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EFFECT OF FLAP-ADHESIVE PATTERNS ON END-LOAD BOX COMPRESSION

Project 1108-4

Report to

TECHNICAL COMMITTEE

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EFFECT OF FLAP-ADHESIVE PATTERNS ON END-LOAD BOX COMPRESSION

SUMMARY

The engineering studies have shown that end-to-end compression strength decreases markedly as the gap between inner flaps increases. The effective gap depends on adhesive coverage on the inner flap as well as box dimensions. The present study investigated the effect of varying adhesive coverage (area and location) on end-load strength. The primary results were as follows:

(a) When adhesive was applied all the way to the exposed edge of the inner flaps, the end-load box strength was 25.6% higher than for the standard manner of sealing (adhesive 1/2-inch from exposed edge).

(b) An increase in box strength of 30% occurred when a 1-1/2 inch adhesive-free zone was at the scoreline rather than at the exposed edge, showing the importance of location of adhesive.

The results stress the importance of full adhesive coverage on the inner flaps for maximum end-load strength.

INTRODUCTION

An analysis of end-to-end compression strength of RSC boxes has resulted in a preliminary formula relating box strength to combined board properties and box dimensions. Work currently in progress is directed to refinements in the theory with the intent of improving the accuracy of the formula to better than the 8-1/4% average experienced in the preliminary work.

The analysis of end-load compression has revealed a number of interesting and important aspects of box behavior which may be utilized directly or indirectly

in the design and manufacture of corrugated boxes. Among these are the dominant role of the flap panels, that is, the two panels which are comprised of flaps. These panels carry three to four times as much load as the side panels (for equivalent panel width), and moreover, are the critical panels in the sense that failure of the box is triggered by failure in the combined board of the outer flaps in the gap between inner flaps.

The gap between inner flaps is an important dimension. It has been shown that the end-load compression strength decreases markedly as the gap is increased. The gap is determined mainly by the outside dimensions in the case of an RSC box, being the difference between the length, L, and width, W, dimensions of the box. Thus, higher end-load strength is achieved by approaching a square perimeter box (length = width); in fact, a very marked increase in load occurs for a square perimeter box wherein the inner flaps abut.

It may be appreciated that the true gap is given by (L-W) only if the inner flaps are adhered to the outer flaps completely to the exposed edge of the inner flap. If the adhesive area extends only to within one inch of the exposed edge of each inner flap, for example, the effective gap may be somewhat greater than the apparent gap, (L-W)--possibly by as much as two inches.

An exploratory study was carried out to study the effect of adhesive patterns (from the standpoint of gap) on the end-load compression strength of an RSC box.

TEST PROCEDURE

Twenty-five boxes of C-flute, 200-lb. series construction, having dimensions 16x12x11 inches, were randomized and divided into five groups of five each.

A silicate adhesive was used to seal the boxes. It was applied to within one-half inch of each edge of the inner flaps, in accord with standard laboratory practice, except for the exposed edge of the inner flap. The distance from the exposed edge to the adhesive boundary was varied to give four degrees (A through D) of "effective gap", as outlined below and illustrated at the bottom of Table I. A fifth pattern of adhesive coverage (E) was also studied, as described later.

Condition	Boundary of Adhesive Coverage
A	Exposed edge
B	One-half inch from exposed edge. (Standard laboratory practice)
C	1-1/2 inches from exposed edge
D	4 inches from exposed edge
E	1-1/2 inches from scoreline

It may be seen that Conditions A through D represent four progressively increasing effective gaps, inasmuch as the adhesive boundary recedes progressively from zero to 4 inches from the exposed edge of the inner flaps. Condition E has adhesive all the way out to the exposed edge but a 1-1/2-inch zone at the score-line was free of adhesive.

DISCUSSION OF RESULTS

The end-load compression strength of each box is given in Table I for the several degrees of adhesive coverage, along with the average, the per cent difference from the standard condition (B), and a sketch of the adhesive area immediately below each column of data.

It may be seen that, on the average, end-load strength decreased as the adhesive boundary receded from the exposed edge of the inner flap, that is, as the effective gap between inner flaps increased. The loads decreased from 789 lb. to 492 lb. over the range of Conditions A to D.

Relative to the standard laboratory box (B), the box with minimum coverage (D) supported 21.7% less compression load. At the other extreme, extending the adhesive all the way out to the exposed edges of the inner flaps (A) increased the box load by 25.6% relative to the standard case where 1/2-inch of adhesive-free flap is left at the exposed edge.

Statistical analysis reveals that each of Conditions A, C and D differs significantly from the standard Condition B. Moreover, the 95% confidence limits for the effect of adhesive all the way to the exposed edge indicate an increase of no less than 100 lb. over the standard laboratory sealing practice (B); this is an increase, therefore, of at least 16%.

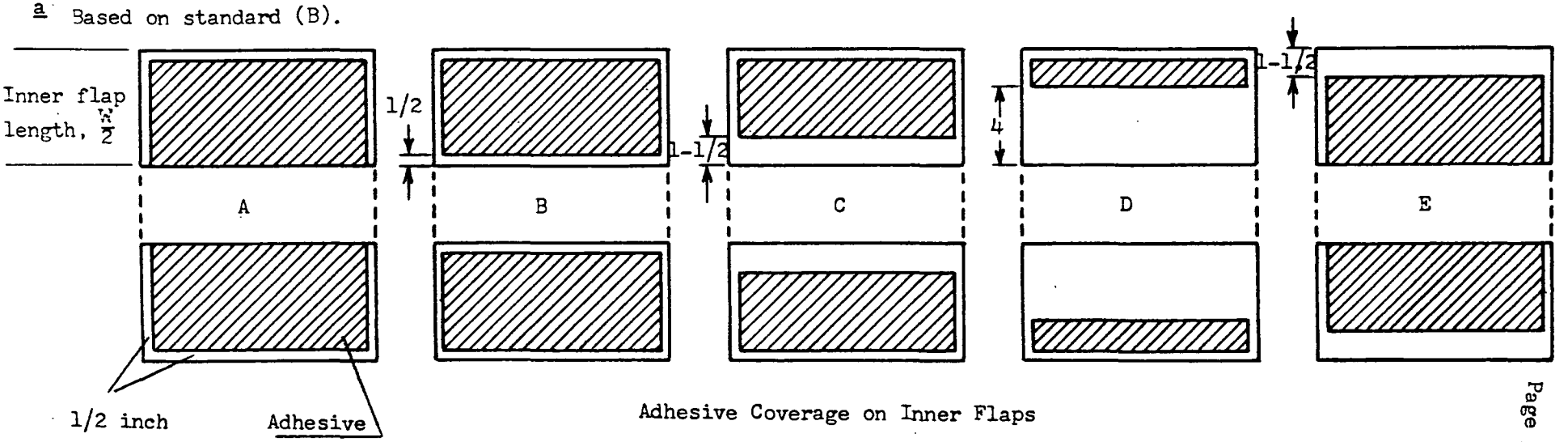
These results indicate that the important factor of flap gap depends on the adhesive coverage and pattern between inner and outer flaps as well as the external dimensions L and W of an RSC box. While the extreme variations in adhesive patterns such as were studied in Conditions A through D would not ordinarily be

TABLE I

END-LOAD COMPRESSION WITH VARYING FLAP-ADHESIVE COVERAGE

Spec. No.	Coverage	Compression Load, lb. A	B	C	D	E
1		758	571	624	469	696
2		817	651	458	458	749
3		850	578	565	537	708
4		733	637	580	475	706
5		789	702	504	523	689
Av.		789	628	546	492	710
Diff., %[a]		+25.6	-	-13.1	-21.7	+13.1

[a] Based on standard (B).



Adhesive Coverage on Inner Flaps

done purposely in case sealing operations, it may be appreciated that spotty or inadequate adhesion between flaps could very well cause comparable effects.

To illustrate that the effects described above are not solely a result of the amount of adhesive area, Condition C may be compared with the fifth condition studied, namely, E. In this latter case the adhesive boundary was placed 1-1/2 inches from the scoreline and extended all the way to the exposed edge. There is approximately the same adhesive area in both C and E (actually the area of E is about 12% greater than that of C), but the load sustained by the E boxes was 710 lb. as compared with 546 lb. for C, a difference of +30% reflecting the smaller gap of the E boxes. Moreover, the strength of the E boxes exceeded that of the B boxes (standard) by 13.1% (a significant difference), revealing that the reduction in gap afforded by the E boxes more than offset the sacrifice of adhesion area at the scoreline. This result may be taken to mean that adhesion adjacent to the gap is of greater importance than adhesion near the scoreline. However, it cannot be said that end-load depends only on adhesive location irrespective of area; comparison of Conditions A and E reveals that the subtraction of 12 square inches of adhesive near the scoreline of E accounted for a 10% reduction in end-load.

The results of this experiment emphasize that care should be taken on the sealing line to achieve complete adhesion of the inner flaps to the outer flaps. In this way the potential end-load compression strength of the box can be realized. This may be of considerable importance to the manufacturers and users of boxes fabricated with Fourdrinier liners because, as is well known, these boxes possess inherently less end-load strength than their counterparts fabricated with cylinder liners.