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Performance Expectations for Microcrystalline Waxes
for the Seismic Protection of Art Objects

Anne Crowley and Debra F. Laefer
University College Dublin

BACKGROUND
Use of microcrystalline waxes for the protection of ceramic art objects from seismic events is an inexpensive and relatively popular technique in museum exhibition practice (Fig. 1). Unfortunately, because of the high porosity of some ceramics and the fragility of their glazes and paints, the surface of many art objects may be vulnerable to damage from the microcrystalline wax application. Thus, a conservative approach is needed—applying only as much as is actually required to resist predicted levels of ground motion and transmitted forces caused by an earthquake movement. Determining the appropriate and most effective quantity of wax as well as verifying the best application technique (e.g., hot versus cold) is not clearly established by either industrial standards, museum conservation standards or product-oriented guidance. How much wax to use for specific sizes and weights of objects is left to a matter of empirical knowledge, judgment and a good deal of guess work. While sometimes reliable these approaches can lead to the application of a greater amount of wax being used than needed (resulting unnecessary risk to the object) or too little wax with respect to the object’s mass and the anticipated earthquake threat (leading to an increase in the potential for).

This ongoing study has begun to develop some performance expectations for microcrystalline waxes and suggests a number of application guidelines, based on chemical microstructure and physical.

TESTING
The initial testing regimen of 100 tensile and 215 shear tests established the range of physical performance expectations, in terms of minimum and maximum capacities, as
well as consistency. Six waxes were tested: two candle waxes and four microcrystalline waxes.

Conservators usually apply microcrystalline waxes cold, often with a protective coating (an acrylic resin, Paraloid B-72) applied to the specific area of the object’s surface where the wax will be in contact. In the tensile and shear tests, investigations into the impact of application method on capacity were conducted. Samples were tested that had been applied by a hot method (the wax was liquid when applied) and a cold method by which the wax was applied at approximately room temperature. The application methods were tested with and without the protective coating applied to the object surface.

Nuclear Magnetic Resonance (NMR) and Scanning Electron Microscopy (SEM) were conducted on the waxes tested to understand the relationship between crystallinity of the wax (the extent to which a three dimensional order exists on the level of atomic dimensions, based on definite and ordered chemical and geometrical structure); branching (a type of structure), and predicted shear and tensile capacities. To better understand the results and find a simple test that could serve as a reliable predictor of tensile and shear performance, further experiments were conducted such as relative hardness (through needle penetration tests), contraction, density, softening point and melting point.

RESULTS
Candle waxes were found to be inappropriate due to their brittle failure mechanisms (figs. 2 & 3). Results of the tensile evaluations indicated that capacities of the waxes ranged from 129-222kPa hot applied and 107 –208kPa cold applied. The coating increased the capacity of the hot applied samples (51%), however its impact on compacted samples was inconsistent [Table 1].

Capacities for interface shear ranged from 12-91kPa when hot applied and 10-38kPa when cold applied. Coating increased cold applied capacity by 80% but gave less consistent results for the hot applied samples. Microcrystalline waxes generated an average of a 126% increase in shear strength with a 470% increase in normal load, an approximate
25% increase in capacity as a function of additional normal load. Average inherent shear capacities were over 300% higher than their average interface shear capacities (fig. 4a), and proved a poor indicator of interface shear capacity, despite similar failure mechanisms. (fig. 4b).

**Analytical Results**
SEM scans revealed the waxes’ microstructures, which can impact tensile and shear capacities. Paraffin wax has a linear crystalline structure (fig. 5a). As force is applied, the chains can slide away from one another relatively easily, thereby failing suddenly, in a brittle manner. In contrast, the branching of the microcrystalline waxes (fig. 5b, c) generates a slower, more progressive failure as the branches act as mini-shear keys along the failure plane, resulting in a ductile failure mode.

**Simple Measures**
Different simplified testing techniques proved effective at predicting specific application arrangements (table 2). Values closer to 1.0 more accurately predicted capacity.

**CONCLUSIONS AND RECOMMENDATIONS**
- When applied cold, Multiwax gave consistently high tensile and shear capacity, but to be applied cold it had to be taken in small pieces (approximately 1 g) and warmed between index finger and thumb to obtain good adhesion, and it required a large force (approximately 235 kPa) during placement to displace air voids.
- For successful cold wax application, surfaces must be free of contaminants and air pockets.
- Simplified experimental procedures can be used to predict performance but must be applied to a specific application method.

Captions:
Fig. 1—Typical Application Arrangement of Microcrystalline Wax to an Art Object
Fig. 2—Inherent shear failures
(a) Brittle (b) Ductile

Fig. 3—Tensile failures
(a) Adhesion (b) mixed (c) Cohesion

Fig. 4—Inherent versus interface results
(a) Average results for 5 tests (b) Average comparative failure patterns Fig. 5.

Fig. 5—SEM scans of the surface of the waxes
(a) Paraffin (b) Multwax (c) Secure Wax™

Table 1—Summary of Results

<table>
<thead>
<tr>
<th>Wax</th>
<th>Tensile Tests</th>
<th></th>
<th></th>
<th>Interface Shear Tests at 50kPa</th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>Hot applied range</td>
<td>Cold applied range</td>
<td>Hot applied range</td>
<td>Cold applied range</td>
<td>Hot applied range</td>
</tr>
<tr>
<td></td>
<td>No coating</td>
<td>Coating</td>
<td>No coating</td>
<td>Coating</td>
<td>No coating</td>
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<tr>
<td>Multiwax</td>
<td>161-172</td>
<td>254-335</td>
<td>117-208</td>
<td>158-201</td>
<td>45-91</td>
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<tr>
<td>Quake Hold™</td>
<td>129-229</td>
<td>209-395</td>
<td>107-170</td>
<td>125-259</td>
<td>7-29</td>
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<tr>
<td>Secure Wax™</td>
<td>179-277</td>
<td>293-350</td>
<td>76-123</td>
<td>1112-140</td>
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Table 2—Simplified measures

<table>
<thead>
<tr>
<th>Test</th>
<th>Application</th>
<th>Needle penetration</th>
<th>Contraction</th>
<th>Density</th>
<th>Softening/Melting point</th>
<th># Branches</th>
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</thead>
<tbody>
<tr>
<td>Tensile</td>
<td>Hot with coating</td>
<td>0.99</td>
<td></td>
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<tr>
<td></td>
<td>Hot non-coating</td>
<td>1.05</td>
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<tr>
<td></td>
<td>Cold with coating</td>
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<td></td>
<td>Cold non-coating</td>
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<td></td>
<td>1.31</td>
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<tr>
<td>Shear</td>
<td>Hot with coating</td>
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<td></td>
<td></td>
<td></td>
<td>2.03</td>
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<tr>
<td></td>
<td>Hot non-coating</td>
<td>1.24</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cold with coating</td>
<td></td>
<td></td>
<td>0.98</td>
<td>1.02</td>
<td>0.88</td>
</tr>
<tr>
<td></td>
<td>Cold non-coating</td>
<td>0.92</td>
<td></td>
<td>1.39</td>
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</tbody>
</table>


BS. 1970. Method for the determination of melting point and/or melting range, BS 4634 London: British Standards.


**SOURCES OF MATERIALS**

Acryloid B-72, Adhesives and Consolidants. 2000. URL: http://nautarch.tamu.edu/class/anth605/File2.htm (accessed [17 February 2005]).

Adhesives and Consolidants and Archival Storage and Display. URL: http://www.silcom.com/~css/ (accessed [17 November 2004]).

FIGURES:

Fig. 1—Typical Application Arrangement of Microcrystalline Wax to an Art Object

Fig. 2—Inherent shear failures

(a) Brittle          (b) Ductile

Fig. 2—Inherent shear failures
Fig. 3—Tensile failures

(a) Adhesion           (b) mixed                   (c) Cohesion

(a) Paraffin            (b) Multiwax         (c) Secure wax™

Fig. 5. Scanning Electron Microscopy images of the surface of the waxes at 500μm

Fig. 4--- Inherent versus interface results (a) Average results for five tests (b) Average comparative failure pattern