Quality Control Based On Internal Bond

- Designing the "Bond-o-Matic"

Stephen Young

TimberTest, New Zealand

Keywords: Internal Bond, Quality Control, Bond-o-Matic, Wood-based Panels

ABSTRACT

Internal Bond strength is a primary quality control test for MDF manufacturers. In this investigation, LabCheck trials were used to examine the differences in assessment of internal bond between laboratories. A second trial investigated differences between four operators within one site. After first producing a definition for the "correct" internal bond, the "Bond-o-Matic" was developed. The Bond-o-Matic will enable faster, more accurate and standardised quality control in the factory, independent of the operator doing the test. Better data will in turn reduce resin use and lower production costs.

INTRODUCTION

The process of quality control involves repeating three steps;

measurement
↓
comparison with
control limits
↓
adjustment

The above quality control (QC) process relies totally on good quality data. Poor data will lead to bad decisions and erroneous adjustments, and, ultimately, move the production process in the wrong direction.

In an MDF plant a primary QC test is the internal bond strength (IB). Studies carried out by TimberTest indicate that there are differences within and between laboratories for this test, and discussions with technical managers suggest that there are large savings to be made if the test is improved. Additionally most managers thought investment in better systems was justified and needed. To meet the desire for better test data, TimberTest has developed a new IB instrument (the "Bond-o-Matic"). This instrument produces faster and more uniform IB results. During the development of the Bond-o-Matic a number of hurdles had to be overcome.

In an ideal world test instruments would be developed progressively. The project would start when the opportunity to make a better test system is discovered. A cost analysis would be carried out with an estimate of the technical work required to investigate the issue and for building a range of prototypes. The prototype design must enable manufacture to match the projected sale price - an estimate of which is based on the projected benefits. Based on these *guess*-timates the technical team can then carry out trials, build a prototype and finally put the machine into production and onto the market.

The actual process is often not so systematic. In the case of the Bond-o-Matic, trials were started ten years ago when it was first observed that there were large differences within and between laboratories for the internal bond test. However the project was delayed since there was initially no obvious instrument design which would solve all the issues within an acceptable cost. Hence there have been many years of trying ideas and filling the “back shed” with rejected prototypes.

Inevitably, progress was affected by several difficulties, a major one being that of defining the “correct results”. Since there is very poor reproducibility between laboratories and every technical manager interviewed believed that his methods produced the correct result, it was hard to determine when results from prospective designs were good. This is complicated by the desire of all technical managers to achieve high values as quickly as possible, so often the systems observed within factories and research laboratories were biased toward methods which maximise the internal bond values and minimised the waiting time. Deviations from the international standard were universally accepted since, in the case of QC, large numbers of test values are needed with short delay times and the international methods normally require reconditioning after gluing.

Another constraint was the need to comply with international standards. From the beginning all the experimentation revolved around the development of an instrument for IB testing which was repeatable, minimised variability and allowed compliance with the international standards. Compliance with the international standards would make acceptance of the new instrument faster than if the method relied on regression to produce standard IB.

Part way through the process of instrument development, world events influenced the direction of the project. Initially the instrument design was aimed at providing a machine to be marketed at a similar price to the universal testing machines commonly used in factories. However this budget did not stretch to the design of a machine which significantly reduced the waiting time for results and also the simple instruments designed could not control every variable. The increasing focus on energy and carbon conservation over the past years provides pressure to reduce resin use – which implies tighter production control at the factory. This issue offered the justification of an increased estimate of the maximum sales price and allowed a more sophisticated instrument to be developed. Consideration was also given to the energy budget for the instrument itself and the instrument was designed to use the minimum energy. Another factor affecting the project budget was the move to low emission products – this has led to development of a range of bio-based and low emission formaldehyde based resins. A quicker and more reliable assessment of mechanical properties is an advantage for research and technical development of these newer resins.

EXPERIMENTAL

Objectives

1. To develop a method for assessment of prototypes and define "correct" result.

2. To assess the differences between laboratories.

3. To assess differences within a single laboratory.

4. To observe testing on a number of factory sites and list differences.

5. To design an instrument which;
   - complies with and gives the same values as international standard methods
   - minimises the reconditioning phase after gluing
   - shortens the time taken to prepare the test samples
   - has a low energy use

Methodology

1. Method for Assessment of Prototypes

Before prototype testing could begin, a system for assessing the prototype had to be developed. To rank the prototypes, internal bond was plotted against density. The highest R^2 was assumed to indicate the prototype with minimum variability introduced by the testing process. The machine was developed to minimise variability not related to the panel product itself and this was defined as the "true" bond strength. Additionally the results were compared with the standard methods, which involved reconditioning the panel after gluing.

2. Assessment of differences between laboratories

The past 10 years of LabCheck results were examined to assess the difference between laboratories for two sample types. The results for 18mm MDF, and 12 mm particle-board were used for this study.

3. Assessment of differences within laboratories

Three sets of MDF samples were cut and randomised and tested by four technicians at one site. Each technician tested 50 samples of each type.

4. Observation of testing at a number of sites

A number of research and factory sites were visited and the differences in technique and equipment were listed. This process included laboratories in South East Asia, Japan, Germany, Norway, Sweden, UK and Australia and New Zealand. From this a list of differences that potentially affect the results was produced. Because of the number of possible inter-relationships between these factors they were not rated in any manner.

5. Design and construction of a test instrument for IB determination

A number of instruments were built and then tested at the TimberTest laboratory and on factory sites.

RESULTS AND DISCUSSION

1. Assessment of Prototypes

The method used for assessment of results from prototypes was to plot IB results against density; the larger the R^2 the lower the test variability. This method removed the tendency to aim for high results and instead focused on minimising variability caused by factors within the test procedure.

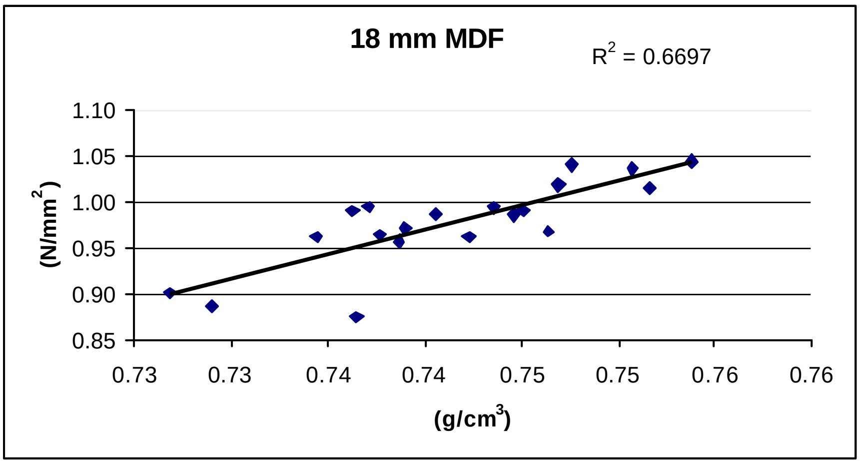

Figure 1. Assessment of internal bond by internal bond against density

Figure 1 shows an example of the assessment of a particular internal bond prototype. In this case a single board of 18mm MDF was cut into test samples. Each test-piece was measured and weighed for calculation of density. The internal bond was plotted against density and the test system assessed based on the R^2 value. The objective of assessment was to minimise the density effect, which can result in high coefficient of deviation.

2. Assessing difference between laboratories using analysis of LabCheck

LabCheck results over the past ten years were examined to assess the differences between laboratories. The following examples are plots from two LabCheck trials, one on MDF and the other on particleboard. These show a wide range of values from different laboratories carrying out tests on a randomised sample sent pre-cut to each laboratory.

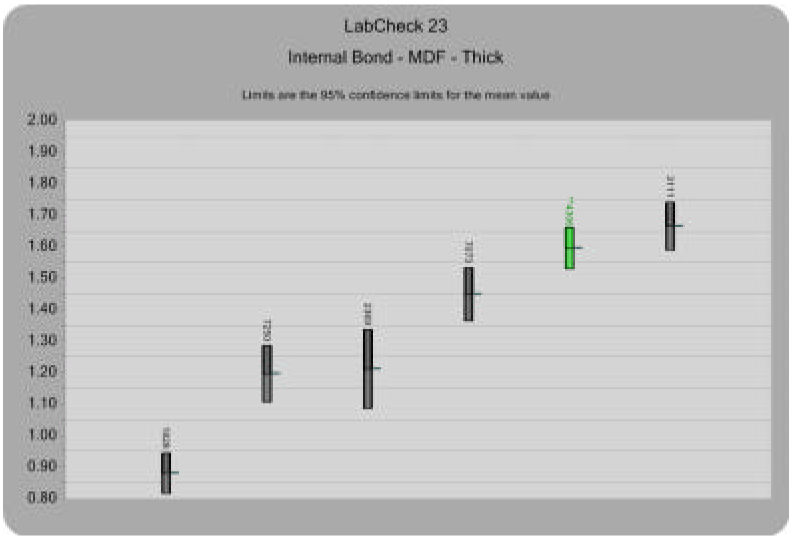

Figure 2. LabCheck results for 18mm MDF.

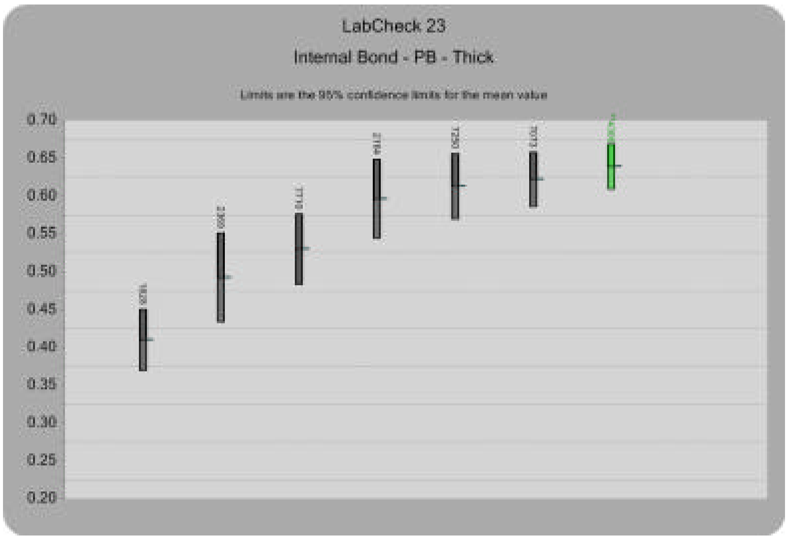

Figure 3. LabCheck results for 12mm particleboard.

2. Assessing difference within a company.

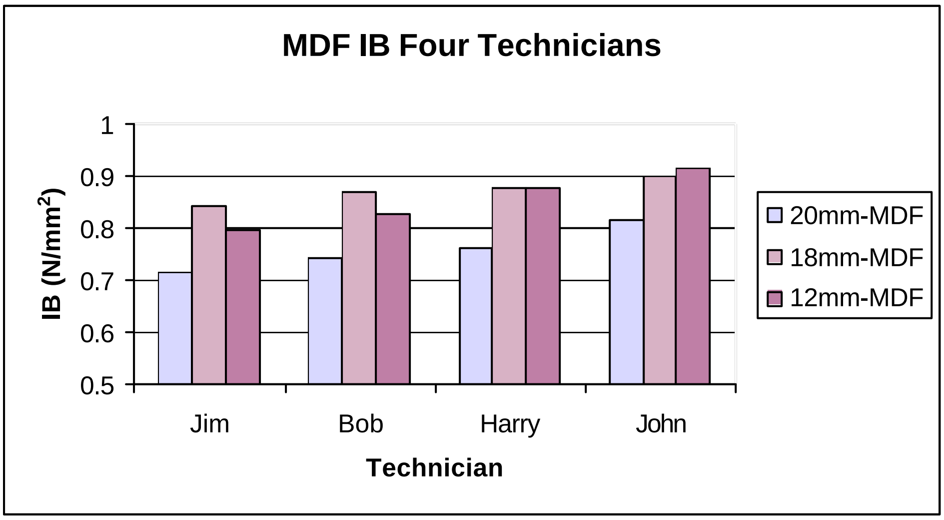

Figure 4. Difference between operators on one site.

Figure 4 shows that there is a systematic difference between four operators on one site. Operator Jim had the lowest results for all products tested. Operator John had the highest values for all three products. There were differences in how the products were ranked by the operators. Jim ranked the 18mm highest, John ranked the 12mm highest.

3. Factors affecting the standard IB result

Tables 1 to 3 present the differences in test methodology observed over ten years of visiting laboratories.

Table 1. Materials Used for Internal Bond Testing

BLOCK MATERIAL	GLUE TYPE
wood	PVA
plywood	two part mixes
aluminium	P.U.
steel	hot melts

Table 2. Gluing methodology

PRIOR TO GLUING	GLUING TECHNIQUE	AFTER GLUING
time after manufacture	temperature	time before testing
conditioning time	positioning on blocks	conditions of RH and temperature
conditions of RH and temperature		

Table 3 Testing procedures.

TESTING PROCEDURE
rate of loading
definition of the rate of loading
sampling interval for peak determination
swivel position

4. Bond-o-Matic Design

There were many prototypes tested. A simple controlled temperature press and hot-melt glue was trialed on two factory sites, however while the system had worked well in the TimberTest laboratory the system did not produce a significant reduction in variability at the factories.

The final prototype which will be taken to the market controls all the variables identified and produces results similar to very controlled laboratory testing followed by reconditioning at 65%RH and 20°C

Picture Bond-o-Matic

CONCLUSIONS

The commercial constraints mean that final instrument design is dictated by the projected sale price. While total automation could not be achieved within the estimated maximum sale price, the machine can be made with up to four test heads – which enables more data to be collected in the same time. Visits to a number of manufacturing sites in the EU indicated that this approach would be acceptable. A fully automated machine is also possible and for larger sites this may be an option.

Defining “correct” internal bond was a difficulty for the project since, without this definition there was no basis on which to the develop prototypes. Every technical manager and technician we interviewed had a strong opinion on this. In all cases a deviation from the international standard was thought necessary and acceptable for quality control testing where fast feedback for production control is required. However this has led to many in-house systems for speeding up the gluing process, from exposure to sub-zero temperatures to gluing at high temperatures. Normally higher values were assumed to be “correct” as poor gluing practices normally, (but not always) leads to lowered results. The lack of consensus within the industry made the development of a system to give fast repeatable results challenging. After running trials involving several thousands of tests it was realised that without a better method for assessing the instrument it would take too long to trial the many options. The method finally used was based on:

1) The repeatability of the test each time it is performed on standard samples.
2) The best fit of the plot of internal bond versus density. The R^2 value were compared and it was assumed that the higher the R^2 the better the test procedure.
3) The final method was compared with the results for the same product in tests that fully complied with international standard methods. This reference testing was used with conventional techniques of gluing by highly skilled operators using both hot melt and two part glue mixes. For the reference testing the samples were reconditioned after gluing.

The final design that will be taken to market has proven to have all the desired benefits. The test can be completed very quickly, minimises the variability and substantially reduces operator time input.

The benefits of improved test data are obvious, the plant can potentially be more tightly controlled, the incoming resin and fibre more accurately assessed and the need for re-testing reduced. All these efficiencies potentially reduce resin use, save money and lower the carbon footprint.

Indications to date are that the market price for this instrument will be accepted. The product will be released first in Europe where there is growing pressure to reduce energy use.

The product will be released with a comprehensive technical support package.

ACKNOWLEDGEMENTS

Graeme Radford and Monty Ammundsen, TimberTest, for the technical work on this project.