



## Understanding **quality** can be a surprise package

Many businesses see quality as a cost and a nuisance but, with the right technology, understanding quality can improve customer relationships, strengthen markets and save money.

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For many businesses quality measurement and control can have associations with profits being burnt at a high rate. But quality is an essential part of any successful and sustainable business. For the corrugated industry quality means both absolute performance in a chosen application and consistency of performance over time. For boxes that have a stacking requirement the box strength is an important consideration. Most box manufacturing companies have in-house or favoured design tools that allow box strength to be estimated from the component strengths and weights. Often these design tools are based on the well tried and proven McKee equation:

$$BCT = ECT^{0.75} (D_x D_y)^{0.25} Z^{0.5}$$

In this equation, the Edge Crush Test (ECT) and the flexural rigidity of the board ( $D_x$  and  $D_y$  for the panel) are integrated with the box perimeter,  $Z$ , to give an estimate of the box strength. The McKee equation works remarkably well and has stood the test of time. Part of the flexural rigidity of the box panel comes from the resistance of the medium to change its shape when the box is loaded and the vertical panels start to bulge. This property of the medium is called the lateral, machine or making direction shear stiffness.

A limitation of the McKee equation is that it assumes that component strengths and structural integrity (medium damage) remain negligible (or if not negligible constant). Is this the case? And if not how important is medium damage to the performance of the box?

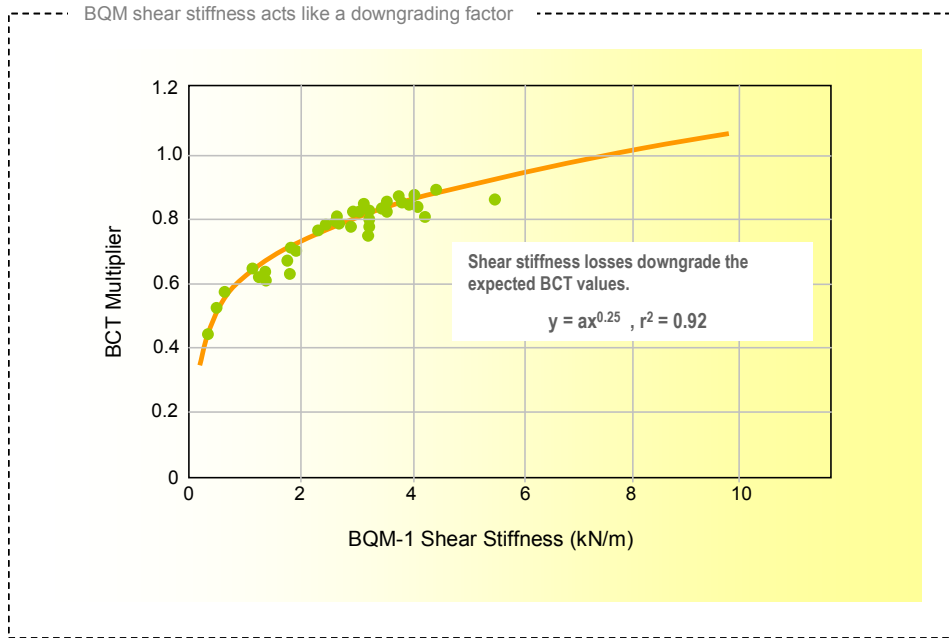
The XQ innovations BQM unit non-destructively measures the shear stiffness of the medium independently of liner effects. Shear stiffness is very sensitive to medium damage and has the effect of lowering the flexural rigidity component of the McKee equation. It lowers BCT by degrading the flexural rigidity term to the power of 0.25 – the same proportionality as the flexural rigidity in the McKee equation.

Based on this theoretical background and measurements taken at XQi using the BQM instrument, Exhibit 1 shows the loss in estimated BCT as the shear stiffness is degraded through damage. The plot shows the loss factor that should be applied to expected board performance (equivalent to loss in a standard box strength) as damage lowers the shear stiffness of the medium. It is possible to lower box strength by up to 50% below design expectations due to high levels of board crushing.

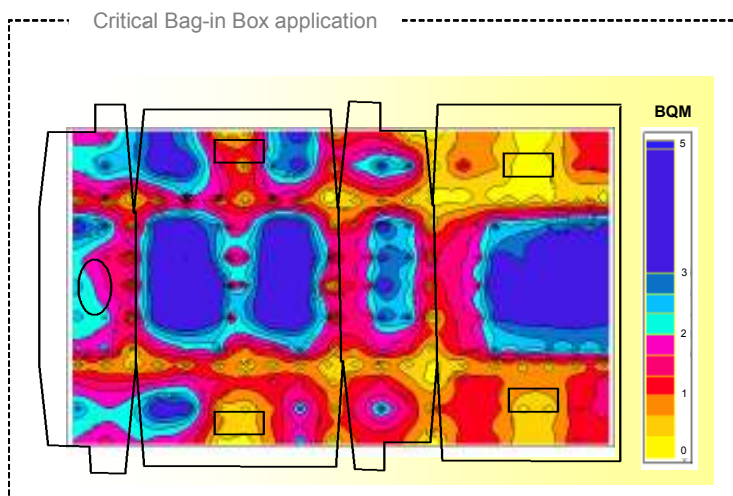
Above medium md shear stiffness values of 3.3 kN/m, losses in BCT appear lessened – and this level remains a suitable specification for most stacking grades in the box plant.

## EXHIBIT 1

### Shear stiffness can lower expected BCT by up to 50%.



Using the BQM-1 it is possible to characterise medium damage in box blanks and knocked-down boxes in great detail. XQi have undertaken this type of work for many box end-users and have amassed a significant data base of run-of-mill box quality. Exhibit 2 gives an example of a bag in box application where it was critical that performance consistency was maintained. Exhibit 2 shows a damage mapping formed by taking BQM shear stiffness readings at 50 mm distances across the area of the box.

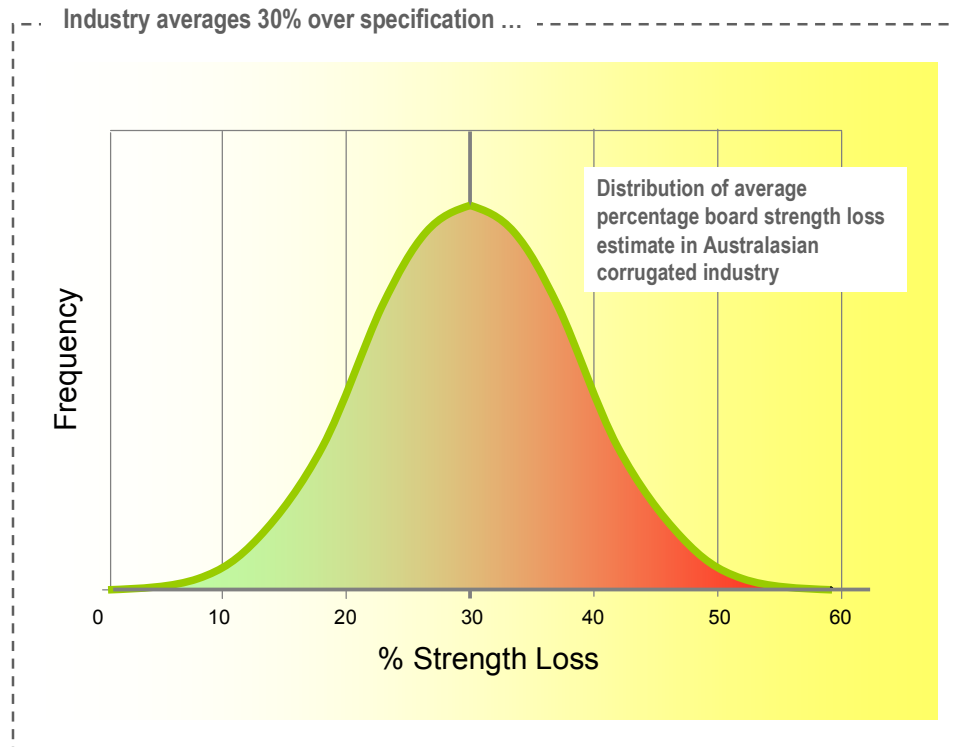


In Exhibit 2, colours represent the level of damage attracted in each region of the box. In this case hot colours (yellow and red) represent areas of high damage and cool colours (greens and blues) represent areas of lesser damage. For this box much of the area has been significantly damaged as reflected by lower shear stiffness values.

Using the relationship in Exhibit 1 it is possible to convert these damage values to localised strength retention values.

## EXHIBIT 3

### Box strength loss due to lateral shear stiffness loss in the box plant

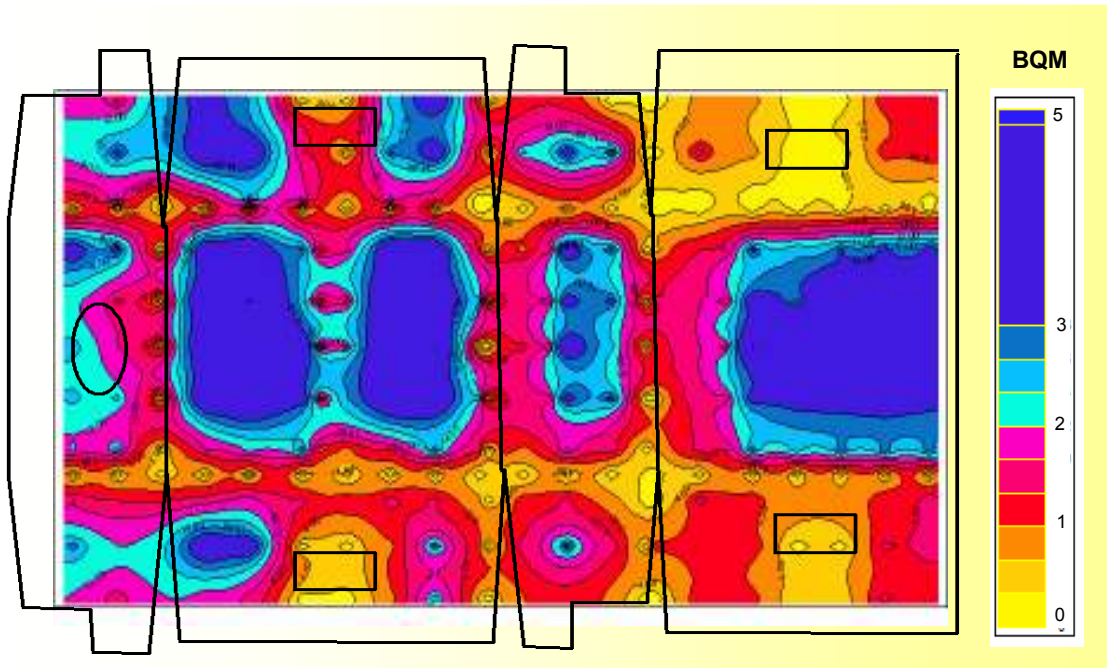


Is the damage to the box shown in Exhibit 2 common? XQi have tested a large number of different box designs from various manufacturers and the results are presented in Exhibit 3.

Exhibit 3 shows the frequency distribution of board quality in terms of lost strength estimated from medium shear stiffness for a range of box designs, manufacturers and end-use applications that have been tested by XQi over the last few years. Losses were calculated as the difference between the best shear stiffness result obtained on a tested knock-down box and individual measurements across the area of the same box. Values are considered to be conservative estimates of real medium shear stiffness loss and so conservative estimates of box strength loss.

As Exhibit 3 shows, performance of corrugated board produced by the industry is very variable and uncontrolled. To a first approximation performance loss judged as BCT can be approximated directly to weight in the box. The results suggest that, on average, boxes are 30% over specified in weight (and therefore in cost). Some samples tested are under performing by up to 50% and it is likely that specifications set on historical experience push the over specification of corrugated boxes to even greater levels. Moreover, as the reported values making up the distribution plot are average values for the box (ignoring obvious low value features like creases and cut-outs), there are areas on these boxes which show much greater damage than reported in Exhibit 3.

Critical Bag-in-Box application



BQM shear stiffness acts like a downgrading factor

