Quantification of the yields of Irish grown

Sitka spruce

in the new CEN strength classes

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Summary

Data were collected from *c.* 5 000 Sitka spruce timber pieces of nine different section sizes using three types of grading machine. The sections were of three thicknesses, 44 mm, 35 mm and 38 mm. Yields were greatly affected by the thickness of the timber being graded. The thinner sections gave lower yields. Yields for the new European Standards Organisation's (CEN) strength bands C14 and C16 were very high - up to 95%. The yield for C18 was also high at 90%, but thinner sections gave poorer yields. The yields for C22 ranged from 33% to 83%, while for C24, yields ranged from 16% to 70%. Grading to strength classes higher than C24 is not recommended unless further work is conducted with these grades. Confirmatory strength tests should be carried out on samples within the different strength classes.

1 Introduction

When S.R. 11 (Standard Recommendation: Structural Timber for Domestic Construction) was published in 1988 it gave a significant boost to the homegrown timber sector. It provided a strength classification that established homegrown timber, and Sitka spruce in particular, in the domestic construction market. This standard also contained tables for maximum safe spans for floor joists, ceiling joists and roof rafters for different sizes and strength classes.

Three strength classes were designated: A, B and C, prefixed by the letters SC. The strength classes were commonly referred to as SCA, SCB and SCC. Each strength class had appropriate strength properties assigned to it, which therefore made it easier for a designer/specifier to design and specify the timber required for a particular application. At that time, the prevailing grading method was visual. The standard used for the grading of timber was British Standard (BS) 4978. The two visual grades specified in the BS standard, and for which limits for the different timber characteristics were assigned, were GS (general structural) and SS (special structural). The rules and limits specified were applicable to all softwood species. However, because each species has its own inherent strength, the visual grade (GS or SS) of one species did not necessarily equate in strength to the same visual grade of another species. Thus, for example, the GS grade of homegrown Sitka spruce had strength properties which complied with the SCA strength class whilst the GS grade of imported European whitewood/redwood complied with SCB. S.R. 11, also provided a table with the assignments of the species/visual grade combinations to the strength classes.

I.S. EN 127 was introduced in 1990 and used as the grading standard in Ireland. The latter standard, although similar to BS 4978 with respect to grading, contained some differences that specifically addressed the Irish market. Moreover, some of these were subsequently adopted in later versions of BS 4978.

With the advent of the single European market, harmonisation of European standards began to take priority within the European Union. Mandates were given to working groups to produce standards, under the auspices of the European Standards Organisation (CEN), which would be acceptable throughout Europe. CEN standards EN 338: Structural Timber - Strength Classes was published in 1995. The associated standards were EN 518, EN 519, EN 384 and EN 408.

All these standards were given the status of national standards upon publication and prefixed by I.S. Existing national standards had to either comply with, or be replaced by, CEN standards.

I.S. EN 338 has a new strength classification: nine for coniferous species (including poplar), and six for deciduous species. The strength classes are sometimes referred to as the ‘C’ grades and are as follows: C14, C16, C18, C22, C24, C27, C30, C35 and C40. The nine strength classes for the coniferous species and poplar range from C14 to C40.

Each of the strength classes has associated strength and stiffness properties which are outlined in I.S. EN 338. The number in the strength class designation refers to the characteristic bending strength for that strength class. Thus, timber graded to strength class C16 has a characteristic bending strength value of 16 N mm^{-2}, whereas C24 has a characteristic bending strength value of 24 N mm^{-2}.

Visual grading has been the traditional method of timber grading in most countries and is still widely used. In Ireland and the UK, the present visual grading rules provide for only two grades- SS (special structural) and GS (general structural). The rules and limits for the measured characteristics for each of these two grades are the same regardless of the species being graded. However, since each species has its own inherent strength characteristics the same visual grade for two different species is most likely to have different associated strength properties. Thus the visual SS grade of Douglas fir would have different strength properties than the visual SS grade of Sitka spruce and would, therefore, meet the requirements of different strength classes.

Since each European country has its own specific visual grade designations, with associated sets of grading rules, it was not possible to harmonise the various European visual grades. It was necessary, therefore, to list all the grades and species available in Europe. In addition, some timber, which was being imported from other countries, was similarly treated in order to assign the grades and species to the different 'C' strength classes, depending on their strength properties. It was for this reason that I.S. EN 1912 was produced. It lists visual strength grades, species and sources of timber, and specifies the strength classes from I.S. EN 338, to which they are assigned. The assignment of each European visual grade and species to a strength class was based on data that were made available from each country within the EU. The data were made available to a special technical group which was given the task of making the assignments. As a result of this work, Irish grown Sitka spruce, visually graded in accordance with I.S. EN 127, has been assigned to specific strength classes based on the strength attributes of these visual grades determined from strength tests. Irish grown Sitka spruce visually graded to the SS grade has been assigned to C18 and the GS grade has been assigned to C14. This information has been published as I.S. EN 1912 - Structural Timber - Strength classes - Assignment of visual grades and species. It will form one of a series of standards for building materials derived from performance requirements published in the Eurocode for the design of Timber Structures (ENV1995-1-1).

The limitation of visual grading is that a species/visual grade combination can only be assigned to one 'C' strength class. With machine grading however, it is possible to grade to any of the strength classes provided settings for the different strength classes are available for the species and type of machine being used.

Although new types of machine are being developed, the 'bending type' machine is the most common. With this machine, the timber is non-destructively tested over a short span between 900 and 1 000 mm, and continuously - every 100 mm or 150 mm - over the length of the timber. The settings for the bending type machines are obtained from relationships between what the machine measures and the ultimate strength and stiffness of timber measured on the edge. These relationships are produced after a substantial number of tests - usually comprising of about 900 samples - which cover the range of sizes and quality of timber. It is also the practice to cover different geographical locations and sawmills in a country when conducting these tests. This has been done for Sitka spruce grown in Ireland.

2 Objective

An important fact for machine grading is that each species has its own specific strength/stiffness relationship. Although there are occasions where two species may have very similar relationships, for example, European redwood and whitewood from Scandinavia, these relationships have to be developed for each species if they are to be machine graded.

The new CEN strength classes in I.S. EN 338 have been designed to promote the acceptance of timber originating from different areas within Europe and traditional sources outside Europe, provided it is properly graded.

The sawmilling sector has been concerned about the yields from home grown timber in the strength classes that are presently not obtainable by visual grading. This concern is due to the fact that imported whitewood/redwood from central and northern Europe can be visually graded to strength classes higher than visually graded Irish timber. Although it is not certain what the actual trading band for strength classes will be, particularly in the export market, indications are that it is likely to be C16 for domestic floor construction and the higher strength classes (possibly C24) for roof trusses. By using machine grading, Irish grown Sitka spruce can be graded into the higher strength classes. However, in order that commercial decisions can be made on whether or not to grade to the higher strength classes, the yields for these higher strength classes have to be quantified.

The objective of the project was to quantify the yields of homegrown Sitka spruce in the CEN strength classes.

3 Materials and methods

The quantification of yields in the new 'C' strength classes was determined by collecting data from grading machines. Grading machines have a facility for downloading measurements made by the machine in the grading process. All the machines presently being used in Ireland are of the bending type produced by two companies – MPC[1] and Tecmach. MPC produces the COMPUTERMATIC and MICROMATIC machines. Tecmach produce the COOK-BOLINDER machine.

The operation of the bending type machines is based on the accepted principle that there is a good relationship between stiffness measured on the flat side of the timber section and the ultimate strength of the piece measured on the edge.

The Cook-Bolinder strength grading machine (Figure 1) operates on the principle of measuring the load resulting from applying a constant deflection to the specimen over a known span. The datum rollers are at a fixed span of 900 mm centre to centre. The load measurements are taken every 100 mm along the board, and within 600 mm of each end. The effect of bow and twist are accounted for by passing the board a second time through the machine and deflecting the opposite face of the board. The readings taken from the two passes are then averaged at each point measured. The machine has been approved for feed speeds of up to 150 m min^{-1}.

The Computermatic was developed as a result of research and development carried out by the Division of Wood Technology, Forestry

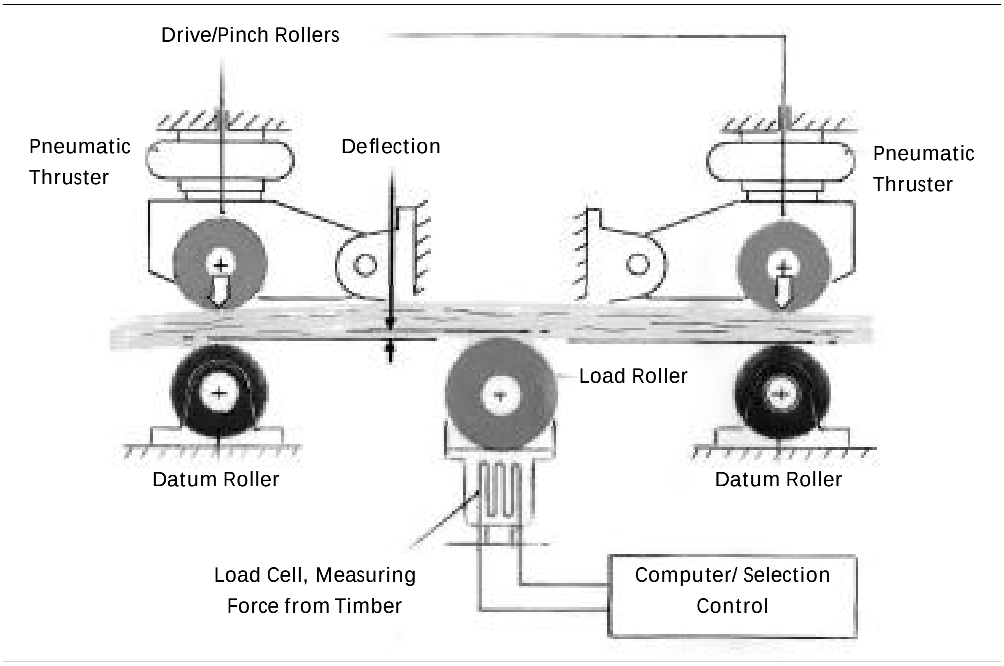

Figure 1: Schematic plan view of three point bending test in the Cook-Bolinder machine.

[1] MPC, Essex, England. Techmac Ltd., Herts, England

Commission of New South Wales. The Computermatic MK P IVa is the latest version of the machine. It uses a solid-state computer to co-ordinate and control the multiple operations conducted on each piece of timber.

The Micromatic was developed from the Computermatic and uses the same basic technology and principles of operation. The main difference is that it is a fixed speed machine operating at 68 m min^{-1} and it does not have sprays to mark the individual spot grades along the plank. Instead it employs a roller marker to give the final grade allocation. The principle is similar to the Cook Bolinder but the measurement taken is that of deflection under a fixed load applied at the centre of a span of 914 mm. The operating principle used in the MPC machines is shown in Figure 2. The fixed load applied is dependent on the size of the timber section being graded. Measurements are taken at 152 mm intervals along the plank and within 600 mm of each end. The deflection measurements are made using two transducers.

The first transducer measures the natural bow of the piece, while the second measures the deflection under the prescribed load. The first deflection is subtracted from the second to give the true deflection under the load. These measurements are taken every 150 mm and are synchronised in the grading process by clock pulses. The machine converts linear motion to rotary motion using a precision band and drum arrangement. It then converts this rotary motion to machine code via a precision rotary brush encoder. The measuring arm displacement is measured in 0.1905 mm increments, also referred to as a 'bit'.

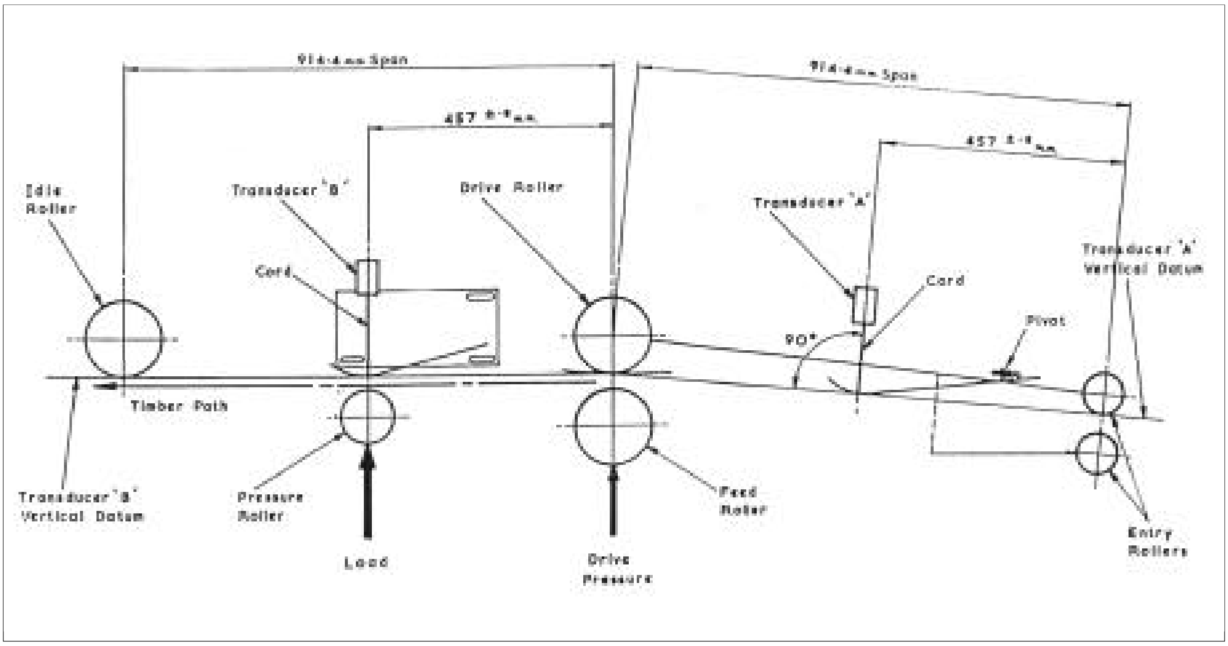

Figure 2: Schematic plan view of three point bending test in the MPC machines (Computermatic and Micromatic)

3.1 Data collection

It was decided to visit all the sawmills that operated grading machine in order to obtain a good spread of data. Before any data were collected, machines were checked according to calibration procedures outlined in the accompanying machine manual. In addition, the sawmills visited were participants in the quality control machine grading schemes run either by the TQBI (Timber Quality Bureau of Ireland) or TRADA (The Timber Research and Development Association) based in the UK. Some of the sawmills were in both schemes.

In all, four sawmills were visited, two of which were visited twice. The number of samples tested and dimensions of planks for which data were collected are shown in Table 1.

Although, more than 5000 planks were tested, some data had to be discarded due to machine malfunctions during collection. Nine different section sizes were tested. A specially fabricated interface box and software (Datacol) produced by MPC, was used with both their machines.

A readily available communications software package –'Mirror'- was used with the Cook-Bolinder machine. However the memory buffer in the machine was downloaded at every fourth plank and, therefore, slowed data collection. After the data were collected, a special macro was written in order to transform the data into a more convenient format for analysis.

The data were transferred to EXCEL datasets, examined, and spurious values discarded. The data were sorted so that all planks of the same

Table 1: Number and dimensions of planks for which CEN yields were determined

Sawmill	Machine Type	Dimensions (mm)	Number of planks
1	COMPUTERMATIC	100 x 44	288
		115 x 44	176
		115 x 35	109
		125 x 44	160
		150 x 35	169
		150 x 44	144
		175 x 44	125
		225 x 44	112
2	MICROMATIC	89 x 38	844
		225 x 44	1374
3	MICROMATIC	115 x 35	433
		115 x 44	454
		150 x 44	158
		175 x 44	83
4	COOK-BOLINDER	89 x 38	299
Total			**4928**

length and with the same number of valid data points were evaluated together. This was important in the following stage when the position of the grade determining point was being analysed. The format of the data is shown in Table 2.

Table 2: Sample data showing the deflection measured in ‘bits’ at each 152 mm interval along a plank. (One bit represents a deflection of 0.1905 mm).

Mill **Sawmill 2**
Machine **MICROMATIC**
Species ***Sitka spruce***
Section Size **225 x 44**
Load **4602 N**

Bit value of deflection

Measurement Number	Plank Number									
	1	2	3	4	5	6	7	8	9	10
1	23	23	28	19	20	28	23	23	25	34
2	29	30	37	25	25	33	27	33	32	41
3	34	38	40	24	29	34	28	34	38	37
4	34	34	40	21	27	36	28	26	38	31
5	27	31	43	25	27	37	28	25	36	31
6	26	32	44	25	31	37	29	29	35	37
7	33	40	43	27	29	40	29	31	36	39
8	35	38	43	26	28	44	28	31	37	43
9	32	38	47	27	29	45	27	31	40	51
10	29	36	48	28	31	45	28	30	41	49
11	32	39	45	29	30	44	29	30	37	46
12	29	36	41	28	30	41	29	31	34	45
13	29	36	43	25	30	42	28	30	37	42
14	29	33	46	22	33	43	22	26	37	41
15	26	32	47	21	29	45	19	25	35	39
16	25	32	47	21	28	44	20	25	32	36
17	23	32	48	20	26	39	17	24	29	32
18	21	27	41	20	27	36	16	26	29	35
19	19	24	44	27	25	36	18	31	33	37
20	23	28	41	28	31	38	28	31	29	36
21	29	30	40	30	33	38	23	31	29	34
22	28	31	39	32	33				27	34
No. of bits	**22**	**22**	**22**	**22**	**22**	**21**	**21**	**21**	**22**	**22**
Position of max. bit	**8**	**7**	**10**	**22**	**14**	**9**	**6**	**3**	**10**	**9**
Max. bit value	**35**	**40**	**48**	**32**	**33**	**45**	**29**	**34**	**41**	**51**

3.2 Data analyses

Analyses of the data consisted of determining:

1. the position of the grade determining point;
2. the actual value of the grade determining measurement;
3. the optimal grade for each plank based on ‘2’ above, and limits for the grade.

For 1 and 2 above, simple functions available in EXCEL were used to determine these values for each plank. Examples are shown in Table 2. In the case of 3 above, limit settings for the various ‘C’ grades were obtained and then used to determine the optimal grade for each plank.

3.2.1 Position of the grade determining point

The grade determining point is usually the maximum bit value for the MPC machines and the lowest load value in the case of the Cook-Bolinder. No visual override was used and neither were the ungraded ends evaluated. The frequency of the position of the grade determining point in each plank was illustrated and shown in histogram format for each size and sawmill. Figure 3 is an example of such a histogram.

Representation of such information in histogram format can be used to indicate:

1. any peculiarities about machine performance; and
2. the quality of the timber in terms of occurrence of defects.

3.2.1.1 Peculiarities in machine performance

Any peculiarities in machine performance would be shown by the high occurrence of the grade determining point at any one point in the plank. The interpretation of any such occurrence ought to be examined in conjunction with the length of the plank being graded. Some of the planks were short – 2.4 m in length - therefore, only half the plank was graded (since the first and last 600 mm were not tested in the machine).

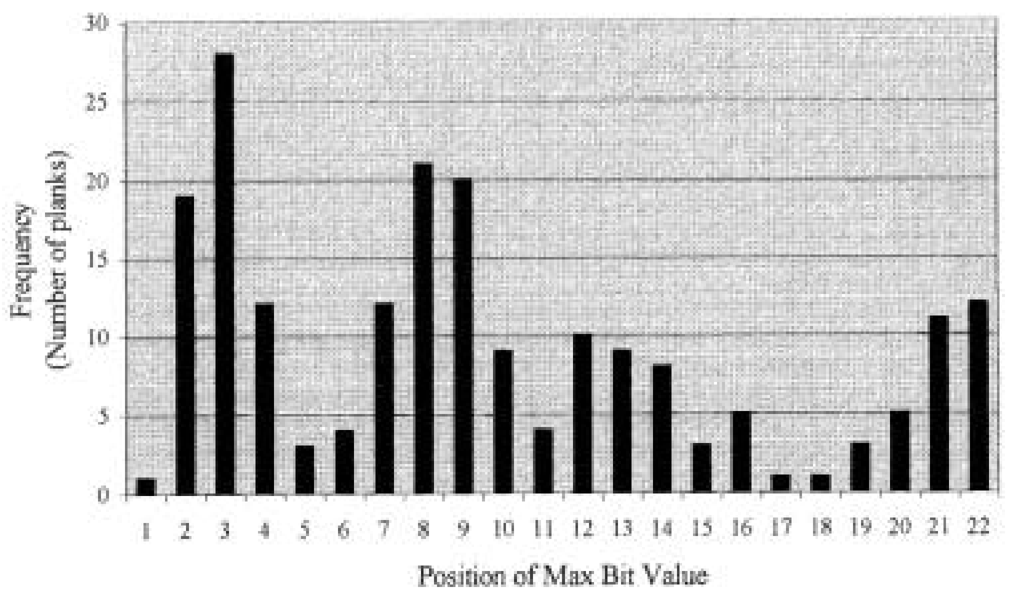

Figure 3: Frequency distribution of the maximum ‘bit’ value at each point of measurement.

(Note: Data from 225 x 44 mm planks at sawmill 2).

The machine in Sawmill 1 showed a tendency for the grade determining point to be located between positions 5, 6 and 7. It appears to be a peculiarity of this particular type of machine (Computermatic MK IVa) and has been observed in other countries.

At Sawmill 4, which used a Cook-Bolinder, it appears there was a relatively higher incidence of the grade determining point occurring at the last position measured in the machine. However, as only one size was graded in this machine it was not possible to conclude whether other sizes would behave in the same way.

In any case, it should be noted that the grade determining point indicated by the machine is not necessarily a reject point and therefore, the actual value measured is important.

3.2.1.2 Indication of the quality of timber

The position of the grade determining point could indicate a particular characteristic of the material being graded. For example, the position of the grade determining point could indicate that the planks were sawn from logs with an inherent defect at one end.

3.2.2 Value of the grade determining measurement

The measured value at the grade determining point is also shown in Table 2. Using sample data from Sawmill 2, Figure 4 indicates the frequency of each bit value at the grade determining point.

Such representation of data provides information that can be used to:

a) indicate the quality of the timber that was graded; and

b) quantify the yields in each C grade.

The quality of the timber is reflected in the shape of the histogram below. If the distribution is skewed to the right[2] (as was the case in the MPC machines) it indicates that there are more planks

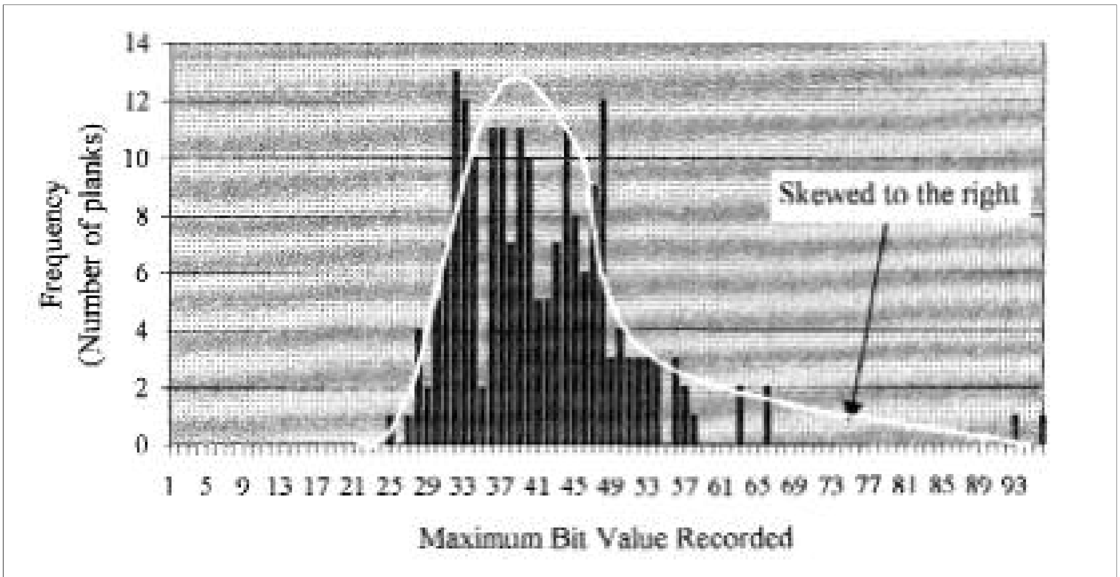

Figure 4: Frequency Distribution of the maximum bit value recorded for each plank.
(Note: Data from tests with 225 mm x 44 mm planks at Sawmill 2.)

[2] Skewness is a term applied to nonsymmetrical distributions which have a longer tail in one direction than in the other. The pattern in Figure 4 is said to be skewed to the right; the direction of skewness is the direction of the thin tail.

with lower bit values, which means stronger planks. In the case of the Cook-Bolinder machine, the more it is skewed to the left the better because the stronger planks have higher measured values. However, if a general indicator is required, then the mode of the distribution is a good overall indicator of the quality when compared to the machine limits for the size.

The quantification of the yields in each of the C grades was determined by comparing the value at the grade determining point to limits for the different grades. It was thus possible to 'optimise' the grade for each graded plank without having to re-grade the plank through the machine, by using different sets of limits depending on which grade was required.

3.2.3 Determination of machine settings

In order to machine grade to any particular strength class it is necessary to determine the machine settings that will be used to produce the desired strength class. This requires examining the existing strength properties database from which a suitable mathematical model can be developed incorporating the indicating parameter used in the grading machines and the required bending strength properties.

The method outlined in BS 4978 was followed to determine settings for the two of machine types. Using this method, limits were calculated and used to quantify the yields in each of the grades and grade combinations. The calculated settings are shown in Table 3. The settings were calculated for grading to single strength classes C14, C16, C18, C22, C24, C27 and C30.

In multiple or combined strength class grading there is a limitation as to the strength classes that can be graded together. If the strength classes are adjacent, the settings are too close to each other and the machines will not be capable of distinguishing the strength classes accurately. Differences in the yields will also depend on the overall quality of the material being graded.

The machines currently used in Ireland are capable only of grading to two strength classes in one pass. The settings were calculated for the strength class combinations most likely to be used in Ireland, namely C24/C14, C24/C16 and C18/C14. (Table 3)

Table 3: Machine Settings for Single and Combined Strength Classes.

Machine Type	MPC									Cook Bolinder
	100 X44	115 X 44	125 X 44	150 X 44	175 X 44	225 X 44	115 X 35	150 X 35	89 X 38	89 X 38
	Load (N)									Deflection (mm)
Machine Settings	2045	2352	2557	3068	3579	4602	1505	1963	1298	7.4
SETTINGS FOR SINGLE STRENGTH CLASS										
Strength Class(es)	Bit Settings									Load (N)
C14	90	90	89	88	87	85	106	104	102	0.53
C16	63	62	62	61	60	59	75	74	72	0.76
C18	55	55	55	54	53	52	66	65	64	0.85
C22	44	44	44	43	43	42	53	52	51	1.06
C24	39	39	38	38	38	37	46	46	45	1.22
C27	26	26	26	25	25	25	31	31	30	1.82
C30	25	24	24	24	24	23	30	29	28	1.92
SETTINGS FOR COMBINED STRENGTH CLASSES										
Strength Class(es)	Bit Settings									Load (N)
C24	39	39	38	38	38	37	46	46	45	1.22
C14	89	88	89	88	87	85	106	104	102	0.53
C24	39	39	38	38	38	37	46	46	45	1.22
C16	43	43	62	61	60	59	75	74	72	0.76
C18	46	46	45	45	44	43	55	54	53	1.03
C14	51	50	50	49	49	48	60	60	58	0.93

4 Results

The yields for single and combined strength class grading are shown in Table 4. The yields shown have not been corrected to take account of visual override, although in the case of Sawmill 3 visual override was carried out before grading. The visual override characteristics referred to in the standards (I.S. EN 127, I.S. EN 519) would affect yields and therefore, are not measured by the machines. Such characteristics include warp, wane and abnormal defects such as rot and damage. From past experience, up to 5% could be rejected on visual override.

The yields were greatly affected by the thickness of the timber being graded (Table 4). The 35 mm thick sections generally gave lower yields than the other two thicknesses tested i.e. 28 and 44 mm, except for C14.

With respect to the 38 mm sections, 74% of the sample consisted of 2.4 m lengths. All of these section thicknesses were classed as CLS (Canadian Lumber Standard) for studding. This meant that they were planed and had rounded edges.

Yields in the different strength classes depend on whether grading is conducted to a single or to multiple/combined strength classes in one pass. For machine grading to multiple strength classes, the model used to derive settings has to take account of the fact that when the higher grade material is taken out of the sample it will affect the strength properties of the lower strength class being graded at the same time and, therefore, will have different settings. This is why in most cases there will be a difference in the yields between single and multiple strength class grading as is shown in Table 4.

4.1 Single strength class grading

Overall, C14 showed extremely good yields. Therefore, after making allowances for visual override, yields can be expected to be in excess of 95% for C14 .

C16	good yields, ranged from 70% for the 35 mm thickness to 94% for the thicker sections.
C18	yields ranged from 55% for the 35 mm thickness to 90% for the thicker sections.
C22	ranged from 33% for the 35 mm thickness to 83% for the thicker sections.
C24	ranged from 16% for the 35 mm thickness to 70% for the thicker sections.

There was a sudden drop in yields for C27 and C30. This would be expected because the strength properties of these grades are proportionately higher than the lower grades. Since the numbers attaining these higher strength classes were very much lower than the lower strength classes, the strength data for these strength classes was considered to be unreliable. Therefore, it is not recommended that these higher strength classes be specified for Sitka spruce until further investigations specific to these strength classes are conducted.

4.2 Combination strength class grading

Yields were determined for the strength class combinations C24/C14, C24/C16 and C18/C14. Yields were shown to be good and compared well with the single strength classes except for the last combination where the reject increased from 8% to 12% when comparing C18 single grading to C18/C14 combined grading.

Table 4: Yields for single and combined strength classes

	SECTION SIZE (mm)																					
	100 X 44		115 X 44		125 X 44		150 X 44		175 X 44		225 X 44		115 X 35		150 X 35		89 X 38		89 X 38		ALL SIZES	
Total no. of Boards	288		630		159		301		207		1482		542		169		842		296		4916	
Strength Class	No. PER GRADE	% of SAMPLE	No. PER GRADE	% of SAMPLE	No. PER GRADE	% of SAMPLE	No. PER GRADE	% of SAMPLE	No. PER GRADE	% of SAMPLE	No. PER GRADE	% of SAMPLE	No. PER GRADE	% of SAMPLE	No. PER GRADE	% of SAMPLE	No. PER GRADE	% of SAMPLE	No. PER GRADE	% of SAMPLE	Total Number	% Total
Single Strength Class																						
C14	288	100.0	628	99.7	159	100.0	301	100.0	207	100.0	1481	99.9	542	100.0	169	100.0	842	100	296	100.0	4913	**100**
C16	287	99.7	611	97.0	157	98.7	298	99.0	202	97.6	1468	99.1	416	76.8	149	88.2	827	98.2	296	100.0	4711	**96**
C18	277	96.2	596	94.6	154	96.9	295	98.0	197	95.2	1446	97.6	334	61.6	129	76.3	805	95.6	288	97.3	4521	**92**
C22	240	83.3	559	88.7	135	84.9	264	87.7	174	84.1	1316	88.8	206	38.0	82	48.5	668	79.3	257	86.8	3901	**79**
C24	181	62.8	520	82.5	96	60.4	230	76.4	144	69.6	1181	79.7	117	21.6	41	24.3	519	61.6	214	72.3	3243	**66**
C27	23	8.0	324	51.4	12	7.5	100	33.2	36	17.4	762	51.4	9	1.7	3	1.8	53	6.3	21	7.1	1343	**27**
C30	12	4.2	292	46.3	8	5.0	92	30.6	31	15.0	704	47.5	8	1.5	3	1.8	30	3.6	15	5.1	1195	**24**
Combined/Multiple Strength Class																						
C24	181	62.8	520	82.5	96	60.4	230	76.4	144	69.6	1181	79.7	117	21.6	41	24.3	519	61.6	214	72.3	3243	**66**
C14	107	37.2	108	17.1	63	39.6	71	23.6	63	30.4	300	20.2	425	78.4	128	75.7	323	38.4	82	27.7	1670	**34**
REJ	0	0.0	2	0.3	0	0.0	0	0.0	0	0.0	1	0.1	0	0.0	0	0.0	0	0.0	0	0.0	3	**0**
C24	181	62.8	520	82.5	96	60.4	230	76.4	144	69.6	1181	79.7	117	21.6	41	24.3	519	61.6	214	72.3	3243	**66**
C16	46	16.0	29	4.6	61	38.4	68	22.6	58	28.0	287	19.4	299	55.2	108	63.9	309	36.7	78	26.4	1343	**27**
REJ	61	21.2	47	7.5	2	1.3	3	1.0	5	2.4	14	0.9	126	23.2	20	11.8	14	1.7	4	1.4	296	**6**
C18	249	86.5	566	89.8	138	86.8	273	90.7	181	87.4	1335	90.1	236	43.5	90	53.3	700	83.1	261	88.2	4029	**82**
C14	20	6.9	20	3.2	10	6.3	15	5.0	11	5.3	82	5.5	47	8.7	20	11.8	59	7.0	14	4.7	298	**6**
REJ	19	6.6	44	7.0	11	6.9	13	4.3	15	7.2	65	4.4	259	47.8	59	34.9	83	9.9	21	7.1	589	**12**

Note: REJ=Reject

5 Conclusions

The conclusions are based on the results obtained from

- three types of grading machines, using
- nine different section sizes, and
- 5,000 pieces comprising of: 35, 38 and 44 mm thickness.

Yields discussed below are based on the results presented in Table 4 *with a fixed reduction of 5% to allow for rejection due to visual override.*

1 The yields for C14 and C16 were very high – up to 95% was observed. However, the lowest yield obtained for C16 was about 72% for the 115 x 35 mm section size.

2 The yield for C18 were observed to be as high as 90% after allowance for visual override but the thinner sections gave relatively poor yields (115x35 mm returned a yield of 57% and 150x35 mm yielded 71%).

3 The yields for C22 ranged from 33% to 83%.

4 The yields for C24 ranged from 16% to 78%.

5 Yields were greatly affected by the thickness of the timber being graded. In general, the thinner sections gave lower yields for grades above C14. However, the 35 mm thickness comprised only 14.6% of the total sample.

6 The relatively lower yields obtained for the 35mm thickness section are not unexpected. Although no detailed investigation has been carried out to determine the reasons for this, several contributory factors have been suggested based on observations made in previous studies. These include :

a) the same size knots occupy a greater proportion of a smaller section than of a larger section;

b) since the smaller sections are generally converted from smaller sized logs the proportion of juvenile wood (which has lower strength) is greater in these sections;

c) the effect of thickness to span ratio in the machine may be too severe for the thinner sections.

7 The use of combined strength class grading produced lower yields in the lower strength classes.

8 Yields for combined strength classes, which are adjacent to each other, such as C16/C14 or C18/C16, have not been produced because such combinations are not permitted. This is because the settings are too close to each other and the machines are not sensitive enough to discriminate between adjacent classes. The considerable overlap that occurs makes it inadvisable, therefore, to grade to such combinations.

9 Grading to strength classes higher than C24 is not recommended until further work is conducted with this grade to ascertain if the strength properties of the timber graded into this class meet the strength requirements of this class.

10 As quality varies between forests and regions, confirmatory strength tests should be conducted on samples within the different strength classes and from different sources. This would be particularly necessary if strength classes higher than C24 are required in the market place.

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