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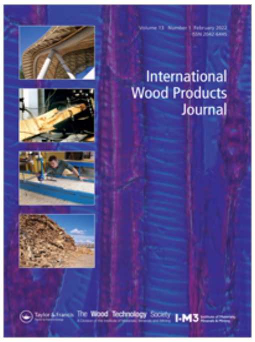

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RESEARCH ARTICLE

Strength grading of timber in the UK and Ireland in 2021

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ABSTRACT
This paper summarises the state of the art for strength grading of construction timber grown in the United Kingdom and the Republic of Ireland. It includes the latest approvals based on recent research on spruce, larch and Douglas-fir. It lists the following information along with the primary references: visual grading grades and strength class assignments; grading machines with approved settings for machine control grading; the species, size ranges and strength class combinations covered; and grade determining properties of specific strength classes for the UK and Irish markets. This paper is useful for those grading timber, and those specifying UK and Irish grown timber.

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Grades; classes; machine strength grading; visual strength grading; structural timber; EN14081

Introduction

In Europe, structural timber is graded under the system set out by the European standard EN14081-1 and its supporting standards (e.g. Lycken et al. 2020). It sorts rectangular cross-section timber into categories based on required characteristic values of grade determining properties. For normal construction timber those primary (grade determining) properties are usually bending strength, bending stiffness and density (at 12% reference moisture content).

Instead of bending, grading can also be based on tension strength and stiffness. Either way, characteristic values of strength and density are specified as fifth percentiles and stiffness by the mean. No tension grading has yet been established for UK and Irish grown timber (although some testing has been done: Ó Fátharta et al. 2020; Gil-Moreno et al. 2019a). In the case of grading established on the basis of bending testing, the tension strength is one of the secondary properties, calculated from equations in EN384. In the case of grading on the basis of tension testing, the bending strength is a secondary property. Grading based on tension testing is most commonly done for glulam production, since tension strength is more important for the design. Since little UK and Irish is currently used for glulam manufacture, there has been no priority for developing tension based grading for this resource.

The UK and Ireland have very similar climatic conditions and forest management, and a long-established exchange timber market with logs crossing the border. This is one of the reasons that modern grading rules usually treat both countries as a single growth area, particularly for Sitka spruce but also more recently for Douglas-fir (Gil-Moreno et al. 2019b) and larch. Collaborative research between Edinburgh Napier University and the National University of Ireland Galway, in the 'Strategic Integrated Research in Timber' projects and the 'WoodProps for Ireland' programme have confirmed the timber to be suitably similar for the purposes of grading. The research has also shown that the resource is dissimilar to timber grown elsewhere in Europe, with grading tending to be limited by wood stiffness for spruce and larch, as opposed to strength in other places. This is due to differences in climate, forest management, species choice and seed selection. One major difference is higher wind exposure; its effects on wood properties and limits on rotation length.

This paper covers the position in the UK and Ireland as of December 2021 and is for guidance only. When grading, the primary references should be consulted, noting that new assignments and settings can be added, existing ones can be changed, and even the definition of EN338 strength classes may change. The machine grading reports listed are confidential, but the reference number helps to identify the relevant machine settings table. Contact the machine manufacturer or a Notified/Approved Body to obtain more information about specific settings.

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Current grading possibilities

There are two parallel systems for grading: visual and machine, both of which follow the same basis: timber is sorted into grades according to a non-destructive assessment that is predictive of the grade determining properties; and the collective characteristic properties of the timber sorted into those grades determines the strength class (see Ridley-Ellis et al. 2016a for a more detailed explanation). The timber design properties are therefore usually specified with reference to one of the strength classes listed in the European standard EN338, although there are other strength classes in use (see below). It is also possible to declare all properties directly, without reference to a strength class.

The so-called 'user-defined' strength classes are convenient when grading for particular uses, as part of a fabrication process, or for a specific customer, since it makes better use of the real properties of the graded timber and/or the performance requirements for the intended use (see Ridley-Ellis et al. 2016b for discussion of the potential for this, and illustration with UK grown timber). The definition of UK and Irish specific strength classes is given in Table 1. Also included is TR26, which has been in long standing common usage in the trussed rafter industry in the UK and Ireland, and has its origins in previous design codes. The other strength classes are more recent and were developed to maximise the potential of home-grown timber.

Species are commonly grouped for grading, in which case the individual species do not have to be differentiated during production. The species and species groupings in use for UK and Irish grown timber are listed in Table 2. These groups are based on long standing practice and reflect the mixtures grown and harvested together, although single batches of timber may well be of only one species. Note that the name 'British spruce' suggests a certain geographical origin, but that is not part of the species combination definition and the mix of Sitka and Norway spruce is also used elsewhere. Research is currently

Table 2. Species codes and combinations in use with UK and Irish grown timber.

Group	Common name	Botanical name	Reference
British spruce WPCS	Sitka spruce PCST	*Picea sitchensis*	EN14081-1:2016 (§B2)
	Norway spruce PCAB	*Picea abies*	
British pine WPNN	Scots pine PNSY	*Pinus sylvestris*	EN14081-1:2016 (§B2)
	Corsican pine* PNNL	*Pinus nigra* subsp. *laricio*	
Larch WLAD	European larch LADC	*Larix decidua*	EN14081-1:2016 (§B2)
	Hybrid larch LAER	*Larix × marschlinsii (syn. L. × eurolepsis)*	
	Japanese larch LAKM	*Larix kaempferi*	
Douglas-fir	Douglas-fir PSMN	*Pseudotsuga menziesii*	EN13556:2003 (Tab2)
Oak	European oak QCXE	*Quercus petraea*	EN13556:2003 (Tab1)
		Quercus robur	
Sweet chestnut	Sweet chestnut CTST	*Castanea sativa*	EN13556:2003 (Tab1)

*The standards and machine settings tables use the more general specification *Pinus nigra*, but with the relatively large volume of Corsican pine planted in the UK, and the more specific designation in older versions of BS5268-2, it can be assumed to refer to this.

Table 1. Definition of UK and IE specific strength classes (reference moisture content is 12%). Year of approval in bold.

Class	Better than EN338	5th percentile strength (N/mm^2) Bending	Mean stiffness (kN/mm^2) Bending	5th percentile density (kg/m^3)	Reference (first report to use)
TR26	>C24	28.3	11.0	370	See *
C16+	>C16	18.5	8.0	330	TG1/**2014**10/34rev
NapierSA	>C24	25.0	11.0	375	TG1/**2017**03/27rev (intended for use with spruce)
NapierSB	>C22	22.0	10.0	360	
NapierSC	>C16	16.0	8.0	320	
NapierSD	>C14	15.0	7.0	310	
NapierLA	>C30	30.0	13.0	480	TG1/**2017**03/26rev (intended for use with larch)
NapierLB	>C27	28.0	12.0	440	
NapierLC	>C18	21.0	9.0	400	
NapierLD	>C16	20.0	8.0	390	
NapierDA	>C35	35.0	13.0	460	TG1/**2018**04/25 (intended for use with Douglas-fir)
NapierDB	>C30	30.0	12.0	460	
NapierDC	>C16	16.0	10.0	400	
NapierDD	>C14	14.0	9.0	400	
batten14	>C14	14.0	7.5	330	TG1/**2018**10/16 (intended for small dimension spruce)
batten12	–	12.0	7.5	330	
batten10	–	10.0	7.0	330	

*TR26 was introduced in 1996. Limit states characteristic values were later listed in EN14081-4. See also Trussed Rafter Association 2021.

under way to extend these species combinations for more flexible grading (Ridley-Ellis 2020).

Visual grading is carried out according to grading rules that are usually (but do not have to be) national standards. Assignment to a strength class is specific to a combination of grading standard and timber source. Assignments to EN338 strength classes that have been approved by CEN TC124/WG2/TG1 and its predecessors are listed in EN1912. The standard is currently being updated to include the most recent assignments. There are no new visual grading approvals for UK or Irish grown timber to be included. However, the revision of EN1912 is expected to include a change to reflect equivalence between these two countries, of the national softwood grading standards (BS4978 and IS127) and the timber. The current visual assignments for the timber grown in the two countries grown are listed in Tables 3 and 4. When intending to use a particular species, grown in the UK or Ireland, it is important to consider what visual strength classes are possible, and to design and specify accordingly.

Machine grading can be by machine control or output control. Output control requires the producer to periodically test batches of graded timber and, if necessary (by statistical procedures), adjust the grading machine settings to ensure grading proceeds correctly and efficiently. This method is not common in Europe, but it allows the use of any grading machine that meets the general requirements of EN14081. The much more common method is machine control, where settings are determined by previous testing and the grading machines of a certain model are expected to have identical performance. These settings are examined and approved by European Committee for Standardization (CEN) committee TC124/WG2/TG1 ('TG1'), which consists of a panel of experts with sufficient experience to be able to identify potential problems separate from simple compliance with the standards. See http://blogs.napier.ac.uk/cwst/tg1/ for the latest additional rules and guidelines from TG1.

Table 5 shows a summary of the grade determining properties (as means and coefficients of variation) for the species that can be machine graded in both countries. For spruce, Douglas-fir and larch these are based on datasets from recent grading settings work (by Edinburgh Napier University and the National University of Ireland Galway) using current standards. For Scots pine the dataset has not been used for grading settings work, but is considered representative of the resource (it is a combination of unpublished data from BRE, Forest Research, Edinburgh Napier University, and the National University of Ireland Galway, Moore et al. 2008 and Ó Fátharta et al. 2020). A range is quoted as a rough approximation of the typical production variation from batch to batch. For spruce, there is a more scientific exploration of that variation at forest level given in Moore et al. 2013. For Douglas-fir there is an exploration at grading level in Gil-Moreno et al. 2019b. Additional information on the wood properties and uses of Sitka spruce and Scots pine can be found on Moore (2011) and McLean (2019).

Machines currently approved for machine control grading are listed in Table 6. Currently available

Table 3. Visual grading assignments for timber grown in UK and Ireland when grading with BS4978 or IS127 to EN338.

Species	Source	Visual grade	Strength class	Reference
		To IS127		
Norway spruce Sitka spruce	IE	GS	C14	EN1912:2012 (§6)
Norway spruce Sitka spruce	IE	SS	C18	EN1912:2012 (§6)
		To BS4978		
British spruce (Sitka & Norway)	UK	GS	C14	EN1912:2012 (§6)
		SS	C18	EN1912:2012 (§6)
British pine	UK	GS	C14	EN1912:2012 (§6)
		SS	C22	EN1912:2012 (§6)
Larch	UK	GS	C16	EN1912:2012 (§6)
		SS	C24	EN1912:2012 (§6)
Douglas-fir	UK	GS	C14	EN1912:2012 (§6)
		SS	C18	EN1912:2012 (§6)
		SS*	C24	PD6693-1:2019 (§7.2)

Note 1: Assignment via BSI Published Document PD6693-1, possible in combination with the UK National Annex to BSEN1995-1-1, is on the basis of long standing use without problems (assignment was in BS5268-2).
Note 2: It is expected the continuing revision of EN1912 will extend the assignments of BS4978 to apply to IS127 and to change the source of spruce for both standards to UK and IE.
* cross-section area >20,000 mm^2, width and thickness ≥ 100 mm.

Table 4. Visual grading assignments when grading with BS5756.

Species	Source	Visual grade	Strength class	Reference
Oak	UK	TH2	D24	PD6693-1:2019 (§7.1)
		TH1	D30	PD6693-1:2019 (§7.1)
		THB*	D30	PD6693-1:2019 (§7.1)
		THA*	D40	PD6693-1:2019 (§7.1)
Sweet chestnut	UK	TH1	D24	PD6693-1:2019 (§7.1)

Note: Assignment via BSI Published Document PD6693-1, possible in combination with the UK National Annex to BSEN1995-1-1, is on the basis of long standing use without problems (assignment was in BS5268-2).
*cross-section area >20,000 mm^2, width and thickness ≥ 100 mm.

Table 5. Typical average properties of UK and IE grown softwoods before grading (Of a batch of timber at 12% moisture content, with the EN384 k_h factor).

	Dataset size	Mean bending strength (N/mm^2)	Mean bending stiffness (kN/mm^2)	Mean density (kg/m^3)
Sitka and Norway spruce	~2000	30–33 (CoV 30%)	7.5–8.5 (CoV 30%)	380–410 (CoV 10%)
Scots pine	~500	36–46 (CoV 30%)	8.5–10.0 (CoV 30%)	480–550 (CoV 10%)
European, Japanese and hybrid larch	~1000	37–44 (CoV 30%)	9.5–10 (CoV 25%)	480–530 (CoV 12%)
Douglas-fir	~700	28–50 (CoV 35%)	8.5–13 (CoV 25%)	450–550 (CoV 10%)

settings for British and Irish grown timber are listed in Table 7 (spruce), Table 8 (pine), Table 9 (larch) and Table 10 (Douglas-fir). The existence of grading settings for a species and strength class does not mean that the grades will be easily available on the market. Most producers currently aim for maximum yield on a single grade-reject setting that produces the grades commonly placed on the UK and Irish markets, most commonly C16.

Certain machines can work in different modes, and use the settings approved for a different machine, typically from the same manufacturer. Machines from different manufacturers with proven performance equivalence, and agreement of the manufacturers, can also use the same settings. Note that machine grading is based on the assessment of the grade determining properties by methods summarised in Table 6. This is a separate route from visual grading, and parameters like knot size and ring width are not inherent in the definition of the strength classes, which are concerned with the actual characteristic properties. This means that machine grading will pass some pieces that fail visual grading rules and reject some pieces that

Table 6. List of grading machines approved for machine control. In bold the machines with machine control settings available for UK and Ireland.

Manufacturer	Name	ID*	Description
Tecmach Ltd	***Cook Bolinders***	1	Mechanical bending
Measuring and Process Control Ltd	***Computermatic Micromatic***	2	Mechanical bending
VTT	*Raute Timbergrader*	3	Mechanical bending
Microtec s.r.l. – GmbH	*EuroGrecomat-702*	4	X-ray
	Goldeneye 702/802	5	X-ray
	EuroGrecomat-704	6	X-ray & mechanical bending
	Viscan	8	Longitudinal resonance
	EuroGrecomat-706	9	X-ray & longitudinal resonance
	Goldeneye 706/806	10	X-ray & longitudinal resonance
	Viscan Plus	20	Longitudinal resonance & X-ray density
	Viscan Compact	22	Longitudinal resonance & density
	Viscan portable with balance	29	Portable, longitudinal resonance & density
	Viscan portable without balance	30	Portable, longitudinal resonance
Microtec AB (Microtec Linköping)	*WoodEye Strength Grader*	31	Longitudinal resonance,density & laser tracheid grain angle
Microtec Innovating Wood Oy (Microtec Espoo)	*Finscan Nova*	36	Camera scanning (visual & near infrared)
	Finscan HD	37	Camera scanning (visual)
Dynalyse AB	*Dynagrade*	7	Longitudinal resonance
	Precigrader	12	Longitudinal resonance & density
Brookhuis Applied Technologies BV	***MTG 960***	11	Portable, longitudinal resonance & density
	mtgESCAN 962/966	14	Longitudinal resonance & density
	MTG 920	19	Portable, longitudinal resonance
	MTGbatch 962/966	23	Longitudinal resonance & density
	MTGbatch 922/926	24	Longitudinal resonance
	mtgESCAN 922/926	26	Longitudinal resonance
Dimter GmbH	*Grademaster*	13	Longitudinal resonance, density & knots
Luxscan technologies	***Escan FWM/FW***	14	Longitudinal resonance & density
	EScan FM/F	26	Longitudinal resonance
	OptiStrength XE	33	X-ray & longitudinal resonance
	OptiStrength X	34	X-ray
Concept Bois Structure SARL	*Triomatic*	15	Ultrasonic time of flight & pin indentation density
Automatisation J.R.T Inc	*CRP*	16	Mechanical bending
XYLOMECA	*Xyloclass T*	17	Longitudinal resonance & density
	Xyloclass F	21	Flexural resonance & density
SARL Esteves	*Noesys*	18	Flexural resonance & density
Rosén & Co Maskin	*Rosgrade*	25	Longitudinal resonance
	Rosgrade plus	28	Longitudinal resonance & density
Innodura	*E-CONTROL model AC*	27	Longitudinal resonance & density
RemaSawco AB	*RS Strength Grader*	32	Laser tracheid grain angle
	RS Strength Grader Density	39	Laser tracheid grain angle & density
Ilkon	*STIG*	35	Portable, longitudinal resonance
M. Manfred Hudel	*MODULO*	38	Mechanical bending

*ID relates to the TG1 machine number for naming the ITT reports (settings tables). Note that machines 14 and 26 have different names depending on the manufacturer providing it.

Table 7. Machine settings for British spruce WPCS (*Picea sitchensis*, *P. abies*).

Source	Size (mm) & *report by*	Combinations	[Machine] & *table*	Reference
UK IE	35-75 × 60-300 *UKTGC Timbersolve*	[C24/C16] [C18] [C16]	[1]-*1*	TG2/0801/03 TG1/0211/15
UK IE	35-75 × 60-300 *UKTGC Timbersolve*	[C24/C16] [C18] [C16]	[2]-*1*	TG2/0801/03 TG1/0211/15
UK IE	35-80 × 70-260 *HFM*	[C24/C16] [C16]	[5]-*1a* also [10]	EN14081-4:2009 TG1/1005/08
UK IE	35-82 × 57-275 *Napier Uni*	[C24/C16] [C22/C14] [C18] [C16]	[5]-*17* also [10]	TG1/0211/13rev
UK IE	20-83 × 47-275 (*A) *Napier Uni*	[C24/C16] [C22/C14] [C18] [C16] [C16+]	[5]-*34* also [10]	TG1/201410/38rev2
UK IE	34-83 × 57-275 *Napier Uni*	[C24/C16] [C22/C14] [C20/C14] [C18] [C16] [C24/C16+] [C16+]	[5]-*48* also [10]	TG1/201703/21rev
UK IE	20-52 × 35-67 (*B) *Napier Uni*	[C14] [batten14] [batten12] [batten10]	[5]-*54* also [10]	TG1/201810/16
UK IE	35-82 × 57-275 *Napier Uni*	[C22/C14] [C18] [C16]	[8]-*18* also [10] [20] [22]	TG1/0211/10rev
UK IE	20-83 × 47-275 (*A) *Napier Uni*	[C22/C14] [C18] [C16] [C16+]	[8]-*32* also [10] [20] [22]	TG1/201410/35
UK IE	34-83 × 57-275 *Napier Uni*	[C24/C16] [C22/C14] [C20/C14] [C18] [C16] [C24/C16+] [C16+]	[8]-*45* also [10] [20] [22]	TG1/201703/25rev
UK IE	35-82 × 57-275 *Napier Uni*	[C27/C16] [C24/C16] [C22/C14] [C18] [C16] [TR26/C16]	[10]-*22*	TG1/0211/14rev
UK IE	20-83 × 47-275 (*A) *Napier Uni*	[C27/C16] [C24/C16] [C22/C14] [C18] [C16] [TR26/C16] [C16+]	[10]-*43*	TG1/201410/39
UK IE	34-83 × 57-275 *Napier Uni*	[C27/C16] [C24/C16] [C22/C14] [C20/C14] [C18] [C16] [C27/C16+] [TR26/C16] [TR26/C16+] [C24/C16+] [C16+]	[10]-*58*	TG1/201703/22rev
UK IE	20-83 × 47-165 (*A) *Napier Uni*	[C24/C16] [C22/C14] [C20] [C18] [C16]	[11]-*13*	TG1/201410/34rev
UK IE	34-84 × 84-168 *Napier Uni*	[C27/C16] [C24/C16] [C22/C14] [C20] [C18] [C16] [NapierSA/ NapierSC] [NapierSB/NapierSD]	[11]-*18*	TG1/201703/27rev
UK IE	20-83 × 47-165 (*A) *Napier Uni*	[C18] [C16] for grading while green	[11]-*22*	TG1/201410/40rev2
UK IE	20-52 × 35-54 (*B) *Napier Uni*	[C14]	[11]-33	TG1/201807/02rev
UK IE	34-82 × 69-247 *FCBA*	[C27/C18] [C27/C16] [C24/C16] [C24] [C18] [C16] [TR26/C16] [TR26]	[12]-*9*	TG1/1011/11rev
UK IE	34-83 × 57-247 (*C) RISE	[TR26/C16] [C27/C18] [C27/C16] [C24/C16] [TR26] [C24] [C18] [C16]	[12]-*20*	TG1/202104/11
UK IE	20-83 × 47-165 (*A) *Napier Uni*	[C24/C16] [C24/C14] [C22/C14] [C22] [C20] [C18] [C16] [C16+]	[14]-*14*	TG1/201410/34rev
UK IE	20-83 × 47-165 (*A) *Napier Uni*	[C22] [C20] [C18] [C16] for grading while green	[14]-*26*	TG1/201410/40rev2
UK IE	20-83 × 47-165 (*A) *Napier Uni*	[C20] [C18] [C16]	[19]-*10*	TG1/201410/33rev
UK IE	35-82 × 57-275 *Napier Uni*	[C24/C16] [C22/C14] [C18] [C16]	[20]-*6* also [10]	TG1/0211/12rev
UK IE	20-83 × 47-275 (*A) *Napier Uni*	[C24/C16] [C22/C14] [C18] [C16] [C16+]	[20]-*25* also [10]	TG1/201410/37
UK IE	34-83 × 57-275 *Napier Uni*	[C27/C16] [C24/C16] [C22/C14] [C20/C14] [C18] [C16] [C27/C16+] [TR26/C16] [TR26/C16+] [C24/C16+] [C16+]	[20]-*39* also [10]	TG1/201703/24rev
UK IE	35-82 × 57-275 *Napier Uni*	[C24/C16] [C22/C14] [C18] [C16]	[22]-*4* also [10]	TG1/0211/11rev
UK IE	20-83 × 47-275 (*A) *Napier Uni*	[C24/C16] [C22/C14] [C18] [C16] [C16+]	[22]-*24* also [10]	TG1/201410/36
UK IE	34-83 × 57-275 *Napier Uni*	[C27/C16] [C24/C16] [C22/C14] [C20/C14] [C18] [C16] [C27/C16+] [TR26/C16] [TR26/C16+] [C24/C16+] [C16+]	[22]-*37* also [10]	TG1/201703/23rev
UK IE	20-83 × 47-165 (*A) *Napier Uni*	[C24/C16] [C24/C14] [C22/C14] [C22] [C20] [C18] [C16] [C16+]	[23]-*13*	TG1/201410/34rev
UK IE	20-83 × 47-165 (*A) Napier Uni	[C22] [C20] [C18] [C16] for grading while green	[23]-*25*	TG1/201410/40rev2
UK IE	20-83 × 47-165 (*A) Napier Uni	[C22/C14] [C20] [C18] [C16]	[24]-*10*	TG1/201410/33rev
UK IE	20-83 × 47-165 (*A) Napier Uni	[C22/C14] [C20] [C18] [C16]	[26]-*10*	TG1/201410/33rev
UK IE	34-83 × 57-275 Napier Uni	[C24/C16] [C22/C14] [C18] [C16] [TR26/C16] [TR26/C16+] [C24/C16+]	[29]-*20* also [10] [22]	TG1/201703/23rev
UK IE	34-83 × 57-275 Napier Uni	[C22/C14] [C18] [C16]	[30]-*18* also [8] [10] [20] [22]	TG1/201703/25rev

(*A): Minimum cross-section area ≥ 1600 mm^2.
(*B): Minimum cross-section area ≥ 900 mm^2.
(*C): Minimum cross-section area ≥ 2155 mm^2.

pass visual grading. This is not incorrect grading, since grading is about the collective properties of the graded timber and not the properties of any particular piece. Visual grading and different grading machines will achieve the required collective properties of the graded timber by different sorting criteria.

Table 8. Machine settings for British pine WPNN (Pinus sylvestris, P. nigra).

Source	Size (mm) & *report by*	Combinations	[Machine] & *table*	Reference
UK IE	35-75 × 60-300 UKTGC	[C24/C16] [C16]	[1]-*1*	EN14081-4:2009 TG2/0801/02
UK IE	35-75 × 60-300 UKTGC	[C24/C16] [C16]	[2]-*1*	EN14081-4:2009 TG2/0801/02

Note also that the United Kingdom is officially GB in ISO3166-1, but sometimes appears in standards and settings tables as UK. UK is used in this paper as the more familiar abbreviation. In the context of growth areas, Northern Ireland is included with this use of the abbreviation GB.

Table 9. Machine settings for larch WLAD (*Larix decidua*, L. x *eurolepis*, *L. kaempferi*).

Source	Size (mm) & *report by*	Combinations	[Machine] & *table*	Reference
UK	43-82 × 92-250 *Timbersolve*	[C27/C16] [C18] [C16]	[1]-*4*	TG2/0801/03 TG1/0511/02
UK	43-82 × 92-250 *Timbersolve*	[C27/C16] [C18] [C16]	[2]-*5*	TG2/0801/03 TG1/0511/02
UK	20-110 × 47-303 (*D) *Napier Uni*	[C30/C16] [C27/C16] [C24/C14] [C22] [TR26/C14]	[5]-*31* also [10]	TG1/201410/21rev1
UK IE	20-110 × 42-303 (*A) *NUI Galway & Napier Uni*	[C35/C18] [C30/C16] [C27/C16] [C24/C14] [C22] [TR26/C16] [TR26/C14]	[5]-*73* also [10]	TG1/202005/07rev1
UK	20-110 × 47-303 (*D) *Napier Uni*	[C30/C16] [C27/C16] [C24/C14] [C22] [TR26/C14]	[8]-*29* also [10] [20] [22]	TG1/201410/18
UK IE	20-110 × 42-303 (*A) *NUI Galway & Napier Uni*	[C30/C16] [C27/C16] [C24/C14] [C22] [TR26/C16] [TR26/C14]	[8]-*61* also [10] [20] [22]	TG1/202005/06rev1
UK	20-110 × 47-303 (*D) *Napier Uni*	[C35/C18] [C30/C16] [C27/C16] [C24/C14] [C22] [TR26/C14]	[10]-*39*	TG1/201410/22
UK IE	20-110 × 42-303 (*A) *NUI Galway & Napier Uni*	[C35/C18] [C30/C16] [C27/C16] [C24/C14] [C22] [TR26/C16] [TR26/C14]	[10]-*84*	TG1/202005/08rev1
UK	20-110 × 47-303 (*D) *Napier Uni*	[C30/C16] [C27/C16] [C24/C14] [C22] [C20] [TR26/C16]	[11]-*12*	TG1/201410/32
UK	42-112 × 88-307 *Napier Uni*	[C35/C18] [C30/C16] [C27/C16] [C24/C14] [C22] [C20] [NapierLA/NapierLC] [NapierLB/NapierLD]	[11]-*19*	TG1/201703/26rev
UK IE	20-110 × 42-303 (*A) *NUI Galway & Napier Uni*	[C30/C18] [C27/C16] [C24/C16] [C24/C14] [C22] [C20] [NapierLA/NapierLC] [NapierLB/NapierLD] [TR26/C14]	[11]-*29*	TG1/202005/14rev1
UK	32-110 × 60-248 RISE	[C24/C16] [C18] [C16]	[12]-*18*	TG1/201810/11rev
UK	20-110 × 47-303 (*D) *Napier Uni*	[C30/C16] [C27/C16] [C24/C14] [C22] [TR26/C14]	[14]-*16*	TG1/201410/32
UK IE	20-110 × 42-303 (*A) *NUI Galway & Napier Uni*	[C30/C18] [C30/C16] [C27/C16] [C24/C16] [C24/C14] [C22] [NapierLA/NapierLC] [NapierLB/NapierLD] [TR26/C14]	[14]-*35*	TG1/202005/14rev1
UK	20-110 × 47-303 (*D) *Napier Uni*	[C30/C16] [C27/C16] [C24/C14] [C22] [C20] [TR26/C16]	[19]-*9*	TG1/201410/31rev
UK IE	20-110 × 42-303 (*A) *NUI Galway & Napier Uni*	[C30/C16] [C27/C16] [C24/C16] [C24/C14] [C22] [C20] [NapierLB/NapierLD] [TR26/C16]	[19]-*14*	TG1/202005/14rev1
UK	20-110 × 47-303 (*D) *Napier Uni*	[C35/C18] [C30/C16] [C27/C16] [C24/C14] [C22] [TR26/C14]	[20]-*22* also [10]	TG1/201410/20rev
UK IE	20-110 × 42-303 (*A) *NUI Galway & Napier Uni*	[C35/C18] [C30/C16] [C27/C16] [C24/C14] [C22] [TR26/C16] [TR26/C14]	[20]-*61* also [10]	TG1/202005/05rev1
UK	20-110 × 47-303 (*D) *Napier Uni*	[C35/C18] [C30/C16] [C27/C16] [C24/C14] [C22] [TR26/C14]	[22]-*21* also [10]	TG1/201410/19
UK IE	20-110 × 42-303 (*A) *NUI Galway & Napier Uni*	[C35/C18] [C30/C16] [C27/C16] [C24/C14] [C22] [TR26/C16] [TR26/C14]	[22]-*61* also [10]	TG1/202005/04rev1
UK	20-110 × 47-303 (*D) *Napier Uni*	[C30/C16] [C27/C16] [C24/C14] [C22] [TR26/C14]	[23]-*15*	TG1/201410/32
UK IE	20-110 × 42-303 (*A) *NUI Galway & Napier Uni*	[C30/C18] [C30/C16] [C27/C16] [C24/C16] [C24/C14] [C22] [NapierLA/NapierLC] [NapierLB/NapierLD] [TR26/C14]	[23]-*34*	TG1/202005/14rev1
UK	20-110 × 47-303 (*D) *Napier Uni*	[C30/C16] [C27/C16] [C24/C14] [C22] [TR26/C14]	[24]-*9*	TG1/201410/31rev
UK IE	20-110 × 42-303 (*A) *NUI Galway & Napier Uni*	[C30/C16] [C27/C16] [C24/C16] [C24/C14] [C22] [NapierLB/NapierLD] [TR26/C16] [TR26/C14]	[24]-*14*	TG1/202005/14rev1
UK	20-110 × 47-303 (*D) *Napier Uni*	[C30/C16] [C27/C16] [C24/C14] [C22] [TR26/C14]	[26]-*9*	TG1/201410/31rev
UK IE	20-110 × 42-303 (*A) *NUI Galway & Napier Uni*	[C30/C16] [C27/C16] [C24/C16] [C24/C14] [C22] [NapierLB/NapierLD] [TR26/C16] [TR26/C14]	[26]-*14*	TG1/202005/14rev1
UK	20-110 × 47-303 (*D) *Napier Uni*	[C35/C18] [C30/C16] [C27/C16] [C24/C14] [C20] [TR26/C16]	[29]-*11* also [10] [22]	TG1/201410/23
UK IE	20-110 × 42-303 (*A) *NUI Galway & Napier Uni*	[C35/C18] [C30/C16] [C27/C16] [C24/C14] [C22] [C20] [TR26/C16] [TR26/C14]	[29]-*37* also [10] [22]	TG1/202005/04rev1
UK	20-110 × 47-303 (*D) *Napier Uni*	[C30/C16] [C27/C16] [C24/C14] [C20] [TR26/C16]	[30]-*9* also [8] [10] [20] [22]	TG1/201410/23
UK IE	20-110 × 42-303 (*A) *NUI Galway & Napier Uni*	[C30/C16] [C27/C16] [C24/C14] [C22] [C20] [TR26/C16] [TR26/C14]	[30]-*29* also [8] [10] [20] [22]	TG1/202005/06rev1

(*A): Minimum cross-section area ≥ 1600 mm^2.
(*D): Minimum cross-section area ≥ 2000 mm^2

Table 10. Machine settings for Douglas-fir PSMN (*Pseudotsuga menziesii*).

Source	Size (mm) & *report by*	Combinations	[Machine] & *table*	Reference
UK IE	33-84 × 68-248 *Napier Uni & NUI Galway*	[C35/C18] [C35/C16] [C30/C16] [C27/C16] [C24/C16] [C24/C14] [C22/C14] [C20/C14] [C20] [C18] [C16] [TR26/C16]	[5]-*53* also [10]	TG1/201804/16
UK IE	33-84 × 68-248 *Napier Uni & NUI Galway*	[C30/C16] [C27/C16] [C24/C16] [C24/C14] [C22/C14] [C20/C14] [C20] [C18] [C16] [TR26/C16]	[8]-*47* also [10] [20] [22]	TG1/201804/17rev2
UK IE	33-84 × 68-248 *Napier Uni & NUI Galway*	[C40/C30/C16] [C40/C27/C16] [C40/C24/C16] [C35/C18] [C35/C16] [C30/C16] [C27/C16] [C24/C16] [C24/C14] [C22/C14] [C20/C14] [C20] [C18] [C16] [TR26/C16]	[10]-*63 & 64*	TG1/201804/13rev2
UK IE	33-84 × 68-248 *Napier Uni & NUI Galway*	[C35/C16] [C24/C14] [TR26/C14] [NapierDA/NapierDC] [NapierDB/NapierDD]	[11]-*24*	TG1/201804/25rev
UK BE[1]	32-110 × 60-247 (*E) RISE	[TR26/C16] [C24/C18] [C24] [C18] [C16]	[12]-19	TG1/202005/03rev1
UK IE	33-84 × 68-248 *Napier Uni & NUI Galway*	[C35/C16] [C24/C16] [C24/C14] [TR26/C14] [NapierDA/NapierDC] [NapierDB/NapierDD]	[14]-*28*	TG1/201804/25rev
UK IE	33-84 × 68-248 *Napier Uni & NUI Galway*	[C27/C16] [C24/C14] [TR26/C16]	[19]-*11*	TG1/201804/25rev
UK IE	33-84 × 68-248 *Napier Uni & NUI Galway*	[C40/C30/C16] [C40/C27/C16] [C40/C24/C16] [C35/C18] [C35/C16] [C30/C16] [C27/C16] [C24/C16] [C24/C14] [C22/C14] [C20] [C18] [C16] [TR26/C16]	[20]-*42* also [10]	TG1/201804/15rev1
UK IE	33-84 × 68-248 *Napier Uni & NUI Galway*	[C40/C30/C16] [C40/C27/C16] [C40/C24/C16] [C35/C18] [C35/C16] [C30/C16] [C27/C16] [C24/C16] [C24/C14] [C22/C14] [C20] [C18] [C16] [TR26/C16]	[22]-*40* also [10]	TG1/201804/14rev1
UK IE	33-84 × 68-248 *Napier Uni & NUI Galway*	[C35/C16] [C24/C16] [C24/C14] [TR26/C14] [NapierDA/NapierDC] [NapierDB/NapierDD]	[23]-*27*	TG1/201804/25rev
UK IE	33-84 × 68-248 *Napier Uni & NUI Galway*	[C27/C16] [C24/C16] [TR26/C16]	[24]-*11*	TG1/201804/25rev
UK IE	33-84 × 68-248 *Napier Uni & NUI Galway*	[C27/C16] [C24/C16] [TR26/C16]	[26]-*11*	TG1/201804/25rev
UK IE	33-84 × 68-248 *Napier Uni & NUI Galway*	[C40/C30/C18] [C40/C27/C16] [C40/C24/C16] [C35/C18] [C35/C16] [C30/C16] [C27/C16] [C24/C16] [C24/C14] [C22/C14] [C20/C14] [C20] [C18] [C16] [C14] [TR26/C16]	[29]-*21&22* also [10] [22]	TG1/201804/14rev1
UK IE	33-84 × 68-248 *Napier Uni & NUI Galway*	[C30/C16] [C27/C16] [C24/C16] [C24/C14] [C22/C14] [C20/C14] [C20] [C18] [C16] [C14] [TR26/C16]	[30]-*19* also [8] [10] [20] [22]	TG1/201804/17rev2

[1]BE: Belgium.
(*E): Minimum cross-section area ≥ 2840 mm^2

Developments in grading

The timber industry is not oblivious to innovations, and the use of machines for timber quality assessment using acoustic principles is well known in the sector. Since UK and Irish grown timber is mostly grade limited by its stiffness, this technique also has potential for segregation of logs before processing and grading, and also means that strength grading can be carried out by relatively simple longitudinal resonance machines (Table 6) with comparable yields to those from more complicated machines (Gil-Moreno et al. 2019b).

The large-scale multi-partner research work of the Gradewood (Ranta-Maunus 2009 and Ranta-Maunus et al. 2011) and Gradewood Transition projects, the relative simplicity of this acoustic method, and the high repeatability of this kind of measurement, led to the inclusion, in the standard EN14081-2:2018, of fixed settings to grade two of the most important species in Europe: Norway spruce (*Picea abies*) and Silver fir (*Abies alba*) (the combination 'spruce and fir whitewood', WPCA), for the grade combinations C24/C18 and T14/T11 as well as for C24, C18, T14 and T1 as single grades. This means any approved grading machines measuring longitudinal resonant frequency can grade these two species within the specified limitations for timber size and additional requirements for operation and environment and without need for further approval by TG1. The settings cover most of the European countries, and therefore will typically result in lower yields than settings developed for the specific characteristics of a particular timber source. All longitudinal resonance based machines listed in Table 6 are able to use the EN14081-2 fixed settings tables. They do not have to be repeated in the machine's settings tables, although in some cases they are.

Software development is another important field of innovation, since modern machines are able to do more than sort by simple thresholds. Some manufacturers include, in their machines, functions that allow grading of pieces before splitting into smaller cross sections. More recently, an alternative to the common machine grading by machine control has also been added to EN14081-2; the adaptive settings method. This method uses information previously collected by the machine in the grading process, and aims to automatically adjust the settings, adapting to the variability in the incoming timber, and producing a more optimised balance of yield and safety. This is not implemented in any UK or Irish sawmills where it is unlikely to provide a grading advantage for a relatively uniform resource from a relatively small geographical area. Some sawmills instead optimise their production through log pre-grading, which can reduce rejects from grading and visual override by avoiding the processing of logs likely to give problems. Powerful log pre-grading approaches have the potential to cause issues for structural timber grading if they significantly change the resource compared to what the grading settings and assignments are based on, but research is being done to develop new grading approaches to adjust for that, e.g. Weidenhiller et al. 2021. Computer tomography (CT) scanning of logs also brings the potential to grade timber before it is sawn from the log in future (e.g. Fredriksson et al. 2017 and Olofsson et al. 2019).

Concluding remarks

Timber grading in Europe is fast developing, with new machines, updating of standards and processes, and new visual grading assignments and machine grading settings added regularly. There are grading machine settings for timber grown in the UK and Ireland, which exceed the commonly held expectations of what strength classes are possible. Not all the permitted settings have commercially viable yields, but there are some grading possibilities that open up more potential for wider, and more efficient, use of the domestic forest resource, especially as machine grading becomes more accessible to building fabricators.

> Contact machine manufacturer or a Notified/Approved Body to obtain more information about grading settings tables, their limitations and yields. As things change, a supplement of this summary may be obtained from http://blogs.napier.ac.uk/cwst/tg1/

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