A Link Between Light-Weights and ECT Strength

Michael Schaepe and Roman E. Popil
Institute of Paper Science and Technology

Research conducted by Bill Whitsitt of Institute of Paper Chemistry (IPC) (ECT/Component Relationships, Report to the Fourdrinier Kraft Board Group, February, 1983) explored the connection between ring crush and ECT.

THE ANALYSIS WHITSITT PERFORMED INDICATED THAT A NON-LINEAR RELATIONSHIP EXISTED. He fit two straight lines to the data and developed separate equations for the prediction of ECT from ring crush, one for light weight boards (1) and one for heavy weight boards (2). Lightweight boards are constructed with linerboard less than 42 lb/msf and heavy weight boards are constructed with linerboard 42 lb/msf and above.

(1) $ECT = 0.8 * (Lin_1 + Lin_2 + a\ Med) + 12$

(2) $ECT = 1.27 * (Lin_1 + Lin_2 + a\ Med) - 6$

Where: Lin_1 and Lin_2 are the ring crush values for the linerboards (lbf/in)
Med is the ring crush value for the medium (lbf/in)
a is the take-up factor.

This relationship is shown in **Figure 1**.

Recent work lead by Roman Popil at the Institute of Paper Science and Technology has investigated the influence of linerboard bending stiffness and interflute buckling on ECT performance. Reviewing data generated in previous reports produced at IPC/IPST and especially those of Chuck Habeger and Doug Coffin, it was shown that the relationship between ECT and basis weight was weak, (**fig. 2**) that STFI was a much better predictor of ECT, (**fig. 3**) and that ring crush had a slightly higher correlation to ECT than STFI (**fig. 4**). Best, however, was STFI in combination with bending stiffness by applying equation (3) for predicting ECT:

(3) $ECT = C3\ (2SL + \alpha S_M)^b\ (BS/\ b_f^2)^{1-b}$

Where: S_L is STFI for the linerboards
S_M is the STFI for the medium
C_3 and b are constants
BS is bending stiffness
b_f is flute spacing
α is the take-up factor

This last relationship is shown in **Figure 5**.

It is understood that the ring crush test is a combination of compression and bending deformation as illustrated in the Handbook of Physical and Mechanical Testing of Paper and Paperboard by Johnson, et al., and that STFI more closely represents the true compressive strength of linerboard. In Quantifying the Relationship Between the Short Span Compression and Ring Crush Tests, G.R. Rennie found that SCT (STFI) = RCT (ring crush) + $0.005T/t^2$, where T is Taber Stiffness and t is apparent thickness.

Light weight linerboards have relatively low bending stiffness and this translates to low combined-board flexural stiffness. Furthermore, the critical buckling load for a vertically loaded plate (linerboard) is proportional to the geometric mean of flexural rigidity (typically represented by bending stiffness) divided by flute

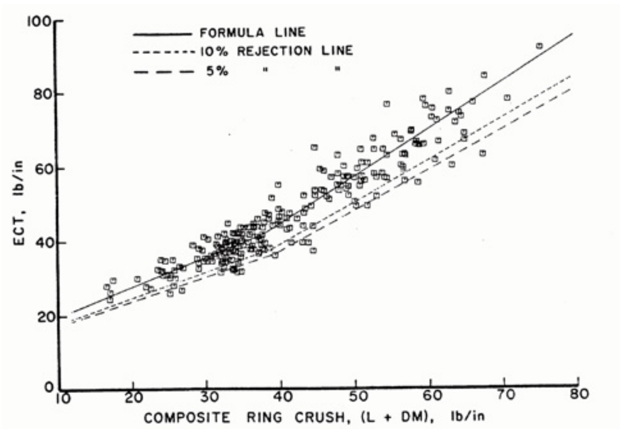

Figure 1: Whitsitt Relationship of ECT to Composite Ring Crush.

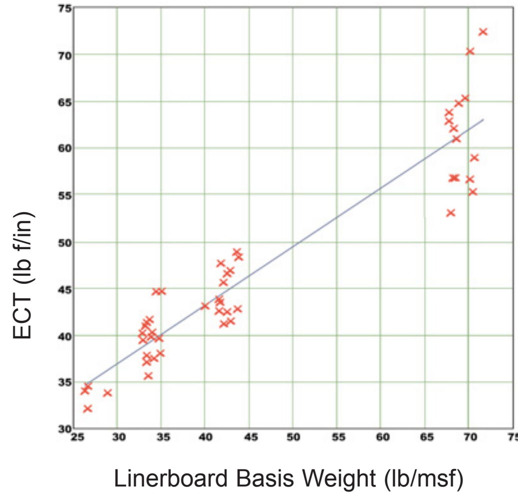

Figure 2) ECT vs Basis Weight

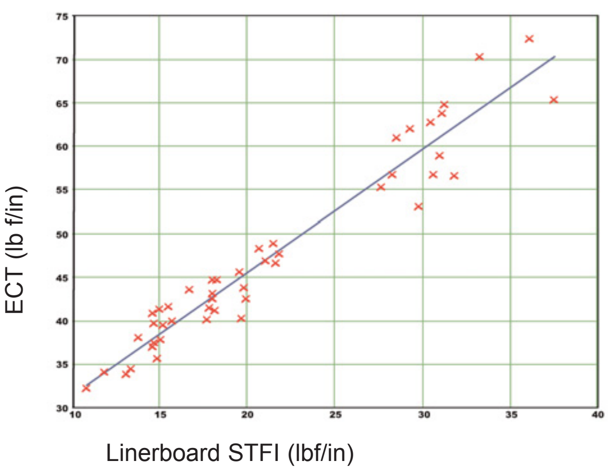

Figure 3) ECT vs STFI

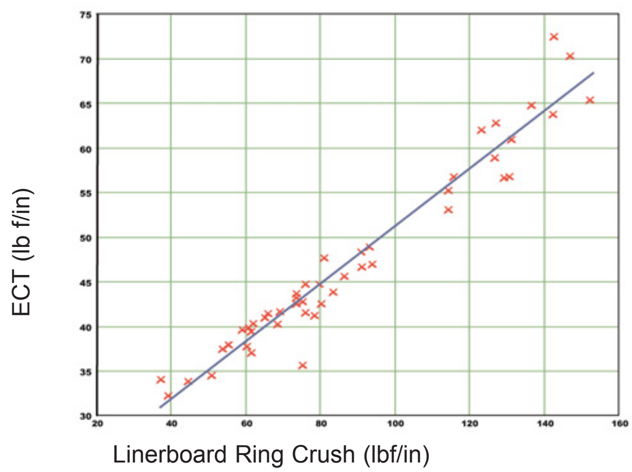

Figure 4) ECT vs Ring Crush

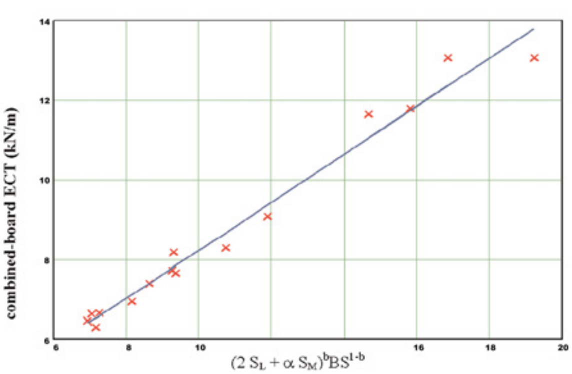

Figure 5) ECT vs STFI with Bending Stiffness

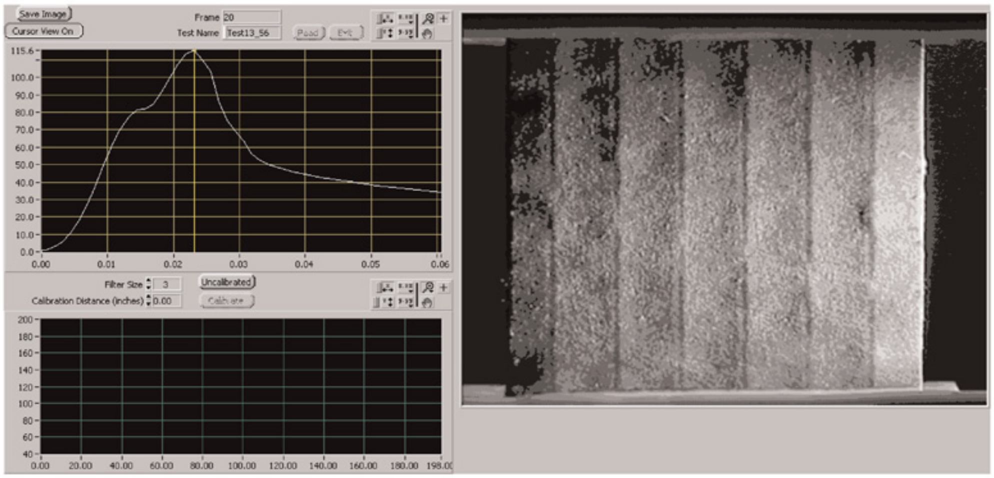

Figure 6) Negligible interflute buckling with 56-26-56 combined-board. Load displacement curve with the cursor corresponding to the photograph is shown on the left.

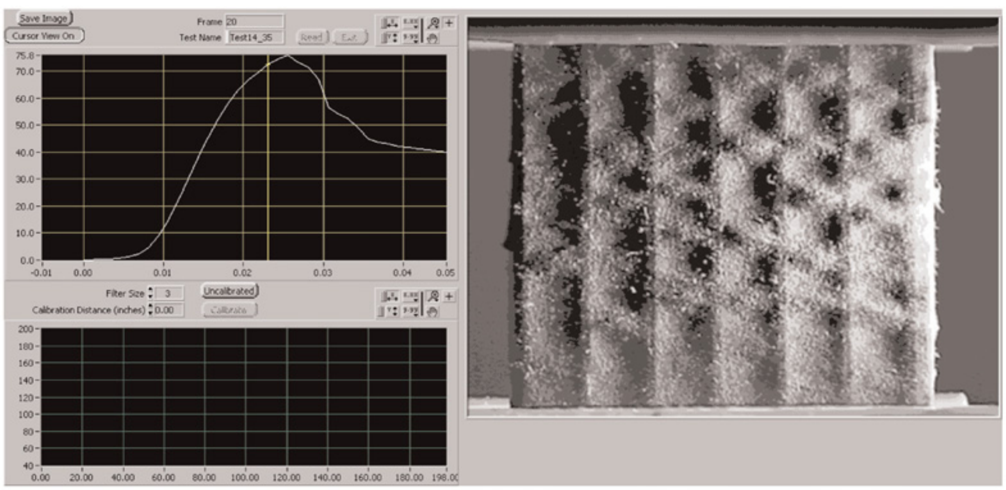

Figure 7) Considerable inter-flute buckling with 35-26-35 combined-board.
Load displacement curve with the cursor corresponding to the photograph is shown on the left.

spacing squared as shown in the following equation:

(4)

$$P_{cr} \cong \frac{4\pi^2 \sqrt{D_{MD} D_{CD}}}{b_f^2}$$

Where: P_{cr} is the linerboard critical buckling load
$(D_{MD}D_{CD})^{0.5}$ is the geometric mean of flexural rigidity (bending stiffness)
b_f is flute spacing

When STFI exceeds the critical buckling load of the linerboard, interflute buckling will occur and ECT will be adversely affected. This effect can be seen in the next two figures. **Figure 6** is a 56-26-56 combination with negligible interflute buckling observed. However, interflute buckling is clearly present in **figure 7** when the combination is 35-26-35. The result of interflute buckling in figure 7 results in a lower ECT than predicted from summing compressive strengths of combined board components.

The dual curves Whitsitt generated over two decades ago for the prediction of ECT from ring crush are the direct result of low bending stiffness and an increased tendency of interflute buckling prevalent with lightweight linerboards. Since Whitsitt completed his work, high ring crush linerboards have become common. The increase in vertical compression strength per unit weight has been achieved primarily through wet pressing. This has resulted in increased densification but lower bending stiffness with the outcome being a greater proclivity of interflute buckling with today's lightweight linerboards. **CI**