Formulating Gesso Fills for Discrimination by X-radiography

Behrooz Salimnejad, Associate Conservator of Furniture and Woodwork,
Philadelphia Museum of Art

Introduction

Like many conservators who have undertaken conservation treatments on gilded objects in recent years, we have used a gesso containing barium sulfate ($BaSO_4$) to fill areas of loss. The barium sulfate gesso was employed to allow detection of fill material by x-radiography, because of its higher x-ray absorbance when compared with the traditional calcium carbonate ($CaCO_3$) and calcium sulfate ($CaSO_4$) gessoes that are found on cultural objects. In 1997 Arlen Heginbotham, summer intern at the Philadelphia Museum of Art (PMA), used x-radiography to examine a gilded American girandole frame that had been treated previously at the PMA with a calcium sulfate gesso containing 10% $BaSO_4$. The resulting x-radiograph showed that it was not possible to discern the $BaSO_4$ containing fills from the original $CaCO_3$ gesso of the girandole. Further x-radiographic examinations of fills made with $BaSO_4$ concentrations as high as 20% gave similar results. Moreover, the addition of larger quantities of barium sulfate to gesso adversely affected its working properties: the barium sulfate tended to clump or settle to the bottom of the container and the gesso became gritty. This tip outlines preliminary testing undertaken to identify a non-toxic gesso fill material with a high x-ray absorbance that allows discrimination by x-radiography while retaining desirable working properties.

Test setup

Two test panels were prepared to observe the effects of pigment composition and gesso thickness on the appearance of x-radiographs. The first test panel was prepared using fifteen gessoes formulated with varying proportions of calcium carbonate, zinc oxide (ZnO), and bismuth oxide (Bi_2O_3). The zinc and bismuth pigments were chosen because they are widely available, inert, and better x-ray absorbers than the traditional calcium pigments.[1] The test gessoes were mixed with rabbit skin glue (RSG)[2], brushed onto a ¾″ x 14″ x 18″ Medex®[3] board, allowed to dry for 5 days, and sanded to a uniform thickness using a jig. The arrangement of the fifteen test gessoes on the panel and their respective formulations are shown in Table 1.

The second panel was designed to measure the effect of gesso layer thickness on the appearance of x-radiographs. Eleven tapered mortises, numbered from top to bottom, shallow end on right, graduated from 1⁄16″ to ¼″ deep were routed on a ¾″ x 14″ x 18″ Medex® board and filled with calcium carbonate gessoes formulated with varying amounts of zinc oxide, bismuth oxide, and barium sulfate as shown in figure 2. Mortises #1–3 were sized prior to the application of gesso with a coat of rabbit skin glue containing 10% bismuth oxide w/v.

Results and Discussion

The panels were examined using x-radiography (Picker SN262 x-ray machine/25KV, 3mA, 70 sec., at distance of 33 in.). The resulting x-radiographs for the panels described in Tables 1 and 2 are shown in figures 1 and 2, respectively. The x-radiograph shows marked variations in photographic density for the different gessoes.

	0%$CaCO_3$			0%ZnO	
0%	$CaCO_3$	----	$CaCO_3$ 50	$CaCO_3$	100
	Bi_2O_3	----	Bi_2O_3 ----	Bi_2O_3	----
	ZnO	100	ZnO 50	ZnO	----
5%	$CaCO_3$	----	$CaCO_3$ 47.5	$CaCO_3$	95
	Bi_2O_3	5	Bi_2O_3 5	Bi_2O_3	5
	ZnO	95	ZnO 47. 5	ZnO	----
10%	$CaCO_3$	----	$CaCO_3$ 45	$CaCO_3$	90
	Bi_2O_3	10	Bi_2O_3 10	Bi_2O_3	10
	ZnO	90	ZnO 45	ZnO	----
15%	$CaCO_3$	----	$CaCO_3$ 42.5	$CaCO_3$	85
	Bi_2O_3	15	Bi_2O_3 15	Bi_2O_3	15
	ZnO	85	ZnO 42.5	ZnO	----
20%	$CaCO_3$	----	$CaCO_3$ 40	$CaCO_3$	80
	Bi_2O_3	20	Bi_2O_3 20	Bi_2O_3	20
	ZnO	80	ZnO 40	ZnO	----

TABLE 1 **Arrangement of the fifteen test gesso formulations on panel #1. For each gesso, the pigments (10 g total) were mixed with 5 ml RSG. All measurements shown are in weight percentages (%).**

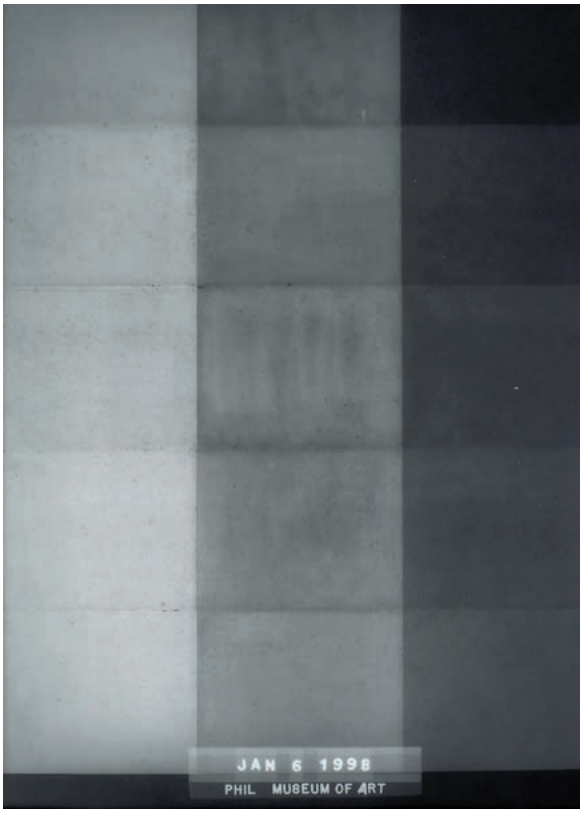

FIG. 1 **The fifteen test gesso formulations in table 1.**

Panel 1

In general, the opacity of the x-radiograph of panel #1 (fig. 1) increases as one moves from the upper left corner to the lower right hand corner of the panel. The greatest opacity is found in the section that contains 85% zinc oxide and 15% bismuth oxide and the least opacity in the section with 100% calcium carbonate.

Panel 2

Row 1. Mortise sized with one coat of 10% bismuth oxide/RSG and filled with 100% carbonate/RSG gesso. The increased opacity of row #1 versus row #11, which contains the same gesso but was not sized, is clearly visible in the x-radiograph.

Row 2. This row was also sized with one coat of 10% bismuth oxide/RSG and filled with 50/50 mix of calcium carbonate and zinc oxide in RSG. It exhibited very good radio-density, and sizing made a clear difference, especially on the thinner end when compared to row #10, which is also a 50/50 mix of calcium carbonate and zinc oxide in RSG. This fill material, however, cracked extensively during drying.

Row 3. The bismuth oxide/RSG sizing in this row made a clear difference compared with row #9 (no bismuth oxide/RSG sizing) especially at the thinner end of the mortise. While Row #3 exhibited excellent opacity it cracked badly.

Row 4. The zinc oxide fill material in this row exhibited excellent x-ray absorbance but the worst cracking of all.

Row 5. The addition of 10% barium sulfate made some difference at the thicker end compared to row 11. As in our earlier tests, the barium sulfate did not stay suspended in the gesso mixture even when ground very well into the mixture.

Row 6. The gesso mixture in this row containing 20% barium sulfate was slightly more x-ray absorbing than row #5 (10% barium sulfate) but the difference is barely perceptible. The line of gritty material located in the middle of this row is residual barium sulfate, which had settled to the bottom of the container after mixing and poured unevenly into the mortise.

Row 7. This mixture exhibited excellent opacity and good drying and working properties.

Mortise #1	$CaCO_3$ 100 g/over a 10% Bi_2O_3 RSG size layer
Mortise #2	$CaCO_3$ 50 g/ZnO 50 g / over a 10% $Bi2O_3$ RSG size layer
Mortise #3	$CaCO_3$ 35 g/ZnO 50 g/Bi_2O_3 15 g/over a 10% Bi_2O_3 RSG size
Mortise #4	ZnO 100 g/
Mortise #5	$CaCO_3$ 90 g/$BaSO_4$ 10 g
Mortise #6	$CaCO_3$ 80 g/$BaSO_4$ 20 g
Mortise #7	$CaCO_3$ 50 g/ZnO 35 g/Bi_2O_3 15 g
Mortise #8	$CaCO_3$ 90 g/Bi_2O_3 10 g
Mortise #9	$CaCO_3$ 35 g/ZnO 50 g/Bi_2O_3 15 g
Mortise #10	$CaCO_3$ 50 g/ZnO 50 g
Mortise #11	$CaCO_3$ 100 g

TABLE 2 **Arrangement of the eleven gesso formulations on panel #2. For each gesso, the pigments (100 g total) was mixed with 50 ml RSG.**

Row 8. This mixture exhibited very good opacity and excellent drying and working properties.

Row 9. See comments above on row #3

Row 10. See comments above on row #2

Row 11. See comments above on row #1

CONCLUSIONS

A sizing treatment of a fill area with RSG containing 10% bismuth oxide provided a perceptible increase in opacity in these tests especially when thin layers of traditional calcium carbonate gesso fill were used. For thicker areas, the addition of up to 35% zinc oxide with 5% bismuth oxide to traditional gesso provided excellent x-ray density without comprising the workability of the gesso material. While concentrations of zinc oxide higher than 40% cracked badly during drying of the test panels, the cracking problems were not as severe if the gesso was applied in layers with a brush rather than poured. Pouring became especially problematic with the barium sulfate gessoes because of the rapid separation (settling) of the barium sulfate from the gesso mixture.

Based on these observations, we developed a fill method using a gesso formulated with 55% calcium carbonate, 35% zinc oxide, and 10% bismuth oxide in RSG. This fill material was used to treat the losses on an 18th-century French console table from the PMA collections after first sizing with RSG containing 10% bismuth oxide. This mixture brushed on well, dried similarly to traditional gesso, burnished well, and was easy to cut with gesso tools. Furthermore, the fills on the French console table have not shown any adverse effects such as cracking, shrinkage, or discoloration after five years in the museum environment. Additional studies would be valuable to study a wider range of formulations including calcium sulfate gessoes, and to determine the effect of environmental conditions on these materials.

ENDNOTES

1. Dr. Chris Tahk, Director, Art Conservation Program, State University of New York, College at Buffalo, suggested bismuth oxide as a possible pigment for the gesso in fall of 1997.

2. The stock solution of rabbit skin glue was made by dissolving 45 g of ground rabbit skin glue in 1000 ml of distilled water.

3. Medex® is an engineered wood-based panel product manufactured by SierraPine, Ltd. (www.sierra pine.com/products/mdf_medex.htm) from softwood fibers combined with formaldehyde-free synthetic resins.

FIG. 2 **The eleven test gesso formulations in table 2.**