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Evaluation Method of Conservation Papers Based on a Subjective–Objective Assessment Model

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Abstract

As an important material directly applied to cultural relics during conservation treatment, conservation paper plays a critical role in the operational stability of restoration procedures and the long-term preservation safety of artworks. Traditional selection and evaluation of conservation papers have long relied on empirical judgment, lacking unified, quantitative, and reproducible evaluation standards. To address the limitations of conventional experience-based assessment methods, this study establishes a comprehensive evaluation framework integrating "objective testing–simulated application–subjective assessment–model fusion." Five key indicators, including folding endurance, tensile strength, peel strength, thickness, and pH value, were selected to characterize the mechanical performance, structural properties, and chemical stability of conservation papers. Simulated application systems corresponding to reinforcing strips, infill papers, and backing papers were constructed. In addition, expert scoring mechanisms were introduced to evaluate flatness, flexibility, compatibility, stiffness, and overall visual performance. Based on these results, a nonlinear subjective–objective fusion model was established to realize systematic and quantitative assessment of conservation paper performance. The proposed method provides a scientific basis for material selection, comparative evaluation, and standardization research in the conservation of Chinese paintings and calligraphy.

Keywords: Conservation paper; Cultural relic conservation; Performance evaluation; Simulated application; Index assessment

1. Introduction

Chinese paintings and calligraphic artifacts are important carriers of traditional Chinese culture. Their primary materials include paper, silk, and other natural organic fibers, which are highly susceptible to environmental deterioration such as fluctuations in temperature and humidity, acidic pollutants, light exposure, and biological damage. These factors may lead to brittleness, tearing, discoloration, powdering, and structural degradation, making conservation treatment essential for their long-term preservation.

Among the materials used in conservation practice, conservation paper directly contacts the original artifact and is widely applied in mending, reinforcing, lining, mounting, and backing

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procedures. The performance of conservation paper therefore significantly affects both the structural stability of restored artworks and their long-term preservation safety.

Traditional Chinese painting conservation has historically relied on craft-based experience and apprenticeship systems. Material selection has largely depended on restorers' empirical judgment. For example, reinforcing strip papers emphasize toughness and mechanical strength, infill papers require compatibility in texture and color with the original artwork, and backing papers prioritize stiffness and structural support. However, such experience-based approaches lack unified quantitative standards and often result in significant inconsistencies among restorers and materials.

With the development of conservation science, material characterization techniques have gradually been introduced into the field of cultural heritage conservation. Previous studies have focused on fiber morphology, aging properties, mechanical behavior, and chemical stability of traditional handmade papers. Nevertheless, most studies concentrate on individual physical or chemical indicators and rarely integrate objective material performance with practical restoration applicability. Moreover, Chinese painting conservation possesses strong artistic and experiential characteristics; therefore, objective physicochemical data alone cannot fully reflect the visual compatibility and operational suitability of conservation materials.

Accordingly, establishing an evaluation model that combines objective material performance with subjective restoration assessment is of great significance for the standardization of conservation papers. This study develops a systematic evaluation framework integrating simulated application systems, objective physicochemical testing, and expert subjective assessment to achieve comprehensive and quantitative evaluation of conservation paper performance.

2. Construction of the Performance Evaluation Index System for Conservation Papers

2.1 Classification and Functional Characteristics of Conservation Papers

Conservation papers used in Chinese painting restoration can generally be classified into three categories: reinforcing strip papers, infill papers, and backing papers.

Reinforcing strip papers are primarily used for structural reinforcement and crack stabilization. Such papers require both flexibility and high mechanical strength to withstand repeated rolling and unfolding during long-term preservation.

Infill papers are used for repairing missing areas of artworks. Their primary requirement is visual compatibility, including matching in color, fiber texture, transparency, and thickness. Significant differences between infill paper and the original artifact may result in visible restoration traces.

Backing papers mainly function as structural support layers and therefore require excellent flatness, stiffness, and dimensional stability to maintain the integrity of mounting structures.

Because these paper types perform different functions, their evaluation criteria also differ accordingly.

2.2 Objective Evaluation Indicators

To comprehensively characterize the performance of conservation papers, five core indicators were selected from the perspectives of mechanical performance, structural uniformity, and chemical stability.

2.2.1 Folding Endurance

Folding endurance measures the resistance of paper to repeated folding and reflects the bonding strength and flexibility of fibers. High folding endurance effectively reduces the risk of fracture in conservation layers subjected to repeated rolling and handling.

Testing was conducted according to GB/T 457–2008 using the MIT folding endurance method.

2.2.2 Tensile Strength

Tensile strength represents the maximum stress that paper can withstand during stretching and is one of the most important indicators of mechanical integrity.

The test was conducted according to GB/T 12914–2008. Tensile strength was calculated as follows:

$$S = \frac{F}{w}$$

where:

- S is the tensile strength;
- F is the maximum tensile force;
- w is the sample width.

2.2.3 Peel Strength

Peel strength reflects the adhesion performance between paper and starch adhesive layers. Insufficient peel strength may lead to delamination, while excessively high peel strength may reduce reversibility.

The 180° peel test method was employed:

$$P = \frac{F}{b}$$

where:

- P is the peel strength;

- F is the average peel force;
- b is the sample width.

2.2.4 Thickness

Paper thickness reflects structural characteristics and directly influences visual compatibility and stress distribution. Infill papers generally require thickness close to the original artwork, while backing papers require sufficient structural support.

2.2.5 pH Value

The pH value is a key indicator of chemical stability. Acidic papers accelerate cellulose hydrolysis and embrittlement, whereas weakly alkaline papers help prolong paper longevity.

The ideal pH range for conservation paper is generally considered to be 6.5–7.5.

3. Construction of Simulated Application Systems

3.1 Design of Simulated Samples

To improve the relationship between evaluation systems and practical restoration procedures, simulated application systems based on traditional mounting structures were established.

Three types of conservation papers—paper mulberry paper, cotton-fiber Xuan paper, and mulberry bark paper—were selected. Wheat starch paste with alum addition was used as the adhesive.

The simulation systems included:

1. Painting core–lining structures;
2. Hanging scroll backing structures;
3. Handscroll backing structures;
4. Mounting margin structures.

These systems simulated the bonding and stress conditions encountered in actual restoration practice.

3.2 Experimental Conditions and Instrumentation

All samples were conditioned for 24 h at 23 ± 2 °C and 50 ± 5% relative humidity prior to testing.

The main instruments included:

- MIT folding endurance tester;
- TA.XT plus texture analyzer;

- 180° peel testing apparatus;
- Thickness gauge;
- Digital pH meter.

All instruments were calibrated before testing.

4. Construction of the Subjective Evaluation System

4.1 Necessity of Subjective Evaluation

Chinese painting conservation involves not only material science but also strong artistic and aesthetic considerations. Even materials with excellent physicochemical properties may fail to satisfy conservation requirements if they exhibit poor visual compatibility or tactile performance.

Therefore, objective physicochemical data alone are insufficient for comprehensive evaluation, making expert subjective assessment indispensable.

4.2 Expert Scoring System

An expert panel consisting of 3–5 experienced conservators conducted evaluations under controlled illumination and environmental conditions.

A 100-point scoring system was adopted.

Reinforcing Strip Papers

- Flatness
- Flexibility
- Compatibility

Infill Papers

- Color compatibility
- Surface flatness
- Overall visual integration

Backing Papers

- Flatness
- Flexibility
- Structural stiffness

5. Subjective–Objective Fusion Evaluation Model

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5.1 Objective Evaluation Model

To eliminate dimensional differences among indicators, min–max normalization was adopted:

$$X_i^* = \frac{X_i - X_{min}}{X_{max} - X_{min}}$$

The objective comprehensive score was calculated as:

$$S_o = \sum_{i=1}^{n} w_i X_i$$

where:

- *So* is the objective score;
- *wi* is the weighting coefficient;
- *Xi* is the normalized indicator value.

5.2 Nonlinear Fusion Model

To better reflect the relationship between subjective and objective evaluations, a nonlinear fusion model was established:

$$S = (S_o^{\alpha} \times S_s^{1-\alpha})^{\beta\gamma}$$

where:

- *S* is the final comprehensive score;
- *So* is the objective score;
- *Ss* is the subjective score;
- α is the objective weighting coefficient;
- β and γ are nonlinear adjustment parameters.

5.3 Consistency Analysis

Pearson correlation analysis was used to evaluate model reliability:

$$r = \frac{\sum(X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum(X_i - \bar{X})^2 \sum(Y_i - \bar{Y})^2}}$$

When $r > 0.8$, subjective and objective evaluation results are considered highly consistent.

6. Conclusion

This study establishes a comprehensive evaluation framework for conservation papers based

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on a subjective–objective fusion model. Five key indicators—folding endurance, tensile strength, peel strength, thickness, and pH value—were combined with simulated restoration structures and expert subjective assessment to realize systematic evaluation of conservation paper performance.

The proposed method comprehensively reflects the applicability and stability of conservation papers in Chinese painting restoration and demonstrates good reproducibility and practical value. The framework provides a scientific basis for material selection, performance comparison, and future standardization research in conservation materials.

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