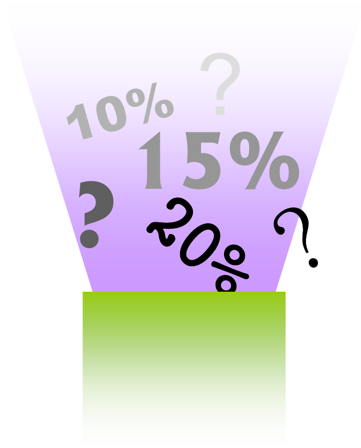
XQ innovations



Choosing the wrong quality measure can be **damaging**.

Retained quality in the box plant is sometimes hard to discern. Historically, board thickness or board caliper has been used to test whether unwanted crushing has occurred during manufacture. In recent times a new type of damage measurement is showing more value.

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In recent years it has become clearer that damage to corrugated board during manufacture and subsequent conversion can lower the designed box strength by up to 50% by the time the box leaves the plant. There is an industry observation that runs something like:

> **“If boxes are failing in the field look at the level of crushing in the plant – if no failures are occurring in the field then the box is over specified by up to 30%.”**

Why should this be the case when many plants are aware of the damaging effect of crushing during manufacture, printing and conversion and actively look for losses in board thickness to identify damaging levels of crushing? Many corrugated manufacturers have spent big money on off-line and continuous on-line measurement of board thickness in an effort to lift their board quality to an acceptable level.

Exhibit 1 may shed some light on this dilemma. It shows the effect on board thickness of various levels of crushing for a a utility corrugated C-flute board grade. After 0.5 mm crushing (nearly 15% of the undamaged board thickness), the change in board thickness measurement is only 1.4% - barely measurable by the usual dead weighted thickness laboratory tests employed. If the plant has gone high-tech, and installed non-contact laser based thickness measurement, the lack of sensitivity of thickness measurement to crushing levels is expected to be an even greater disappointment. Many years of experience now tell us that by the time the plant can reliably measure a significant change in thickness and identify process damage the board may have lost up to 30% of its design strength.

Fortunately, a more sensitive measure of medium damage has been developed – the md shear stiffness of the board. XQi have developed a portable and fast device that non-destructively measures the shear stiffness of corrugated board. Exhibit 1 also shows the sensitivity of the XQi device compared to the usual thickness measurements. It is clear that the onset of damage is more easily identified using the shear stiffness measure. This has the advantage of allowing fast and unambiguous identification of damage in the board at the various process stages in the plant.

The importance of measuring medium damage due to crushing is not a new idea in the corrugating plant. In 1985, Bick presented a practical look at the potential impact poor control of process could have on performance and cost.

EXHIBIT 1

Board thickness is not a sensitive measure of board damage

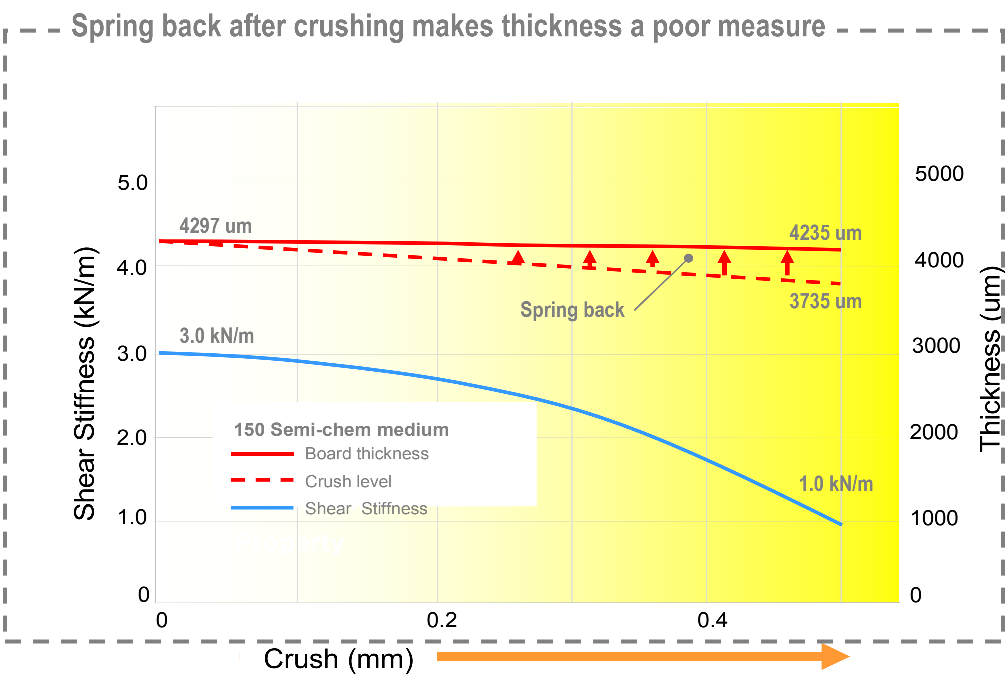
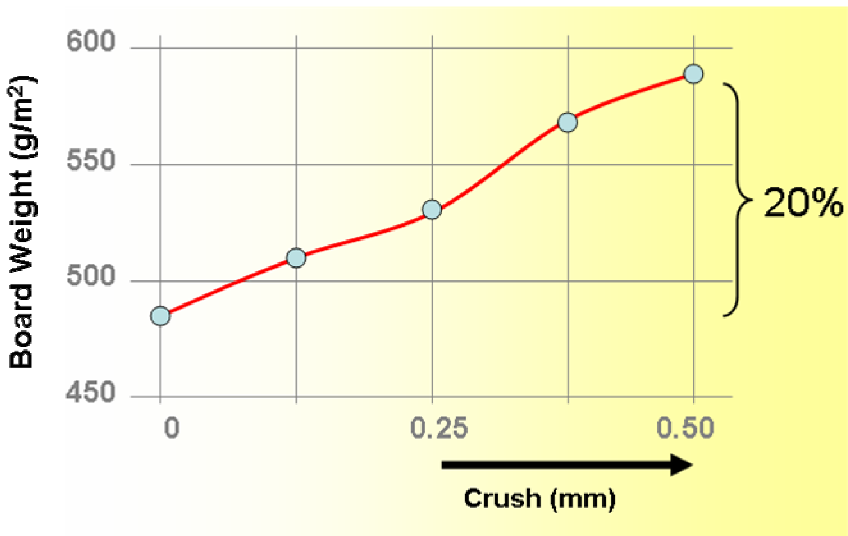


Exhibit 2 shows some of the results from Bick's work. In it he details the effect crushing has on box performance and calculates the additional board weight requirement needed to make up for the lower box performance.

EXHIBIT 2



Let's look at what happens when we try to crush board by putting it through a nip smaller than the pristine board caliper. Such an opportunity occurs routinely in the feed section of flexo folder-gluers, the machine an RSC is most likely to run on.

What happens in the box plant?

A skilled flexo operator can set up standard steel/urethane feed rolls so that blanks will go through this nip with little or no crush.

One procedure is to take an undamaged piece of corrugated board about 6" wide and use it as a feeler gauge. Open the nip, then close it to the point that the nip just barely grips the board. Lock in the nip setting for that run.

The feed rolls must not be worn or unparallel. And the board used as a feeler gauge must be close in caliper to the whole lot. If one of these ingredients is missing, blanks may slip or feed crooked, resulting in jam ups, out-of-square boxes, or registration problems.

The operator's solution to jam ups is to crank down on the nip and crush the board. Experience will tell us that 0.20 mm to 0.30 mm feed roll crush, when measured is not uncommon.

Absence of nip crush at the beginning of the flexo folder-gluer operation can be critical. It sets the stage for how much more crush damage will result.

V.H. Staigle found that "two pass" controlled crush through the same nip caused more permanent loss of board thickness than did a "one-pass" controlled crush. With one pass, the permanent loss of caliper was 0.075 mm, on average. With two passes, the permanent loss was 0.15 mm. This is another way of saying that the less crushed a board arrives into a nip the less overall crushing is experienced by the board. This provides strong incentive for maintaining resistance to crush and controlling crush levels from the corrugator and through subsequent conversion processes.

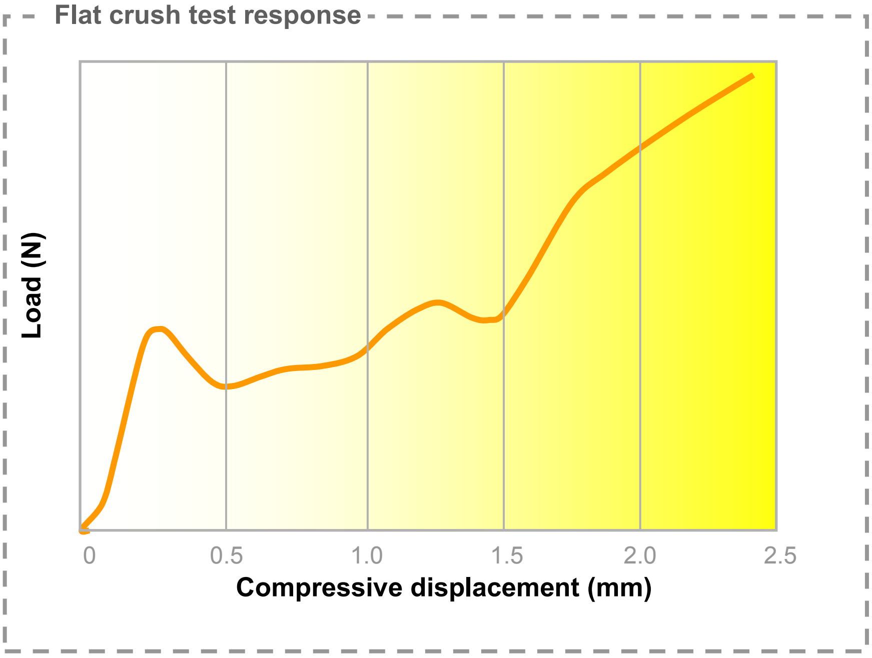
Crush is difficult to measure and commonly understated.

As long as the elastic limit has not been exceeded, flutes spring back to their original thickness. However, compression losses do occur.

C J Crisp et al (working for APM in Australia) studied the effect of nip crush on various properties of corrugated board. Later L. Nordman et al took up this same subject. In both studies, the researchers ran flat crush tests on uncrushed corrugated board using instrumentation, which would give them stress/strain curves. These curves indicate that board can be compressed somewhere between 0.15 mm to 0.25 mm and still be in the elastic region. (See Exhibit 3). As long as the elastic limit has not been exceeded, the compressed flutes should spring back to their original thickness.

EXHIBIT 3

Flat crush response showing initial elastic displacement (< 250 um)



One would expect from these results that board could be passed through a nip that is less than 0.15 mm less than the thickness of the board without measurable change in the board's physical properties. But this is not the case. Nordman reported that when the C flute board was passed through a nip 0.20 mm less than the original board thickness, losses in box compression and other properties resulted. Crisp reported similar results when putting C-flute board through a negative 0.15mm nip. Nordman further suggests that, during box fabrication, pre-compression of the board that was 20 to 25 percent of the original thickness is not uncommon. This amounts to pre-compression numbers between 0.75 mm and 1.0 mm for C-flute board.

It took considerable nip crush to change measured board thickness by a small amount. Crisp found that putting C flute board through a nip 0.83 mm less than the board caliper resulted in approximately a 0.125 mm loss of caliper after crushing, as measured by a micrometer with a foot pressure of 8 psi.

TAPPI method T-411-om-84 calls for pressure of 7.3 psi or 50 kPa. It is clear from work already undertaken by various workers that 50 kPa is not sufficient pressure to overcome the spring back of crushed corrugated board. Moreover, it is shown that thickness is generally misleading, or at best, a very blunt measure of the potential loss in board performance due to crushing.

The economic impact

The other side of the coin is that, if one can eliminated crush, one can reduce costs and still satisfy the box compression and warehouse stacking needs of the box user. Table 1 puts some actual numbers on these cost/[performance relationships.

Although paper prices are a moving target we picked $900[1]/t for our calculations. Prices may change but the savings, percentage wise, won't change much.

What impact could this business of crush have on the overall profits of a typical box plant? Let's develop a couple of scenarios using crush levels of 0.064 mm, 0.125 mm and 0.25 mm which seem to be conservative given our practical experience with commercial corrugated product.

A mix of operation which is 50% compression sensitive, with 1 and 2 shifts at an average speed of 150 m/min and 2.4 meter wide corrugator and 2 shift operation with an average speed of 200 m/min. Table 2 demonstrates the high cost of crush in three plant scenarios.

Crush can cost in other ways. For example the RSC that was crushed in the feed nip so it wouldn't jam the flexo may not set up properly as it goes through the customer's packaging line, causing a jam up there. This can happen if a crushed box panel has lost too much of its inherent stiffness, thereby breaking somewhere besides the score line when the automatic case packer tries to open it up.

In the manufacturing operation, having to increase the weight of board means that removal of moisture (from adhesive addition) becomes harder with the result that the corrugator production rate drops. Most corrugators are specified for a tonnage/hr output. For this reason, decreasing the weight of the board components will allow greater areas of board to be produced in the same time.

Customers will tolerate only so much of this before a truckload of boxes is rejected, or the entire account is lost. This is much more prevalent outside Australasia where competition is more varied in supply. A significant loss in profits from a truckload in in the order of $20,000 to $25,000 of which only around $50/tonne can be recovered as recycled fibre.. The value of a satisfied customer and a reputation for high quality boxes is certainly substantial, but less easily calculated.

[1] South East Asian spot market ranges from 900 to 1000 $/tonne for Kraft 'and $700 to $900 $/tonne for recycled paper components

Table I

Board Crush (mm)	Box Comp Loss (%)	Box (a) Comp Req'd (N)	Board (b) Weight (g/m^2)	Paper Costs ($\$/1000m^2$)	Cost of Nip Crush ($\$/1000m^2$)	Increase in paper Costs (%)
0	0	3559	592	533	0	0.0
0.063525	2.5	3652	608	547	14	2.6
0.12705	5	3745	619	557	24	4.5
0.2541	10	3954	648	583	50	9.4
0.38115	15	4186	688	620	87	16.2
0.5082	18	4337	713	642	109	20.4

Table 2

	SCENARIOS		
	Plant 1	**Plant 2**	**Plant 3**
Total production (SQM/month)	3,600,000	7,200,000	9,600,000
No of shifts (2000 hr/yr per shift)	1	2	2
Average speed (m/min)	150	150	200
% Compression business (C flute)	50	50	50
Production compression sensitive (SQM/yr)	21,600,000	43,200,000	57,600,000
Potential Savings ($/yr)			
Crush level A: 0.064 mm	$303,741	$607,482	$809,976
Crush level B: 0.127 mm	$512,563	$1,025,126	$1,366,835
Crush level C: 0.254 mm	$1,082,078	$2,164,155	$2,885,541