MACHINE MADE ORIENTAL PAPERS IN WESTERN PAPER CONSERVATION

by Kitty Nicholson and Susan Page*

Japanese hand-made paper has traditionally been used to repair and reline Oriental art. It has become the repair and lining material of choice for many Western paper conservators.

The application of Oriental lining techniques to Western paper can cause problems, because of the very different behavior of Eastern and Western papers. In particular, the pronounced directionality of Western machine-made paper can cause much greater differences in expansion parallel and perpendicular to the paper grain, than are found in typical hand-made papers. Recently, Oriental papers that are machine-made with traditional fibers such as kozo have become available in the West. They promise to offer the advantage of directionality and expansion characteristics more closely matching those of Western machine-made papers found in most Western art and artifacts.

This presentation compares the physical properties of five machine-made and five handmade Japanese papers. Four of the machine-made papers are 100% kozo fibers, and one is 100% gampi. The papers (with one exception) are available from Paper Nao, (Tokyo), the only source for roll Japanese papers of which we are aware. The characteristics examined are tensile strength and per cent expansion and contraction parallel and perpendicular to the paper grain. Data is summarized in charts and graphs.

Among the advantages of machine-made roll paper is its limitless length which allows greater ease in working with oversized and extremely oversized Western paper much of which is machine-made. Types of artifacts suitable for aqueous and heat-set linings with Japanese machine-made paper include blueprints, wallpaper, oversized posters, extremely large mechanical drawings, architectural drawings, and other drawings on tracing paper, roll petitions, and works of art on paper.

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On the first wetting, the handmade kozo papers generally showed moderate and generally equal expansion in both directions. An explanation for this behavior is that traditional stretch drying with sheets adhered to flat surfaces leaves the paper under tension and partially stretched in both directions. On subsequent drying, rewetting and drying, they showed greater expansion and contraction, especially in the cross direction (width). It is generally not advisable to prewet and dry handmade kozo before use, if differential expansion/contraction is not desired, e.g. in lining a Western handmade paper. Paper K-31 is an exception, showing less differential contraction on the second drying than on the first.

On the first wetting, the roll kozo papers showed marked expansion in the cross direction only. Apparently, the roll kozo papers dried under tension, leaving the paper under tension and stretched along the paper grain (height). Contraction during the first drying varied considerably. Roll kozo papers RK-17 and RK-5 showed approximately equal contraction in both directions, while RK-2 and RK-19 showed pronounced contraction in the cross direction only. In subsequent wetting and drying, RK-17 and RK-5 continued to show more similar expansion/contraction in both directions, and thus might be suited for lining a handmade Western paper. Prewetting and drying roll kozo prior to use will minimize differential expansion and contraction.

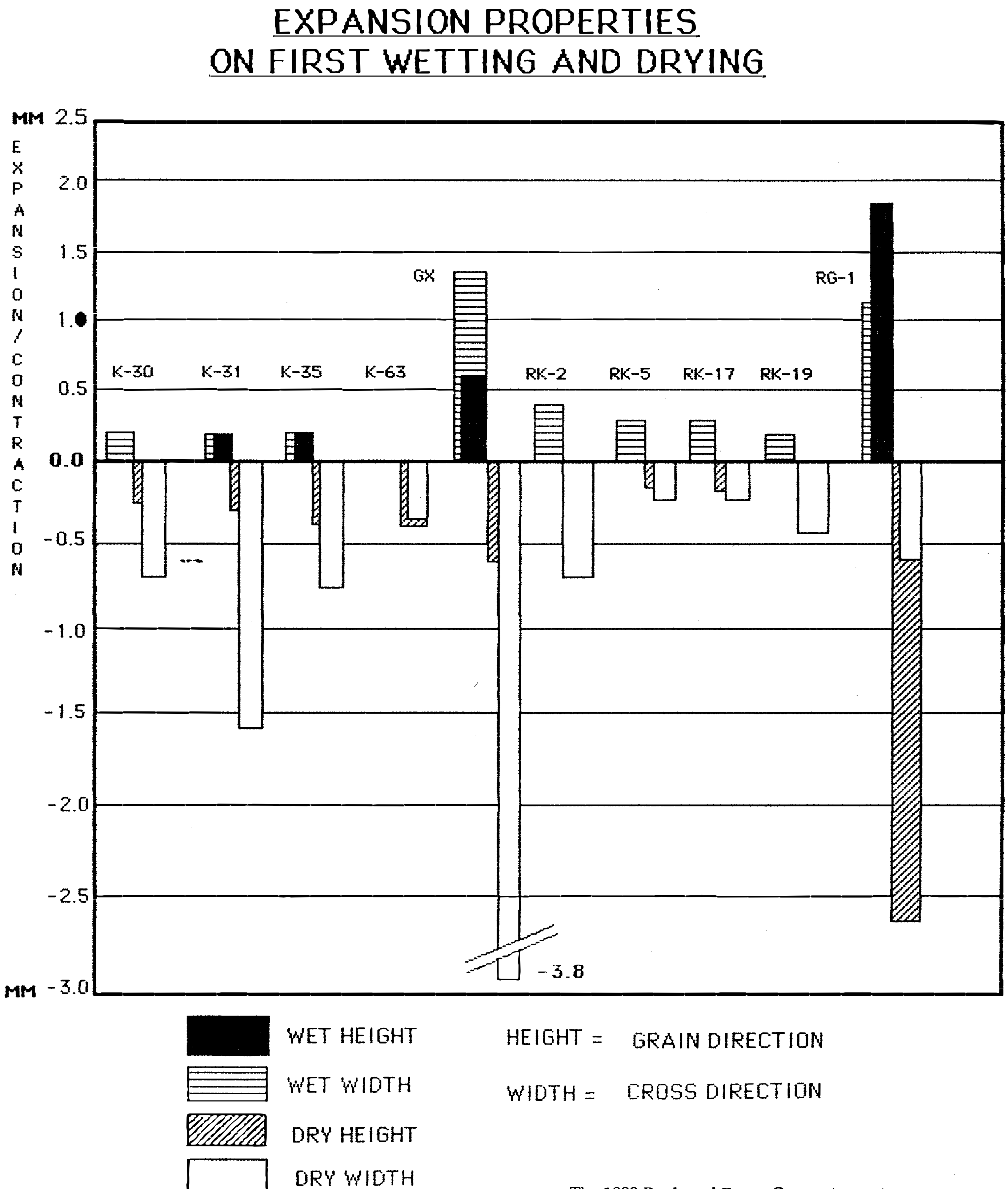
The two gampi papers showed erratic expansion, contraction and distortion on each wetting/drying cycle, with different degrees of expansion/contraction at different measurements points. There appears to be no benefit in prewetting and drying gampi. Pencil notations made on the gampi appeared to diminish after repeated wetting and bright yellow matter migrated to the edge of the sheet. (Yellow edges also appeared on K-35 and RK-5.) Gampi papers showed much greater water uptake to reach full expansion and, on a nonabsorbent polyester sheet, dried slowly relative to kozo papers.

In this discussion, machine or grain direction is used to refer to the direction parallel to the predominate paper fiber orientation, and cross direction, to mean the direction perpendicular to the paper grain. The term differential expansion and contraction is used to refer to paper behavior in which one paper direction expands or contracts to a different extent than the perpendicular direction. In the data table, differential expansion or contraction is indicated by the magnitude of H-W, which is the difference between per cent expansion or contraction in the two paper directions. Because of the high degree of parallel fiber orientation in both handmade and machine-made Oriental paper, greater expansion and contraction is expected in the cross grain direction. The more important consideration in choosing an Oriental paper for a paper conservation treatment is matching the extent of contraction on drying, rather than expansion on wetting. In a typical conservation use, Oriental paper would be applied already expanded and wet to an expanded, damp or wet artifact, and the Oriental paper and paper artifact would dry together, hopefully contracting to a similar degree.

% EXPANSION/CONTRACTION

PAPER SAMPLE	% Change from Dry Size Wet 1x: H	W	H-W	% change from Size Wet 1x Dried 1x: H	W	H-W	% change from Size Dried 1x Wet 2x: H	W	H-W	% change from Size Wet 2x Dried 2x: H	W	H-W
K-30	0	0.2	-0.2	-.03	-0.7	0.4	0.3	0.5	-0.2	-0.4	-0.8	0.4
K-31	0.2	0.2	0	-0.4	-1.6	1.2	0.3	0.6	-0.3	-0.4	-0.6	0.2
K-35	0.2	0.2	0	-0.4	-0.7	0.3	0.2	0.5	-0.3	-0.2	-0.6	0.4
K-63	0	0	0	-0.4	-0.3	-0.1	0	0.2	-0.2	0	-0.4	0.4
GX	0.6	1.4	-0.8	-0.6	-3.8	3.2	0.6	3.3	-2.7	-0.4	-1.4	1.0
RK-2	0	0.4	-0.4	0	-0.7	0.7	0	0.7	-0.7	-0.2	-0.5	0.3
RK-5	0	0.3	-0.3	-0.2	-0.3	0.1	0.2	0.2	0	-0.2	-0.2	0
RK-17	0	0.3	-0.3	-0.2	-0.3	0.1	0.2	0.4	-0.2	-0.2	-0.3	0
RK-19	0	0.2	-0.2	0	-0.4	0.4	0	0.4	-0.4	-0.1	-0.3	0.2
RG-1	1.8	1.2	-0.6	-2.6	-.6	-2.0	1.6	-0.8	2.4	-0.8	-0.3	-0.5

All samples cut to 50cm squares, except K-63 which was cut 25cm high by 50 cm.
Height corresponds to grain direction, width to cross direction.
Samples were wetted by spraying with water till saturated and fully expanded.
Samples were air dried on polyester film.


EXPANSION PROPERTIES
ON FIRST WETTING AND DRYING
MM
EXPANSION/CONTRACTION
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
K-30
K-31
K-35
K-63
GX
RK-2
RK-5
RK-17
RK-19
RG-1
-3.8
WET HEIGHT
WET WIDTH
DRY HEIGHT
DRY WIDTH
HEIGHT = GRAIN DIRECTION
WIDTH = CROSS DIRECTION

The data generally show higher tensile strength for the roll kozo papers in both the grain and cross directions, when compared to handmade kozo paper of similar thickness, e.g. RK-19 compared to K-35, and RK-17 compared to K-30. The one exception is RK-5 which has lower tensile strength than K-31. The medium weight RK-17 and RK-19 are noteworthy because of their high cross direction strength. As a result, their tensile strength measurements are closer in numerical value, both parallel and perpendicular to the paper grain than comparable handmade paper. The roll kozo papers show extremely varied ratios of machine-direction to cross-direction strength. The two thin roll papers, RK-2 and RK-5, have a machine direction tensile strength roughly four times larger than their cross direction strength, while RK-17 and RK-19 have roughly the same tensile strength in both directions. The handmade kozo papers show intermediate MD/CD ratios of ca. 1.5 to 3. The difference between the tensile strengths of RK-19 and K-35, RK-17 and K-30 and RK-5 and K-31 are statistically significant.

The two gampi papers tested show fairly similar tensile strengths and it is probable that GX, a gampi of unknown origin, is machine made like RG-1. It is worth noting the great tensile strengths of both gampi papers, which are comparable to those of K-30 and RK-2, kozo papers twice as thick as the gampi papers.

It is interesting to note that the roll kozo papers are generally about .01 mm thinner than the handmade kozo papers originally chosen as comparable on the basis of "feel." On the one hand, their relative thinness undoubtably contribute to the somewhat lower tensile strengths. On the other hand, if a thin lining paper is desired for an object, a roll papers may give roughly comparable handling properties with less bulk or thickness.

The tensile strength measurements were made on a constant rate of elongation apparatus (Instron) on samples of 15mm width. Tensile strength is defined as the maximum stress developed in a sample, when pulled on, before it ruptures. It is thought to indicate the behavior of paper when the sheet is under stress. Since tensile strengths are usually compared to sheets of similar thickness, the tensile test results have been grouped by thickness in the accompanying chart. Phil Rogers of the Archives Chemistry Lab ran the tensile test and Dr. Susan Lee-Bechtold assisted in interpretation and discussion of the data.

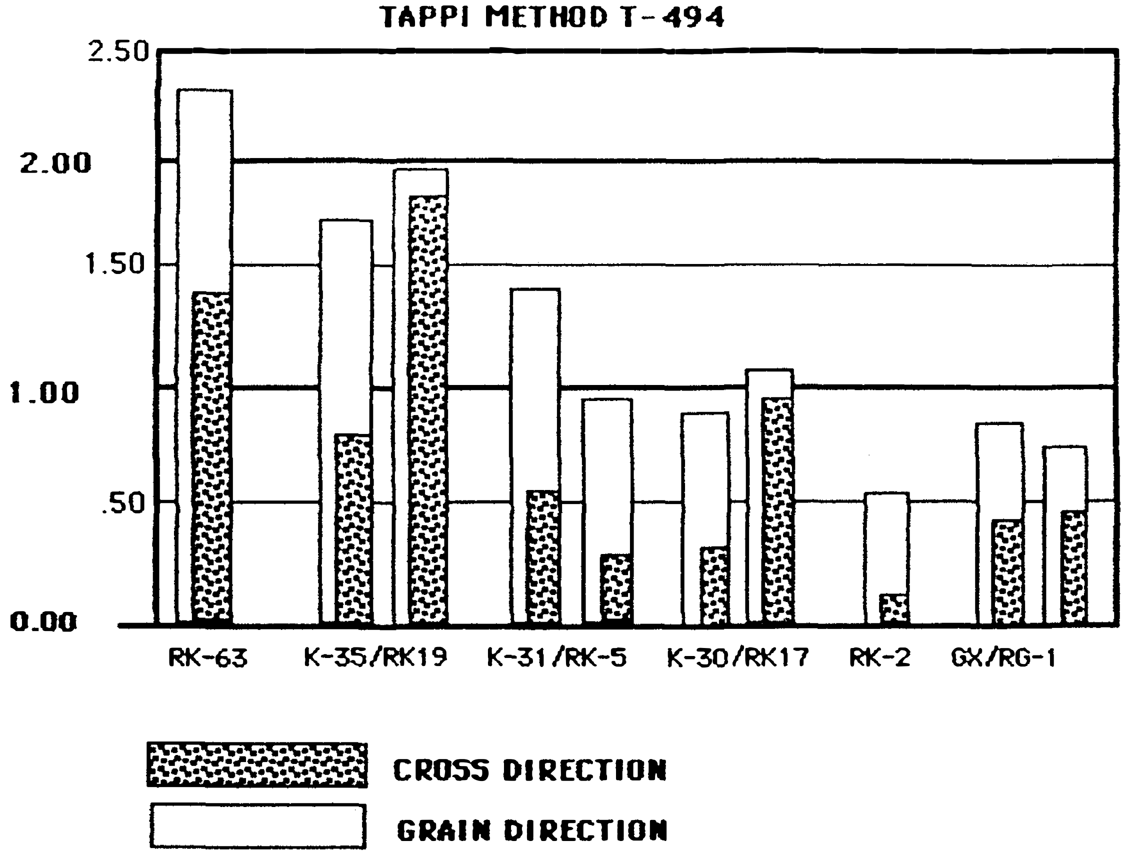
As mentioned above, we made our initial choice of papers subjectively, pairing machine and handmade papers that seemed similar from a conservator's viewpoint of thickness, suppleness, and opacity. Micrometer measurements however showed that the machine-made papers were thinner than the subjectively-chosen "match". The original pairs were K-30 and RK-2, K-31 and RK-5, K-35 and RK-17, K-63 and RK-19, GX and RG-1. To discuss tensile strength, it was necessary to regroup papers by measured thickness. The pairings discussed in terms of tensile strength therefore do not represent a match from the viewpoint of feel or handling qualities. We want to make this clarification in response to comments from Ms. Jesse Munn who has done some very interesting aging studies of Japanese machine-made papers.

TENSILE STRENGTHS
in kiloNewton/meter, TAPPI Method T-494 om-81

Paper Sample	Thickness (mm)	Machine Direction	σ^2	Cross Direction	σ^2
K-63	0.098	2.30	0.0104	1.38	0.0205
K-35	0.075	1.61	0.0182	0.72	0.0143
RK-19	0.077	1.99	0.0594	1.78	0.0053
K-31	0.055	1.35	0.0536	0.58	0.0456
RK-5	0.056	0.93	0.0045	0.23	0.0074
K-30	0.053	0.87	0.0042	0.25	0.0015
RK-17	0.052	1.06	0.0061	0.89	0.0055
RK-2	0.044	0.61	0.0038	0.12	0.0003
GX	0.028	0.82	0.0092	0.41	0.0136
RG-1	0.025	0.71	0.0318	0.45	0.0023

σ^2 = (standard deviation)^2

TENSILE STRENGTHS IN kiloNEWTONS/METER



HEAT SET TISSUE PREPARATION

Heat set tissue is prepared according to a modification of the Library of Congress Workshop Note, Series 300, May 1977. 1 part Rhoplex AC-73 and 1 part Rhoplex 234 is diluted with 1 part water. This mixture is further diluted with 1 part water. Working on a dark background to judge the evenness of the adhesive layer, the acrylic resin/water emulsion is brushed out on a polyester (mylar) film with wide Japanese hake brushes. Preparation of large sheets requires two conservators. Machine-made Japanese tissue is lightly brushed down onto the wet emulsion beginning at the right edge by using a hake brush similar to brushing down a lining. When dry, working with the prepared heat-set tissue face down, the polyester is pulled back at a sharp angle. Heat-set tissue is stored between sheets of silicone release polyester or silicone release paper.