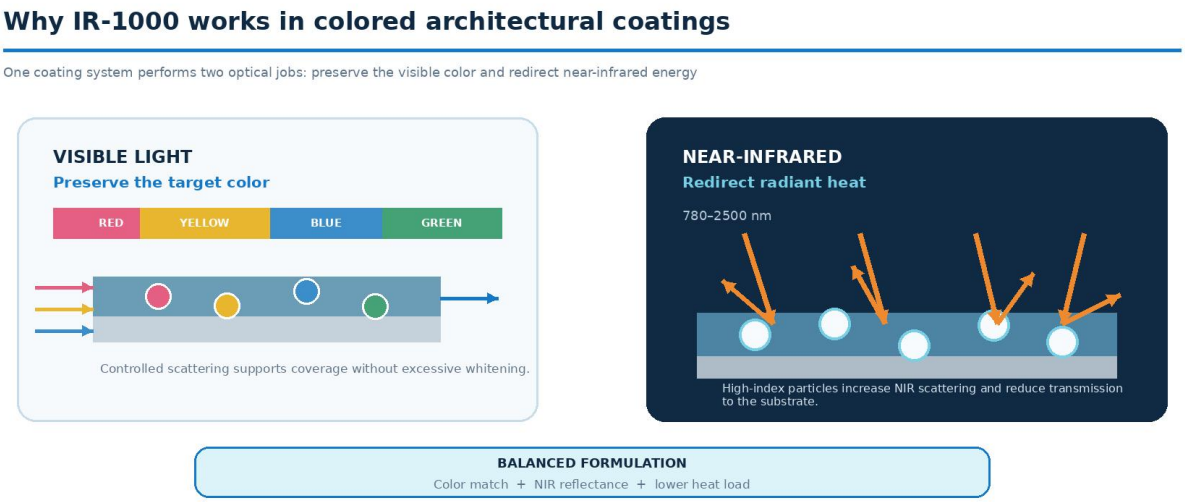

Figure 1 NIR scattering and reflection mechanism of IR-1000 in colored architectural coatings

- Visible-light region: Color pigments determine the target hue and lightness. The lower tinting strength of IR-1000 helps build scattering without excessive whitening.
- Near-infrared region: High-refractive-index particles increase optical path changes and multiple scattering, weaken existing absorption peaks, and reduce the proportion of infrared light transmitted to the substrate.
- UV region and weatherability: Rutile crystal form and inorganic treatment provide the base for outdoor systems, but final durability still depends on resin, pigment package, dispersion, and coating quality.
- Thermal result: When NIR reflection increases, the coating absorbs less radiant energy, and both surface temperature rise and heat flow into the substrate can decrease. The actual magnitude must be verified under consistent equipment and boundary conditions.

Key Distinction

High-reflectance substrates may allow high-transmission coating films to show higher apparent NIR. Formulations intended for building applications should be validated on black or low-reflectance substrates to confirm that the reflection comes from the coating itself, rather than from substrate-assisted reflection.

4. Formulation Design Principles for Colored Architectural Coatings

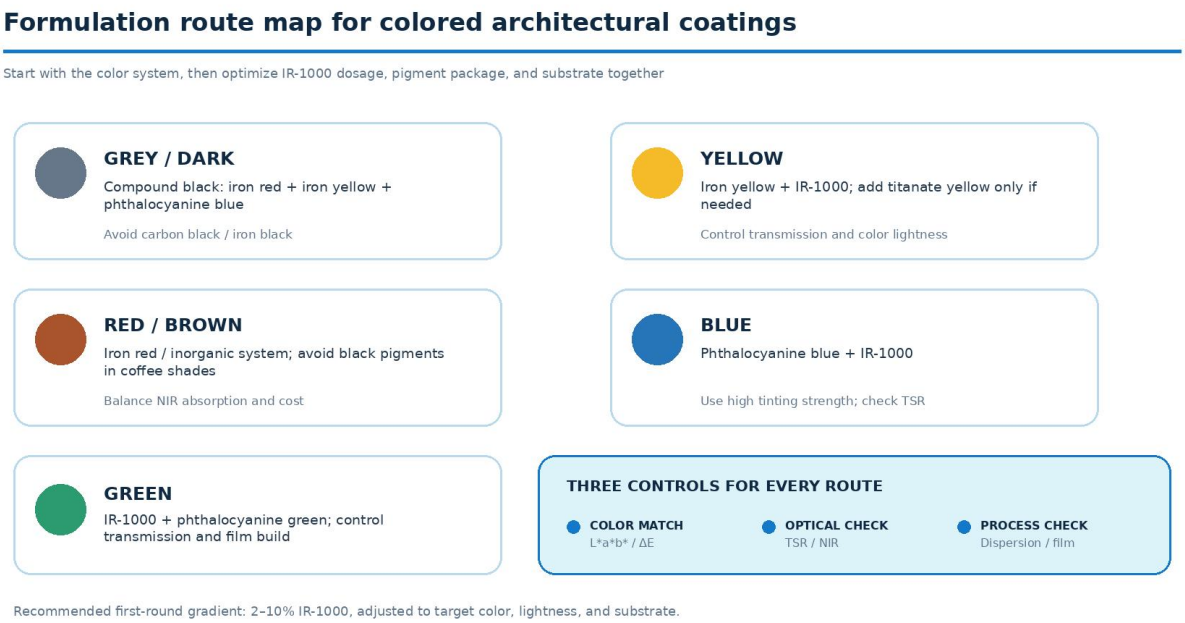

Figure 2 IR-1000 formulation routes for different color systems

4.1 Color-Matched Comparison Is the First Principle

TSR and NIR comparisons are meaningful for formulation only when L*a*b* values are close. Adding IR-1000 changes scattering and tint-reduction behavior. Therefore, when the addition level changes, the color paste should be adjusted at the same time so that color difference is within the project tolerance before comparing spectra and temperature rise.

4.2 Avoid Black Pigments with Strong NIR Absorption

Carbon black and iron black can significantly suppress NIR reflectance even at low dosage. Low-lightness colors such as grey, dark blue, coffee brown, and dark green should preferably use iron red, iron yellow, phthalocyanine blue/green, and high-tinting-strength organic pigments in combination. This reduces total color pigment dosage while IR-1000 improves real reflectance.

4.3 Treat IR-1000, the Pigment Package, and the Substrate as One Optical System

- High-transmission organic pigments can preserve visible color, but IR-1000 or other NIR scattering materials are required to prevent heat energy from passing through.
- Inorganic composite cool pigments offer good weatherability, but may not always be optimal in visible hiding, absorption, or cost. They should be combined according to color-gamut and service-life requirements.
- Substrates such as exterior wall putty, cement board, insulated decorative panels, and metal panels have different NIR properties. Validation should be performed on the target substrate or an equivalent low-reflectance substrate.

5. Typical Waterborne Exterior Wall Formulation and Production Process

5.1 R&D Baseline Formulation

Component	Typical parts by mass	Design note
IR-1000	20-100	Set an approx. 2-10% gradient according to target color and lightness
Color pigments and extenders	320-400 (including IR-1000)	Avoid strong NIR-absorbing pigments; maintain target PVC
Acrylic emulsion and additives	Approx. 320	Prefer low-absorption, weather-resistant exterior wall systems
Water	Approx. 260	Adjust according to dispersion and application viscosity
Total formulation	Approx. 1000	Typical baseline from R&D data

Data note: The colored formulations in the R&D data generally use PVC≈50% and a dry-film thickness of 150 μm. This formulation is only a screening starting point and is not recommended for direct production without validation.

5.2 Recommended Addition-Level Screening

Color / Lightness	Recommended first-round gradient	Key focus
Yellow / Medium-high lightness	2, 5, 8%	Iron yellow transmission; small titanate yellow if needed
Red / Brown	2, 4, 7%	Iron red/organic red absorption; avoid black pigments in coffee shades
Blue / Green	3, 5, 8%	High transmittance of phthalocyanine pigments; film thickness and low-reflectance substrate
Grey / Dark colors	3, 5, 8, 10%	Compound black, low-TSR zone, and color-difference adjustment

5.3 Recommended Production Sequence

1. Premixing: Mix water, dispersant, wetting agent, and defoamer at low speed first.
2. Powder addition: Slowly add IR-1000, color pigments, and extenders under effective shear to avoid agglomeration.
3. High-speed dispersion: Use fineness, viscosity, and temperature rise as endpoint controls instead of relying only on fixed dispersion time.
4. Letdown: Add emulsion and post-additives, then adjust pH, viscosity, defoaming, and application properties.
5. Color adjustment: First match L*a*b* values with the control, then prepare panels with uniform film thickness.
6. Maturation and retesting: After standing, retest fineness, viscosity, color difference, and spectra to confirm storage stability.

6. Performance Evidence and Data Interpretation

6.1 Typical Colored Exterior Wall Formulations

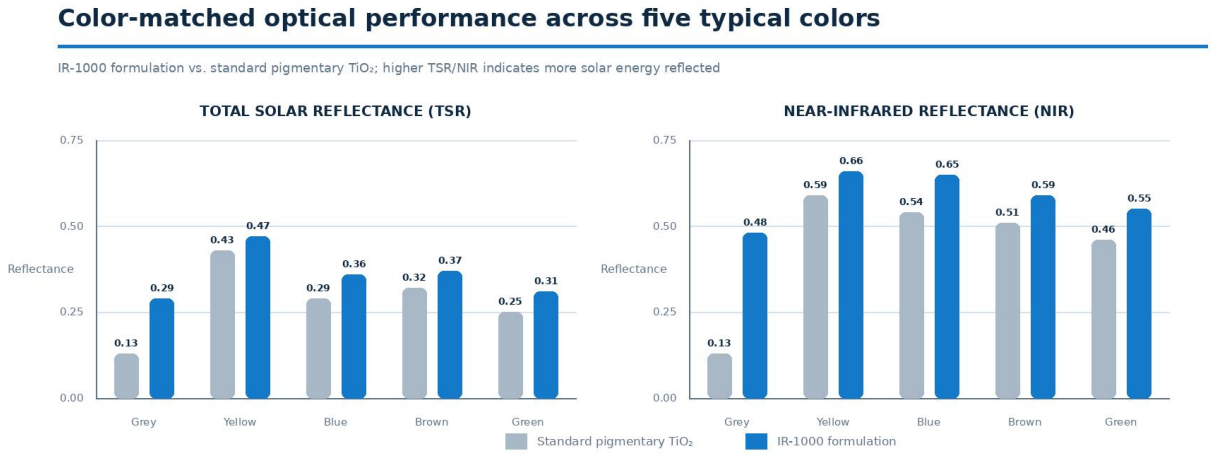

Figure 3 TSR and NIR comparison across five typical colors

Color / RAL	IR-1000 dosage	L* (IR / standard)	TSR (IR / standard)	NIR (IR / standard)	Endpoint temperature difference
Grey RAL 7010	10%	43.00 / 43.86	0.29 / 0.13	0.48 / 0.13	Not provided
Honey yellow RAL 1005	8%	65.95 / 65.78	0.47 / 0.43	0.66 / 0.59	5.0℃
Signal blue RAL 5005	5%	36.30 / 36.28	0.36 / 0.29	0.65 / 0.54	7.4℃
Copper brown RAL 8004	7%	41.52 / 41.37	0.37 / 0.32	0.59 / 0.51	5.2℃

Color / RAL	IR-1000 dosage	L* (IR / standard)	TSR (IR / standard)	NIR (IR / standard)	Endpoint temperature difference
Mint green RAL 6029	6%	44.00 / 43.86	0.31 / 0.25	0.55 / 0.46	8.0℃

Data note: Data are from Application and Formulation Design of Near-Infrared Reflective Titanium Dioxide Materials in Reflective Thermal Insulation Coatings. Temperature differences are relative results under specific equipment, panels, and irradiation conditions.

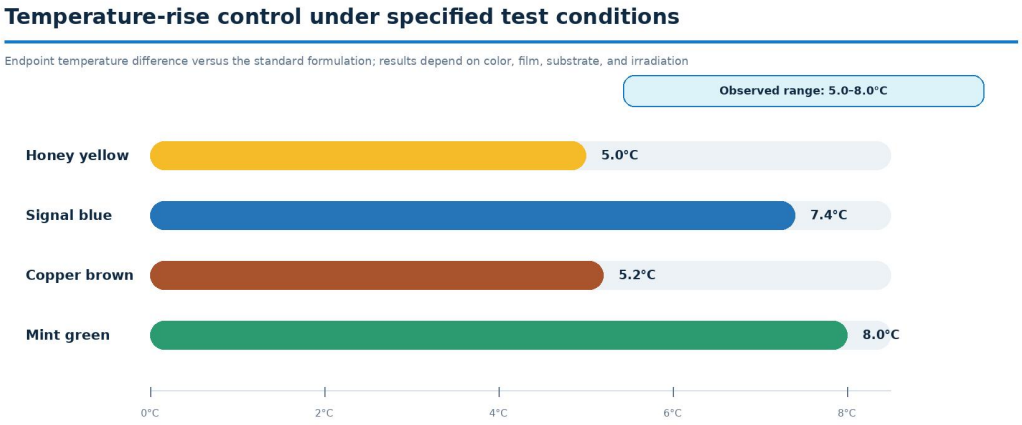

Figure 4 Temperature-difference results of four colored formulations under specific test conditions

6.2 Low-Lightness Compound Black Case

Sample	Substrate	L*	TSR	NIR
Without IR-1000	Black substrate	27.86	0.09	0.14
With 5% IR-1000	Black substrate	30.13	0.25	0.48
With 5% IR-1000	White substrate	30.27	0.33	0.67
Standard carbon black formulation	Control	25.68	0.04	0.04

After adding 5% IR-1000 on a black substrate, TSR increased from 0.09 to 0.25, and NIR increased from 0.14 to 0.48. This result also shows that even when visible colors are close, NIR performance can differ by orders of magnitude. Because the white-substrate result is clearly higher than the black-substrate result, the substrate must always be reported.

6.3 External Colored Coating Validation Data

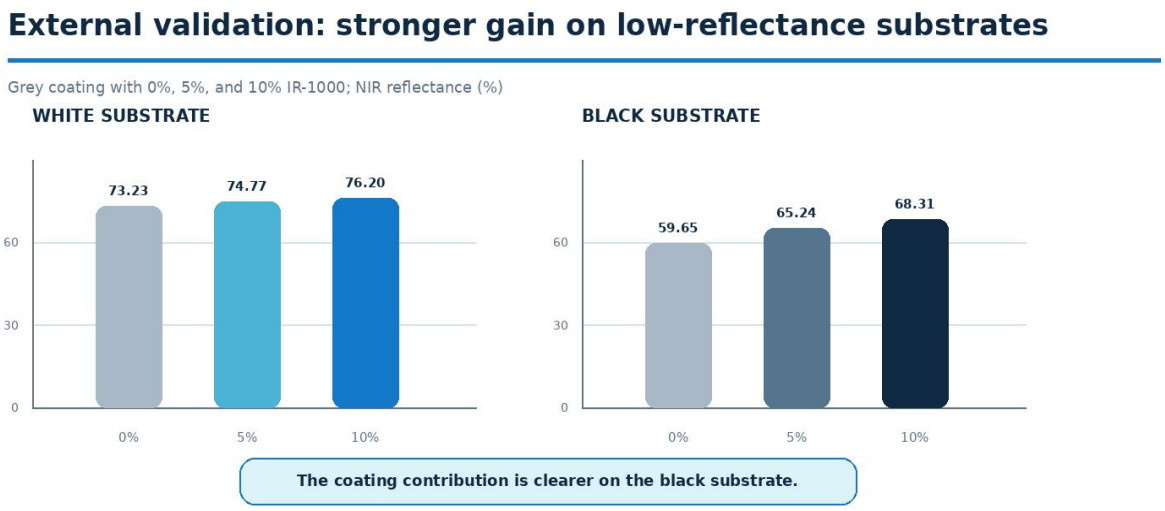

Figure 5 NIR validation results of grey coating on different substrates

An external coating company added 5% and 10% IR-1000 to a grey coating and tested it on both white and black substrates. On the white substrate, NIR increased from 73.23% to 74.77% and 76.20%. On the black substrate, NIR increased from 59.65% to 65.24% and 68.31%. The results indicate that IR-1000 contributes more clearly to reducing NIR transmission and improving real coating reflectance on low-reflectance substrates.

Data Interpretation

The performance advantage of IR-1000 is more significant on low-reflectance substrates. Testing only on high-reflectance substrates such as white panels or aluminum panels may overestimate the real reflectance of high-transmission films and underestimate the actual contribution of IR-1000 in suppressing transmission.

7. Application Routes for Different Color Systems

Grey and Low-Lightness Colors

Use iron red + iron yellow + phthalocyanine blue to build compound black. In the first screening round, use a 3-10% IR-1000 gradient and reduce the compound black color-paste ratio at the same time to maintain L*. Focus on confirming TSR/NIR on low-reflectance substrates at 150 μm dry-film thickness.

Yellow

Iron yellow has relatively high NIR transmission. Use IR-1000 to increase scattering and reduce transmission. For medium-to-high lightness colors with tight standard windows, a small amount of titanate yellow may be added. A typical honey yellow formulation with 8% IR-1000 reached NIR 0.66, compared with 0.59 for the control.

Red and Brown

Iron red systems more easily meet medium-lightness reflectance requirements. Coffee-brown shades should not be darkened with carbon black or iron black. The cost-performance balance of IR-1000 + iron red can approach that of some cool red pigments. A typical copper brown formulation with 7% IR-1000 increased NIR to 0.59.

Blue

Use high-tinting-strength phthalocyanine blue together with IR-1000. In a typical signal blue formulation with 5% IR-1000 and nearly identical L*, NIR increased from 0.54 to 0.65, and the endpoint temperature difference was 7.4° C.

Green

Phthalocyanine green has relatively high NIR transmission, so real coating reflectance should be increased while film thickness is controlled. In a typical mint green formulation with 6% IR-1000, NIR increased from 0.46 to 0.55, and the endpoint temperature difference was 8.0° C.

8. Effects of Substrate, Film Thickness, PVC, and Dispersion

Variable	Effect on results	Recommended control method
Substrate NIR	High-reflectance substrates raise apparent reflectance of high-transmission films	Test white/black substrates as a pair; final confirmation on the real substrate
Dry-film thickness	Higher film thickness usually reduces transmission and increases real NIR; thin films may rely on substrate reflection	Use a wet-film applicator and dry-film measurement; at least 50/100/150 μm gradients
PVC / CPVC	Affects particle spacing, porosity, hiding, and durability; excessive levels may damage the film	Fix resin and extenders; adjust one variable at a time; test water resistance and weatherability together
Dispersion state	Agglomeration causes spectral unevenness, color difference, coarse particles, and storage problems	Judge by fineness, particle size, viscosity, gloss, and storage stability together
Pigment package	Pigments differ greatly in reflection, absorption, and transmission	Screen pigments first, then optimize IR-1000; do not rely only on color-card names
Resin / additives	Organic groups absorb in NIR and affect wetting and weatherability	Prefer low-absorption, weather-resistant systems; compare blank resin spectra

Engineering Judgment

When color-matched samples perform well on white substrates but show significant performance loss on black substrates, film-thickness uniformity, pigment transmittance, and IR-1000 dispersion stability should be systematically checked first. Avoid blindly increasing material dosage to cover potential process defects.

9. Testing and Evaluation Methods

9.1 Recommended Minimum Test Set

Category	Test item	Purpose
Color	L*a*b*, ΔE, gloss	Ensure comparison under the same color and surface state
Optical	300-2500 nm spectra, TSR, 780-2500 nm NIR	Identify visible color, NIR reflection, and absorption peaks
Substrate dependence	White/black or high-/low-reflectance panel comparison	Distinguish real coating reflectance from substrate-assisted reflection through transmission
Thermal	Surface/back-side temperature-rise curves under unified irradiation	Connect spectral improvement to actual temperature-control effect
Application	Fineness, viscosity, storage, hiding, film thickness	Confirm manufacturability and batch stability
Durability	Water resistance, alkali resistance, stain resistance, artificial aging, outdoor exposure	Verify long-term use risks for architectural exterior walls

9.2 Conditions That Must Be Included in Result Reports

- Resin type and solids content, PVC/CPVC, and all pigment/extender grades and dosages;
- Wet-film thickness, measured dry-film thickness, substrate type, and TSR/NIR of the substrate itself;
- Dispersion equipment, rotation speed/linear speed, time, temperature, and fineness endpoint;
- Panel maturation time, test environment, instrument model, and integrating-sphere/portable method;
- Light source, illuminance/irradiance, distance, ambient temperature, wind speed, thermocouple position, and duration for the temperature-rise setup;
- Color difference and gloss difference of the control formulation, to avoid misreading color or surface differences as material effects.

Data note: The R&D data reference method frameworks such as JG/T 235-2014, GB/T 25261-2018, and ASTM E903. Before certification or external claims, the current local standards and versions for the project location should be checked.

10. Engineering Application Recommendations

Application area	Priority value	Formulation / validation focus
Colored exterior walls	Reduce wall heat absorption and surface temperature rise	Weatherability, stain resistance, low-reflectance cement substrates, color difference
Colored roofs	High solar heat input and strong energy-saving potential	Waterproofing, ponding-water resistance, weatherability, reflectance retention after contamination
Insulated decorative panels	Factory coating with controllable film thickness	Panel base color, baking/curing, adhesion, and batch color
Metal roofs and curtain walls	Synergy between substrate reflection and surface temperature control	Adhesion, flexibility, salt spray, baking stability, cut-edge corrosion
Old-wall renovation	Dark-color renovation and thermal-comfort improvement	Existing substrate color, water absorption, primer, and full-system film thickness

Demonstration projects should prioritize dark colors, low-reflectance substrates, and high solar exposure because these scenarios more clearly show the incremental value of IR-1000. Each project should complete full validation around target hue, substrate characteristics, dry-film thickness, and the actual application system.

11. Application Limitations and Precautions

11.1 Main Risks in Colored Coating Formulations

- Treating IR-1000 as an equal-dose replacement for standard TiO2 while ignoring differences in particle size, tinting strength, and resin wetting;
- Using carbon black/iron black first and then relying on high IR-1000 dosage to compensate, causing cost, viscosity, and color to lose control at the same time;
- Testing only on white substrates or aluminum panels, leading to artificially high reflectance conclusions;
- Comparing temperature rise using panels with different colors, gloss levels, or film thicknesses;
- Reporting only initial TSR/NIR without validating reflectance retention after contamination, aging, and outdoor exposure;
- Presenting a 5-8°C temperature difference from a specific test as a fixed cooling promise for all scenarios.

Suggested External Wording Use qualified statements such as "improves TSR/NIR and reduces temperature rise under specific formulations and test conditions." Final energy savings, indoor temperature, and service life should be verified through the complete building system.

12. Recommended Application Validation Path

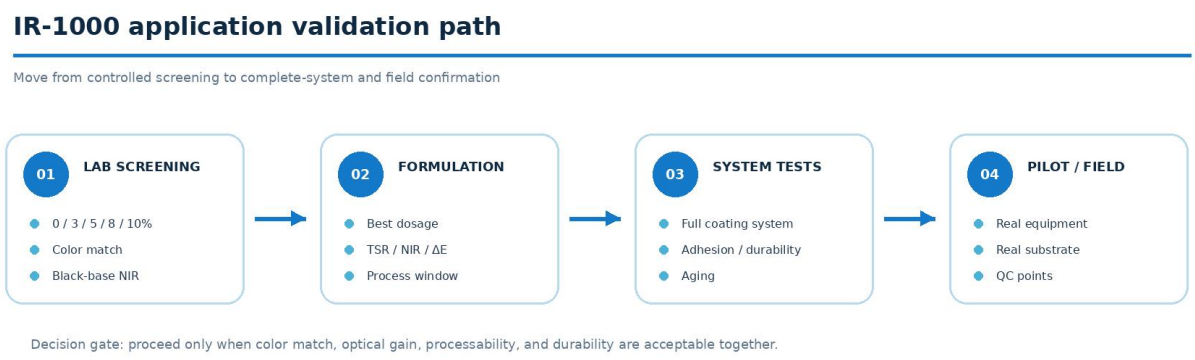

Figure 6 Four-stage validation from laboratory screening to pilot/field trial

Stage	Recommended samples	Example decision threshold	Output
Laboratory screening	0/3/5/8/10% gradient, color-matched adjustment	ΔE acceptable; clear NIR gain on black substrate	Spectral and color screening table

Stage	Recommended samples	Example decision threshold	Output
Formulation optimization	2-3 optimal dosages, film-thickness/PVC gradients	Stable application; balance among TSR/NIR and cost	Recommended formulation and process window
Application performance	Complete primer/intermediate/topcoat system	Adhesion, water resistance, alkali resistance, stain resistance, and aging meet targets	System performance report
Pilot / field	Real equipment, substrate, application, and exposure	Batch stability; temperature rise and appearance meet project targets	Mass-production introduction and QC points

12.1 Recommended Decision Rules

- If improvement is clear on a white substrate but not on a black substrate: prioritize transmission, film thickness, and dispersion.
- If NIR improves but the temperature difference is not obvious: check light-source spectrum, irradiance, heat dissipation conditions, and thermocouple position.
- If reflectance improves but weatherability decreases: reduce PVC, optimize resin compatibility with inorganic treatment, and extend aging validation.
- If the color becomes whitish or saturation decreases: reduce IR-1000, use higher-tinting-strength pigments, and rebalance the pigment package.
- If viscosity or fineness is abnormal: check wetting/dispersant selection, addition order, shear intensity, and powder agglomeration.

Appendix A Typical Data Summary

Evidence source	System	Main result	Interpretation
R&D formulation	Grey RAL 7010	TSR 0.13 -> 0.29; NIR 0.13 -> 0.48	Most significant gain in low-lightness systems
R&D formulation	Yellow / blue / brown / green	NIR increased by 0.07-0.11; temperature difference 5.0-8.0°C	Heat-management gain remains even when visible colors are close
External validation	Grey coating, white/black substrates	NIR gain on black substrate is higher than on white substrate	Confirms the importance of substrate and transmission control

Appendix B Information Sources

- IR Series Technical White Paper_CN
- Application and Formulation Design of Near-Infrared Reflective Titanium Dioxide Materials in Reflective Thermal Insulation Coatings
- Near-Infrared Reflective Titanium Dioxide Material
- IR-1000 Colored Coating Test Results from an External Coating Company

The data and information in this report are typical values or results obtained under specific test conditions. They are intended only for technical communication, formulation screening, and R&D planning. The content does not constitute a product performance guarantee and does not replace the TDS, SDS, current standards, or project validation reports. Before actual use, validation should be completed under the target resin system, pigment package, substrate, film thickness, application process, and service conditions.