Technical evaluation of defect cutting and finger jointing on improving the strength of timber

Prepared for: Mr R Selmes
Forestry Commission

10 March 2005

Forestry Commission

Client report number 222 - 188

1 Technical evaluation of defect cutting and finger jointing on improving the strength of timber

Prepared by

Name	Chris Holland
Position	Senior Consultant
Signature	

Approved on behalf of BRE

Name	Dr V Enjily
Position	Director - CTTC
Date	
Signature	

BRE
Garston
WD25 9XX
T + 44 (0) 1923 664000
F + 44 (0) 1923 664010
E enquiries@bre.co.uk
www.bre.co.uk

Executive Summary

This project has demonstrated the potential of defect cutting and finger jointing of structural timber to significantly improve the yield of the C24 strength class over that which can normally be expected to be achieved for timbers such as Douglas fir and Sitka spruce.

For Douglas fir there is potential to increase the yields for the strength classes C27, C30 and C35 over that which can normally be achieved. This would make the use of UK grown Douglas fir more acceptable for end uses such as glulam, which, utilises the higher strength classes in its manufacture.

Unfortunately, there seems little potential to increase the range of the strength classes that Sitka spruce can be attributed to, as beyond the C24 strength class both stiffness and density become an issues with the ultimate limiting factor being density. In fact density was the limiting factor for all the higher strength classes regardless of species.

Contents

1 Introduction

The United Kingdom Timber Grading Committees' (UKTGC) rules on the strength grading of timber and PrEN18041: Part 4[1] both allow for the machine strength grading of timber that contains finger joints, at a frequency of not less than every 900mm, for bending type machines. This combined with the findings of the Partners in Innovation project "Adding value to UK timber: Development and demonstration of glued laminated products" which clearly illustrated that to make best use of UK timber for glulam applications the strength class range that UK timbers can be graded to would need to be increased. Traditionally in the UK, timber has never been used in high strength applications, the preference being for other forms of structural material. This accounts for the rather low expectations of UK graded structural material, not exceeding the C24 strength class. However, for glulam production a C24 strength class can be considered as the basic entry level. So UK timber is already at a disadvantage compared to European timbers, particularly European whitewood. This combined with the fact that C24 European whitewood is retailing in the UK for the same price as C16 Sitka spruce adds an additional cost penalty to the use of UK grown material. The need to expand the range of strength classes for UK timber is made even more vital by the fact that EN 338 strength classes have been increased to C50, primarily for the glulam market, and though the yield may be low it does highlight the need to move the top UK grades from C24 to higher strength classes such as C27, C30 or C35.

The aim of this project is to see if by removing strength reducing characteristics the strength of timbers such as Douglas fir can be improved so that a larger proportion of the material can achieve the higher strength classes. At the same time it was considered important to investigate the potential to increase the yields of Sitka spruce at the C24 strength class level.

Additionally, better whole tree utilisation may be obtained by finger jointing relatively short lengths of timber that otherwise would have no value as structural timber, and by so doing be able to machine grade them for structural applications.

Douglas fir was chosen for this work as it is known to have good stiffness for its strength, therefore, reducing the likelihood that stiffness would become a limiting factor at the higher strength classes.

Sitka spruce was chosen as it a very important commercial timber for the UK. Whilst it was known that stiffness may be a problem the opportunity to increase C24 yield was worth investigation

2 Description of the project Description of the project

The demonstration of the potential to increase the strength class of timber by removing the strength reducing characteristics is based on getting a good match between the defect cut and finger jointed sample and control (solid timber) sample. Matching timber samples is always difficult due to timber’s innate variability. For this project the method of matching the samples was to acquire parcels of timber and select every second specimen for defect cutting, leaving the remaining specimens as the control sample. It has been noted from extensive experience that parcels of timber frequently contain specimens cut from adjacent timber and much comes from the same log source, therefore this was an economical way of attaining a reasonably well matched set of samples. This produced two samples for each species one for defect cutting and finger jointing and one for controls (solid timber).

The Douglas fir samples each contained 120 specimens (240 in total) and the Sitka spruce samples contain 121 specimens each (242 in total).

All the specimens were first passed through the strength grading machine to capture the strength grading data. On completion of this task all the material was tested to destruction to determine strength, stiffness and density for each specimen. The results were analysed against the machine settings for the strength class combination C16 / C24 and reject for the BS 5268 settings. For this work comparisons with the EN338 settings were not made as prEN 14081 – Part 4 does not have machine settings for either Douglas fir or Larch. This deficiency of machine settings for these two species has been drawn to the attention of the United Kingdom Timber Grading Committee (UKTGC) for correction, as the UK has been responsible for the promotions of Part 4.

In addition to analysis against the requirements of the C16 / C24 strength class combination the data for both species was analysed to estimate the yields of the higher strength classes, for the defect cut material against that for the Controls (solid timber). This was a theoretical grading exercise as machine settings do not currently exist for these higher strength classes, however, the samples still had to meet the target requirements for the appropriate strength classes with regard to 5th percentile strength, mean stiffness and density.

3 Findings

3.1 Results of the grading of Douglas fir samples

3.1.1 Control (solid timber) samples

These results are based on a sample size of 120 specimens and show that from a normal mixed batch of timber there is an equal mix of C16 and C24 strength class timber present, with only five rejects below the C16 strength class, (Tables 1 and 2).

For both the C16 and C24 strength classes all the parameters were met for full compliance to the strength classes. It can be seen that at both the C16 and C24 strength class level neither stiffness nor density was a problem as in both cases the results from testing clearly exceed the requirements for those strength classes.

Table 1. The results for the sample population selected by the C16 settings

Strength (5th percentile) N/mm^2	Mean stiffness N/mm^2 (at 15% moisture content)	Density kg/m^3 (at 12% moisture content)
Data from test sample		
18.05	**8936**	**402.5**
Target values with permissible reductions for the C16 strength class		
14.3	8360	370
The total yield for the C16 strength class setting was 56 specimens (46%).		

Table 2. The results for the sample population selected by the C24 settings

Strength (5th percentile) N/mm^2	Mean stiffness N/mm^2 (at 15% moisture content)	Density kg/m^3 (at 12% moisture content)
Data from test sample		
24.58	**12238**	**445**
Target values with permissible reductions for the C24 strength class		
21.42	10260	420
The total yield for the C24 strength class setting was 59 specimens (49%).		

There were 5 rejects for this sample (4%).

3.1.2 Higher strength classes

When comparing the higher strength classes it became apparent that density was the limiting factor and for all classes (C27, C30 and C35) the potential was limited by the requirement to meet the target density in each case. Though the yields drop with increasing strength class significant yields can still be achieved;

- C27 = 42%
- C30 = 33%
- C45 = 17%

Sample statistics for the C27 to C35 strength classes based on theoretical grading are shown in Table 3.

Table 3 Sample statistics for the control sample for strength classes C27, C30 and C35 respectively.

Strength (5th percentile) N/mm^2	Mean stiffness N/mm^2 (at 15% moisture content)	Density kg/m^3 (at 12% moisture content)
Data from test sample – C27 **Yield = 50 specimens (42%).**		
30.64	**12646.27**	**451.26**
Target values with permissible reductions for the C27 strength class		
24.1	11685	450
Data from test – C30 **Yield = 40 specimens (33%).**		
30.89	**12984.8**	**461.35**
Target values with permissible reductions for the C30 strength class		
26.78	11685	460
Data from test - C35 **Yield = 20 specimens (17%).**		
36.17	**13631.65**	**480.75**
Target values with permissible reductions for the C27 strength class		
31.25	12730	480

3.1.3 Defect cut sample

As with the control sample the defect cut and finger jointed sample comprised 120 specimens but this time the major knot clusters had been removed before finger jointing. However, there was no attempt to remove slope of grain features or other strength reducing characteristics that would be difficult to identify in the sawmill.

The results for the grading of the sample against the settings for the C16 and C24 strength class combination are shown in Tables 4 and 5. The results show a clear improvement upon those obtained for the control sample, previously discussed. With a reduction in the C16 population to 33 specimens but a rise in the C24 population to 87 specimens, and no rejects. This strongly suggests that the removal of the major knot clusters has improved the strength characteristics of the timber allowing more specimens to meet the higher strength class (C24) and reducing the number of rejects.

Table 4. The results for the sample population selected by the C16 settings

Strength (5th percentile) N/mm^2	Mean stiffness N/mm^2 (at 15% moisture content)	Density kg/m^3 (at 12% moisture content)
Data from test sample		
16	**8500**	**421**
Target values with permissible reductions for the C16 strength class		
14.3	8360	370
The total yield for the C16 strength class setting was 33 specimens (27.5%).		

Table 5. The results for the sample population selected by the C24 settings

Strength (5th percentile) N/mm^2	Mean stiffness N/mm^2 (at 15% moisture content)	Density kg/m^3 (at 12% moisture content)
Data from test sample		
26.46	**12699**	**438**
Target values with permissible reductions for the C24 strength class		
21.42	10260	420
The total yield for the C24 strength class setting was 87 specimens (72.5%).		

The were no rejects for this sample

Once again all the criteria for the strength classes have been met with neither stiffness nor density being a problem

3.1.4 Higher strength classes

Sample statistics for the C27 to C35 strength classes based on theoretical grading are shown in Table 6.

Table 6. Sample statistics for the defect cut sample for strength classes C27, C30 and C35 respectively.

Strength (5th percentile) N/mm^2	Mean stiffness N/mm^2 (at 15% moisture content)	Density kg/m^3 (at 12% moisture content)
Data from test sample – C27 **Yield = 68 specimens (57%).**		
27.97	**13292**	**450.3**
Target values with permissible reductions for the C27 strength class		
24.1	11685	450
Data from test – C30 **Yield = 51 specimens (42%).**		
31.4	**13723**	**460**
Target values with permissible reductions for the C30 strength class		
26.78	11685	460
Data from test - C35 **Yield = 28 specimens (23%).**		
39.16	**14091**	**480**
Target values with permissible reductions for the C27 strength class		
31.25	12730	480

Table 6 clearly shows an improvement on the yields for the strength classes C27, C30 and C35 over that of the control sample with yields for the three strength classes of:

- C27 = 57% (compared to 42% for the controls)
- C30 = 42% (compared to 33% for the controls)
- C35 = 23 % (compared to 17% for the controls)

However, for both the defect cut sample and the control sample the yields of C35 are low and it is not considered worth continuing with the investigation above this strength class. As with the control sample the limiting factor to each of the strength classes was density.

If higher strength classes above C35 are to be attained with commercial yields then methods of improving density will need to be sought as neither strength nor stiffness was an issue with Douglas fir. Many of the specimens that were down graded to a lower strength class had values for strength and stiffness above the requirements of the higher strength class but failed to meet the requirement for density. However, there is no straightforward solution to this difficulty and the answer may lie more in a sylvicultural approach rather than a re-engineering intervention.

3.2 Results of the grading of the Sitka spruce samples

3.2.1 Control (solid timber) sample

The results are based on a sample of 121 specimens of mixed quality, the results of the grading exercise for the C16 / C24 strength class combination can be seen in Tables 7 and 8. As would be expected for Sitka spruce the sample graded well to the current machine settings, yielding 40 specimens that graded to the C16 strength class and 76 specimens to the C24 strength class, with 5 rejects. All the criteria for the strength class were fully met, indicating that for these strength classes' stiffness and density were not an issue.

Table 7. The results for the sample population selected by the C16 settings

Strength (5th percentile) N/mm^2	Mean stiffness N/mm^2 (at 15% moisture content)	Density kg/m^3 (at 12% moisture content)
Data from test sample		
16	**877**	**397**
Target values with permissible reductions for the C16 strength class		
14.3	8360	370
The total yield for the C16 strength class setting was 40 specimens (33%).		

Table 8. The results for the sample population selected by the C24 settings

Strength (5th percentile) N/mm^2	Mean stiffness N/mm^2 (at 15% moisture content)	Density kg/m^3 (at 12% moisture content)
Data from test sample		
28.74	**10643**	**423**
Target values with permissible reductions for the C24 strength class		
21.42	10260	420
The total yield for the C24 strength class setting was 76 specimens (63%).		

There was 5 rejects for this sample (4%).

When the higher strength classes were examined both stiffness and density did become an issue. Even the C27 strength class suffered serve loss of yield as a result of trying to meet the stiffness and density requirements.

As can be seen in Table 9 the yield was only 5 specimens, therefore, this does suggest that the C24 strength class is the limit of this species potential unless stiffness and density can be improved.

Table 9. Sample statistics for the solid material for the C27 strength class

Strength (5th percentile) N/mm^2	Mean stiffness N/mm^2 (at 15% moisture content)	Density kg/m^3 (at 12% moisture content)
Data from test sample – C27 **Yield = 5 specimens (4%).**		
33.12	**12953**	**450.8**
Target values with permissible reductions for the C27 strength class		
24.1	11685	450

3.2.2 Results for the defect cut sample

As with the previous samples the results are based on a matched sample of 121 specimens, and this sample like the defect cut Douglas fir had the major knot clusters removed before finger jointing. The results for the grading to the C16 and the C24 strength classes are shown in Tables 10 and 11.

The most obvious result is that the number of C16 specimens has been reduced to 17, around half of the yield for the control samples and the C24 strength class increased to 103 specimens, compared to 76 specimens for the control sample. However, the results for mean stiffness and density for the C24 strength class are on the limits of acceptability suggesting this is the highest strength class that can be achieved for this sample.

Table 10. The results for the sample population selected by the C16 settings

Strength (5th percentile) N/mm^2	Mean stiffness N/mm^2 (at 15% moisture content)	Density kg/m^3 (at 12% moisture content)
Data from test sample		
15.7	**8439**	**372**
Target values with permissible reductions for the C16 strength class		
14.3	8360	370
The total yield for the C16 strength class setting was 17 specimens (14%).		

Table 11. The results for the sample population selected by the C24 settings

Strength (5th percentile) N/mm^2	Mean stiffness N/mm^2 (at 15% moisture content)	Density kg/m^3 (at 12% moisture content)
Data from test sample		
25.84	**10260**	**421**
Target values with permissible reductions for the C24 strength class		
21.42	10260	420
The total yield for the C24 strength class setting was 103 specimens (85%).		

There was 1 reject for this sample (<1%).

For the higher strength classes the results were very similar to the control sample, with the limitations for the higher strength classes being stiffness and density and again ultimately density was the overriding limiting factor. Of the 103 specimens that met the requirements for the C24 strength class only a yield of 2 specimens could be obtained if all the criteria for the C27 strength class were met.

Sample statistics for the C27 class base on theoretical grading are shown in Table 12.

Table 12. Sample statistics for the defect cut material for the C27 strength class.

Strength (5th percentile) N/mm^2	Mean stiffness N/mm^2 (at 15% moisture content)	Density kg/m^3 (at 12% moisture content)
Data from test sample – C27 **Yield = 2 specimens (1.6%).**		
48.7	**13271**	**458**
Target values with permissible reductions for the C27 strength class		
24.1	11685	450

4 Conclusion and recommendations

1. Defect cutting and finger jointing can increase the yield of both Douglas fir and Sitka spruce with regard to the C24 strength class. The increase in yield is from material that otherwise would have been graded to the C16 strength class.
2. Defect cut and finger jointed Douglas fir shows potential to increase the yields for the C27, C30 and C35 strength classes over that for timber that has not been defect cut and finger jointed. This opens the prospect for greater utilisation of the resource.
3. Whilst the yields of C24 Sitka spruce can be increased by defect cutting and finger jointing it does not appear possible to go beyond this strength class. The results for the C27 strength class were very disappointing.
4. For the higher strength classes density appears to be the ultimate limiting factor. All the higher strength classes were determined by the need to meet the target density rather than strength or stiffness. There is a very close relationship between stiffness and density for Sitka spruce that make both important limiting factors but ultimately it was density that determined the yields.
5. The ability to grade Douglas fir to the higher strength classes would be beneficial, particularly for glulam, and the improvements to yields by defect cutting and finger jointing would be an added benefit.
6. Finger jointing of timber for structural applications is not limited to defect cutting, short lengths of other wise low value material can be joined to form longer lengths suitable for structural use, and much of this material could achieve the C24 strength class for Sitka spruce.
7. Pressure should be maintained on the UKTGC to ensure that the EN 338 machine settings for UK grown Douglas fir and larch are placed in peEN 14081: Part 4.

5 References

1. British Standards Institution 2004, Timber structures – Strength graded structural timber with rectangular cross section – Part 4: Machine Grading settings for machine controlled system prEN 14081- Part 4: 2004. London
2. British Standards Institution 2003, Structural timber – Strength classes, BS EN 388: 2003. London
3. British Standards Institution 2002, Structural use of timber: Part 2- Code of practice for permissible stress design, materials and workmanship, BS 5268 - Part 2: 2002. London