

Technology of Vermiculite-Based Paint Production for Fire-Resistant and Eco-Friendly Coatings

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Abstract

The growing demand for sustainable and fire-resistant construction materials has intensified research into mineral-based fillers for coating technologies. Vermiculite, a naturally occurring hydrated laminar aluminosilicate, exhibits exceptional thermal insulation, fire resistance, and sorption properties, making it a promising component for advanced paint formulations. This study investigates the technology of producing vermiculite-based paints using exfoliated and surface-modified vermiculite as a functional filler. The influence of vermiculite content on physical, mechanical, and thermal properties of the coatings was evaluated. The results demonstrate that vermiculite incorporation significantly improves fire resistance, adhesion, and durability while reducing coating density and volatile organic compound (VOC) emissions. The developed technology offers an environmentally responsible solution for protective coatings in modern construction and industrial applications.

Keywords: Vermiculite, Paint Technology, Mineral Fillers, Fire-Resistant Coatings, Sustainable Materials

1. Introduction

The paint and coatings industry are undergoing a rapid transformation driven by stringent environmental regulations and the global shift toward sustainable construction materials. Conventional paints often rely on synthetic fillers and organic solvents, which contribute to VOC emissions and limited fire resistance. Consequently, the integration of natural mineral fillers has gained increasing scientific and industrial attention. Vermiculite is a layered magnesium–aluminum–iron silicate mineral that undergoes volumetric expansion when thermally treated at temperatures above 850 °C. The resulting exfoliated vermiculite exhibits low density, high porosity, thermal stability, and non-combustibility. These characteristics make vermiculite an attractive candidate for multifunctional coatings, particularly for fire protection and thermal insulation. However, comprehensive studies addressing the technological aspects of vermiculite-based paint production remain limited, which defines the objective of this research.

2. Materials and Methods

2.1. Raw Materials

The following components were used.

- Exfoliated vermiculite (particle size: 0.2–1.0 mm)
- Acrylic and silicate binders
- Pigments (titanium dioxide, iron oxide)
- Functional additives (dispersants, plasticizers, fire

retardants)

2.2. Vermiculite Preparation

Natural vermiculite concentrate was subjected to.

- Crushing and granulometric classification
- Thermal exfoliation at 850–950 °C
- Surface modification using silane coupling agents and phosphate solutions to enhance compatibility with binders

2.3. Paint Production Technology

The production process consisted of.

- Pigment dispersion in liquid binder
- Gradual incorporation of vermiculite filler
- High-shear homogenization to control viscosity
- Filtration and packaging of the final paint product

Standardized test methods were applied to evaluate adhesion, density, thermal resistance, water absorption, and coating durability.

3. Results and Discussion

Experimental results indicate that vermiculite contents ranging from 10 to 25 wt.% reduce paint density by 15–30% compared to conventional formulations. The porous lamellar structure of vermiculite contributes to the formation of intumescent micro-layers, significantly

enhancing fire resistance. Coatings exposed to temperatures up to 600 °C retained structural integrity without cracking or delamination. Additionally, thermal conductivity values decreased by approximately 20%, confirming the insulating effect of vermiculite. The natural origin of the filler also led to a measurable reduction in VOC emissions, aligning with EU environmental directives and ISO sustainability standards.

4. Applications

Vermiculite-based paints are suitable for:

- Fire-protective coatings for steel and concrete structures
- Industrial facilities with elevated temperature requirements
- Public and residential buildings under green construction standards
- Humid and chemically aggressive environments

5. Conclusion

The developed technology for vermiculite-based paint production provides a viable pathway for manufacturing lightweight, fire-resistant, and environmentally friendly coatings. The incorporation of exfoliated and modified vermiculite enhances thermal stability, adhesion, and durability while reducing environmental impact. These findings confirm the strong potential of vermiculite-based paints for widespread adoption in sustainable construction and industrial protection systems.

Highlights

- Vermiculite is proposed as a multifunctional mineral filler for eco-friendly paints

- Optimized production technology of vermiculite-based coatings is developed
 - Fire resistance and thermal insulation properties are significantly improved
 - VOC emissions and coating density are reduced
 - High potential for application in green and energy-efficient construction
- Graphical Abstract (description)

The graphical abstract illustrates the technological pathway of vermiculite-based paint production. raw vermiculite → thermal exfoliation → surface modification → dispersion in polymer/silicate binder → formation of lightweight fire-resistant coating with enhanced thermal and environmental performance.

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