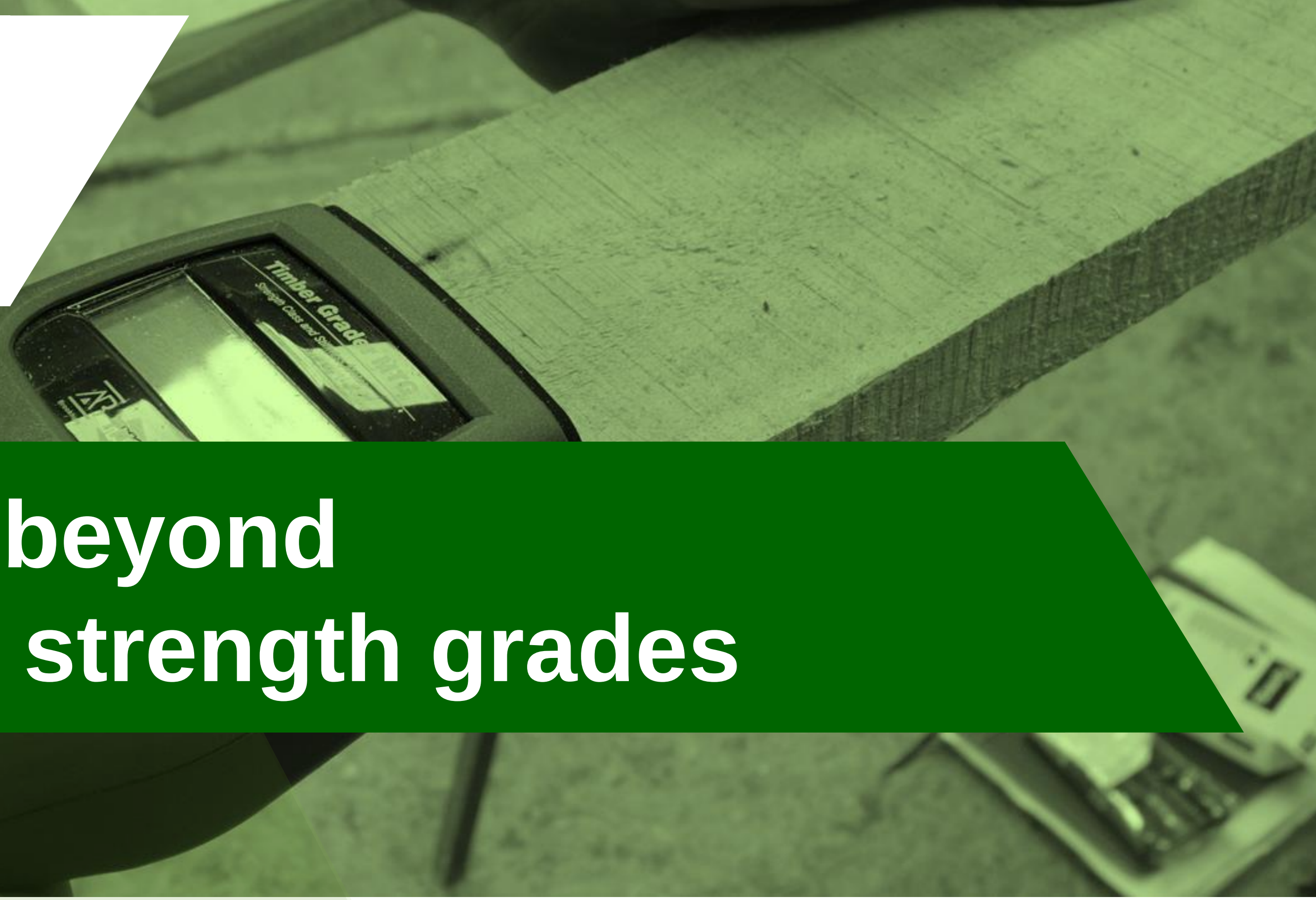
SIRT

Strategic Integrated Research in Timber



Thinking beyond the usual strength grades

Dan Ridley-Ellis
Steven Adams
Stefan Lehneke

Centre for Wood Science & Technology
Edinburgh Napier University (UK)

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2015

Variation of properties

- From species to species
- Within species / species group
  - Between countries
  - Within countries
  - Within a forest
  - Within a stand
  - Between trees in a stand
  - Between boards from a tree

∴ Use grading to get characteristic properties for design & ensure safety

For a fuller description of grading in Europe see:
Ridley-Ellis, D., Stapel, P., and Baño, V.: Strength grading of sawn timber in Europe: an explanation for engineers and researchers. *European Journal of Wood and Wood Products*, 74(3): 291-306, 2016.

Strength grades (or classes)

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e.g. EN 338:2016

'Softwood' based on edgewise bending

	Class	C14	**C16**	**C18**	C20	C22	**C24**	C27	
Strength properties in N/mm²									
Bending	$f_{m,k}$	14	**16**	**18**	20	22	**24**	27	
Tension parallel	$f_{t,0,k}$	7,2	**8,5**	**10**	11,5	13	**14,5**	16,5	
Tension perpendicular	$f_{t,90,k}$	0,4	**0,4**	**0,4**	0,4	0,4	**0,4**	0,4	**0,**
Compression parallel	$f_{c,0,k}$	16	**17**	**18**	19	20	**21**	22	**24**
Compression perpendicular	$f_{c,90,k}$	2,0	**2,2**	**2,2**	2,3	2,4	**2,5**	2,5	**2,7**
Shear	$f_{v,k}$	3,0	**3,2**	**3,4**	3,6	3,8	**4,0**	4,0	**4,**
Stiffness properties in kN/mm²									
Mean modulus of elasticity parallel bending	$E_{m,0,mean}$	7,0	**8,0**	**9,0**	9,5	10,0	**11,0**	11,5	**1**
5 percentile modulus of elasticity parallel bending	$E_{m,0,k}$	4,7	**5,4**	**6,0**	6,4	6,7	**7,4**	7,7	
Mean modulus of elasticity perpendicular	$E_{m,90,mean}$	0,23	**0,27**	**0,30**	0,32	0,33	**0,37**	0,38	
Mean shear modulus	G_{mean}	0,44	**0,50**	**0,56**	0,59	0,63	**0,69**	0,72	
Density in kg/m³									
5 percentile density	ρ_k	290	**310**	**320**	330	340	**350**	36	
Mean density	ρ_{mean}	350	**370**	**380**	400	410	**420**	4	

Grade-determining properties

(definition of a strength class: EN 384 for EN 14081)

- Strength
  - Usually major axis bending strength
  - Characteristic is the 5th percentile
- Stiffness
  - Usually major axis bending stiffness
  - Characteristic is the mean
- Density
  - Used for indirect measure of strength / fire resistance (this is not density for dead weight)
  - Characteristic is the 5th percentile

Grading aims that GDP requirements are met (subject to various adjustments)

Secondary properties

Softwood bending strength classes (as in EN 384:2016)

- Based on bending strength
  - Tension strength parallel to grain
  - Compression strength parallel to grain
  - Shear strength (up to C24, thereafter fixed)
- Based on bending stiffness
  - 5th percentile stiffness parallel to grain
  - Stiffness perpendicular to grain
  - Shear modulus
- Based on density
  - Compression strength perpendicular to grain
  - Mean density
- Fixed value (applies to all strength classes)
  - Tension strength perpendicular to grain

Must work for all species
∴ conservative values
(esp. for hardwoods)

By the way…

The definition of strength classes can (and does) change

EN338:2016 compared to 2009 version												
	Softwood											
	C14	**C16**	**C18**	C20	C22	**C24**	C27	**C30**	C35	C40	C45	C50
Strength												
Bending	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Tension parallel	-10%	-15%	-9%	-4%	0%	4%	3%	6%	7%	8%	11%	12%
Tension perpendicular	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Compression parallel	0%	0%	0%	0%	0%	0%	0%	4%	0%	4%	7%	3%
Compression perpendicular	0%	0%	0%	0%	0%	0%	-4%	0%	-4%	-3%	-6%	-6%
Shear	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Stiffness												
Mean MoE parallel	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
5% MoE parallel	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	0%
Mean MoE perpendicular	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mean G	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Density												
5% density	0%	0%	0%	0%	0%	0%	-3%	0%	-3%	-5%	-7%	-7%
Mean density	0%	0%	0%	3%	0%	0%	-4%	0%	-2%	-4%	-6%	-5%

Not just secondary properties – grade determining property requirements can also change

Example data for this paper

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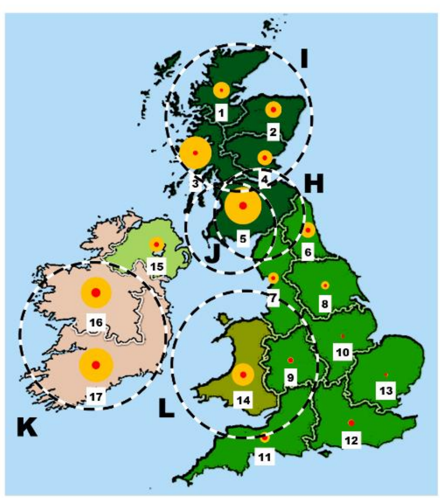
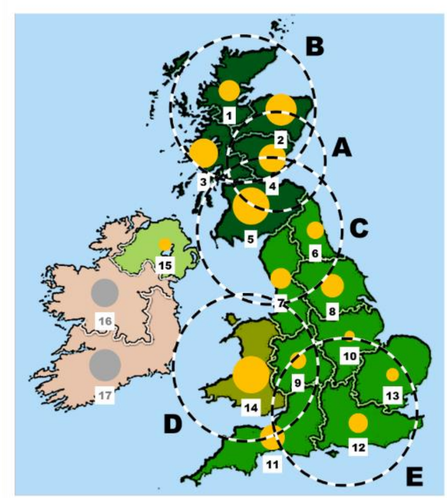
Cross-section (nominal)	Number of pieces	
	British spruce *Picea sitchensis* *Picea abies*	UK larch *Larix x eurolepis* *Larix kaempferi* *Larix decidua*
22×47	138	57
38×100	70	-
47×100	343	418
47×120	79	-
47×150	75	17
75×150	158	160
100×275	-	54
Total	**863**	**706**





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Example machines (Brookhuis)

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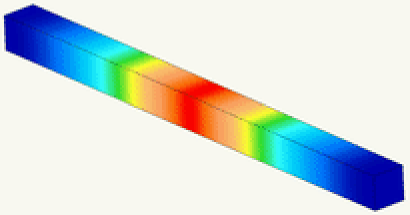
Measurements	In line (with k_v factor*)	Portable (no k_v factor)
Acoustic velocity	mtgBATCH 922/926	MTG 920
Acoustic velocity & density	mtgBATCH 962/966	MTG 960

* EN 384: Reduces characteristic strength target for classes ≤ C30 by 11%

[dynamic MOE]=[density]×[speed of sound]^2

where

[speed of sound]= 2×[length]×[1st frequency]



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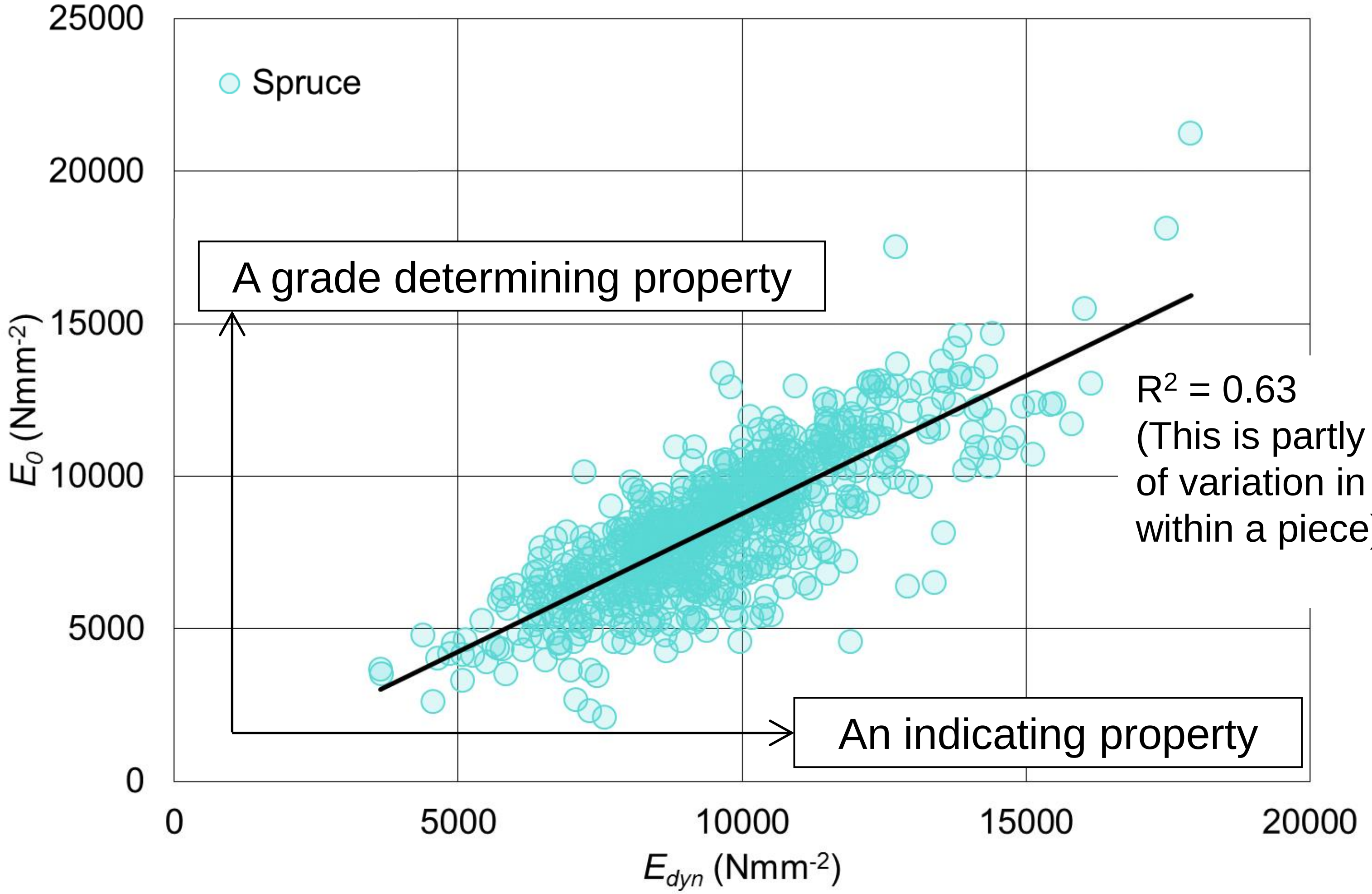
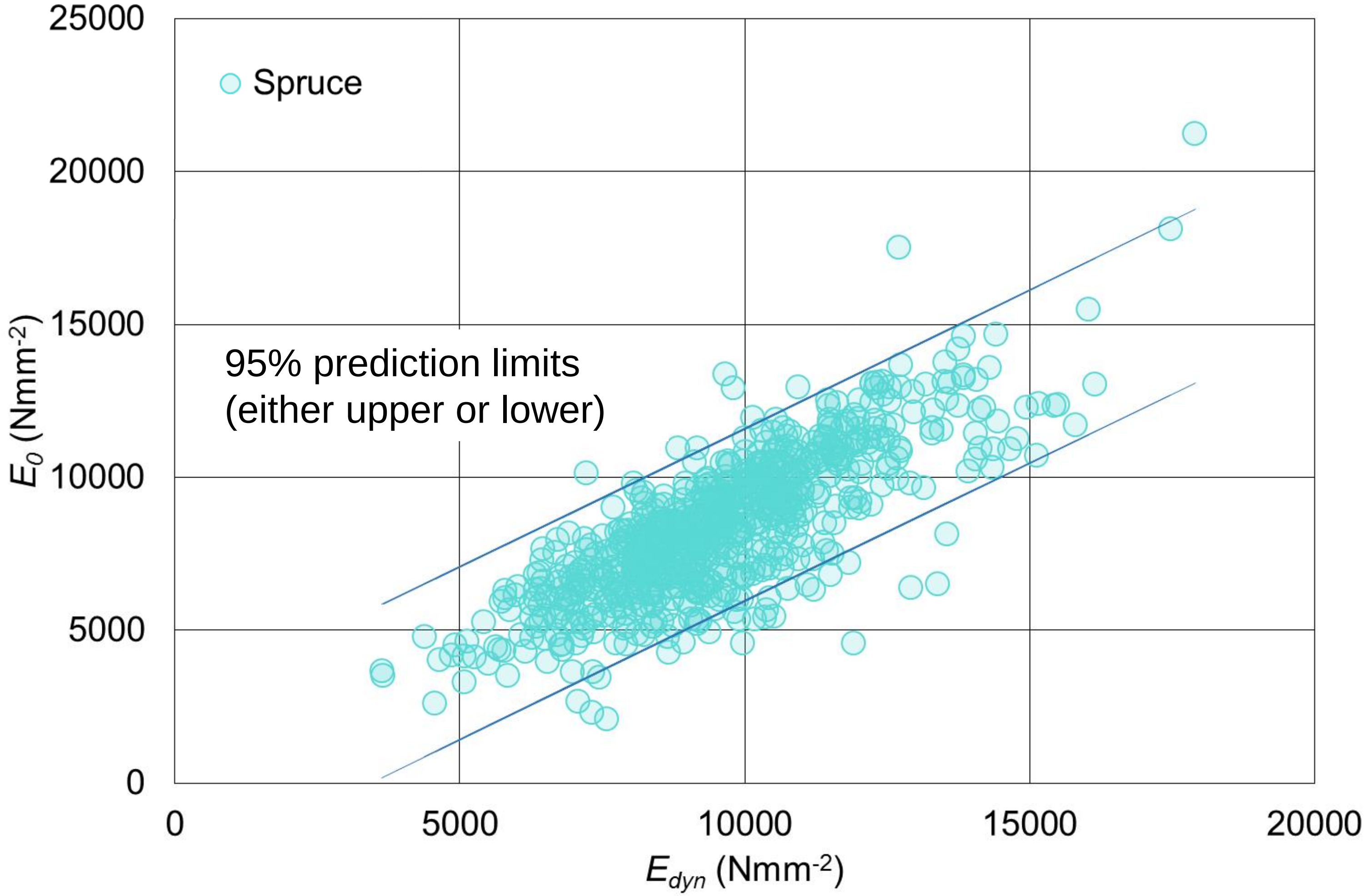
Models for bending stiffness



Note: this does not include the 22×47 dimension as they are unusually small

Models for bending stiffness



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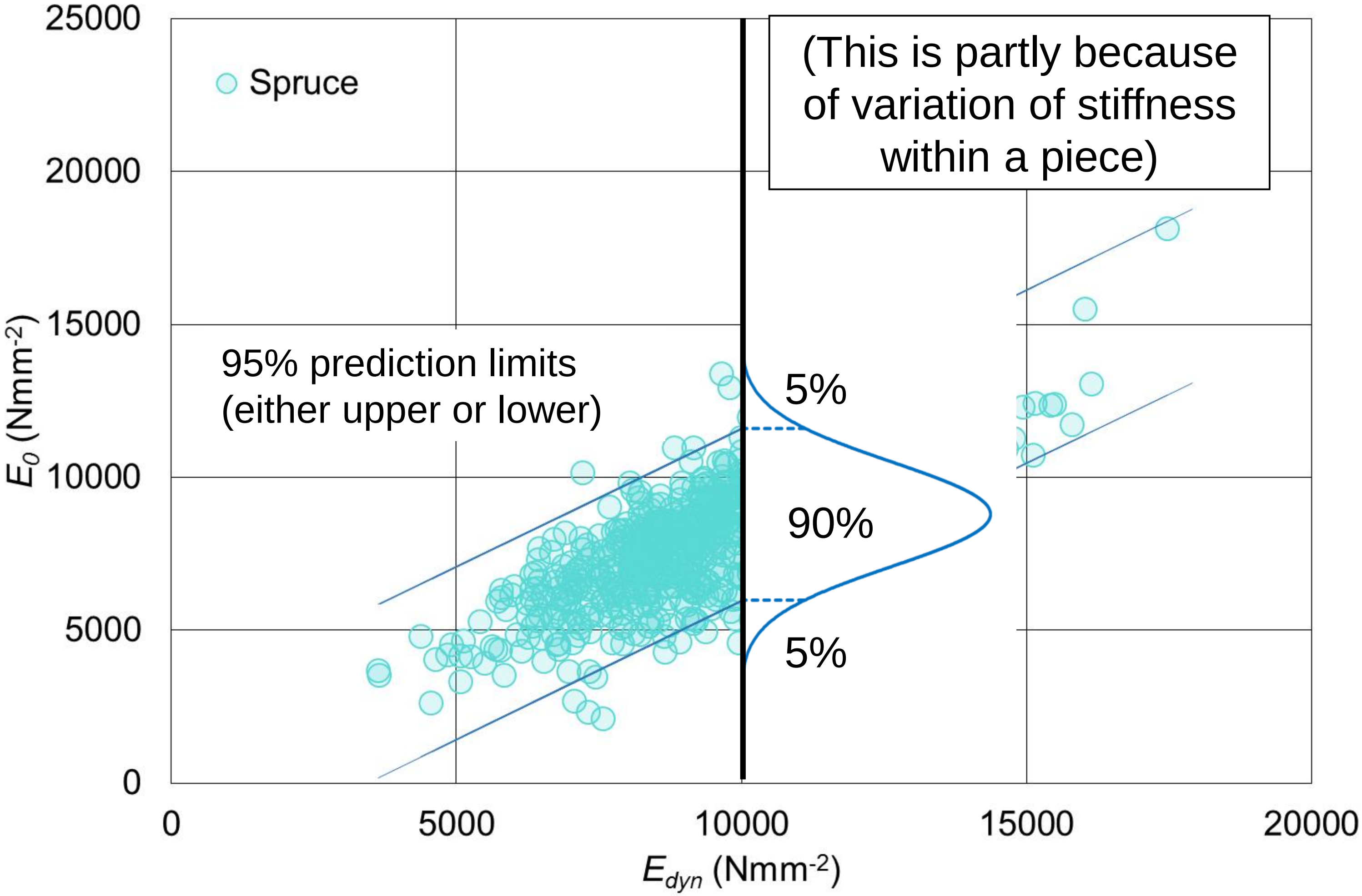
Models for bending stiffness



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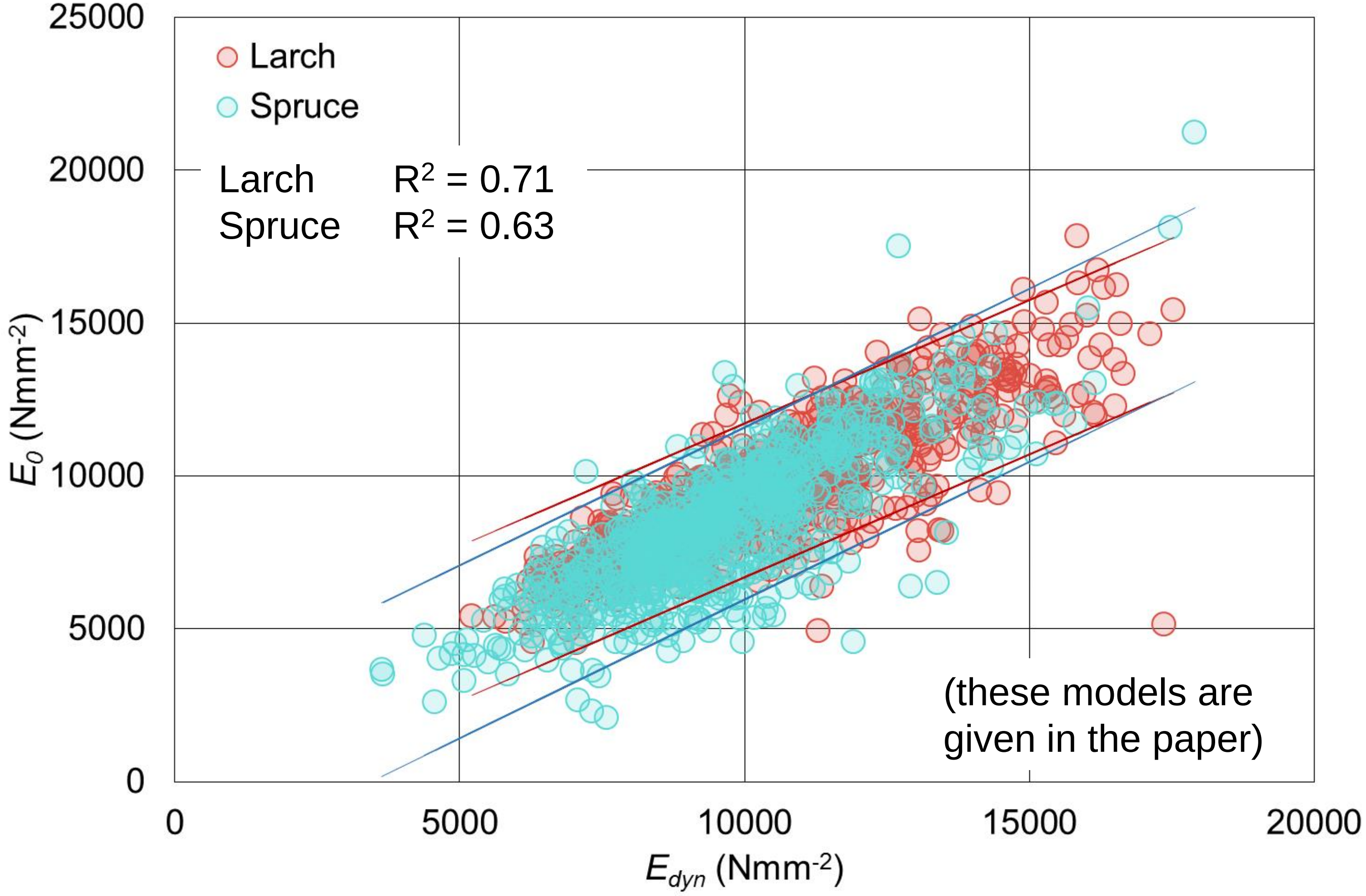
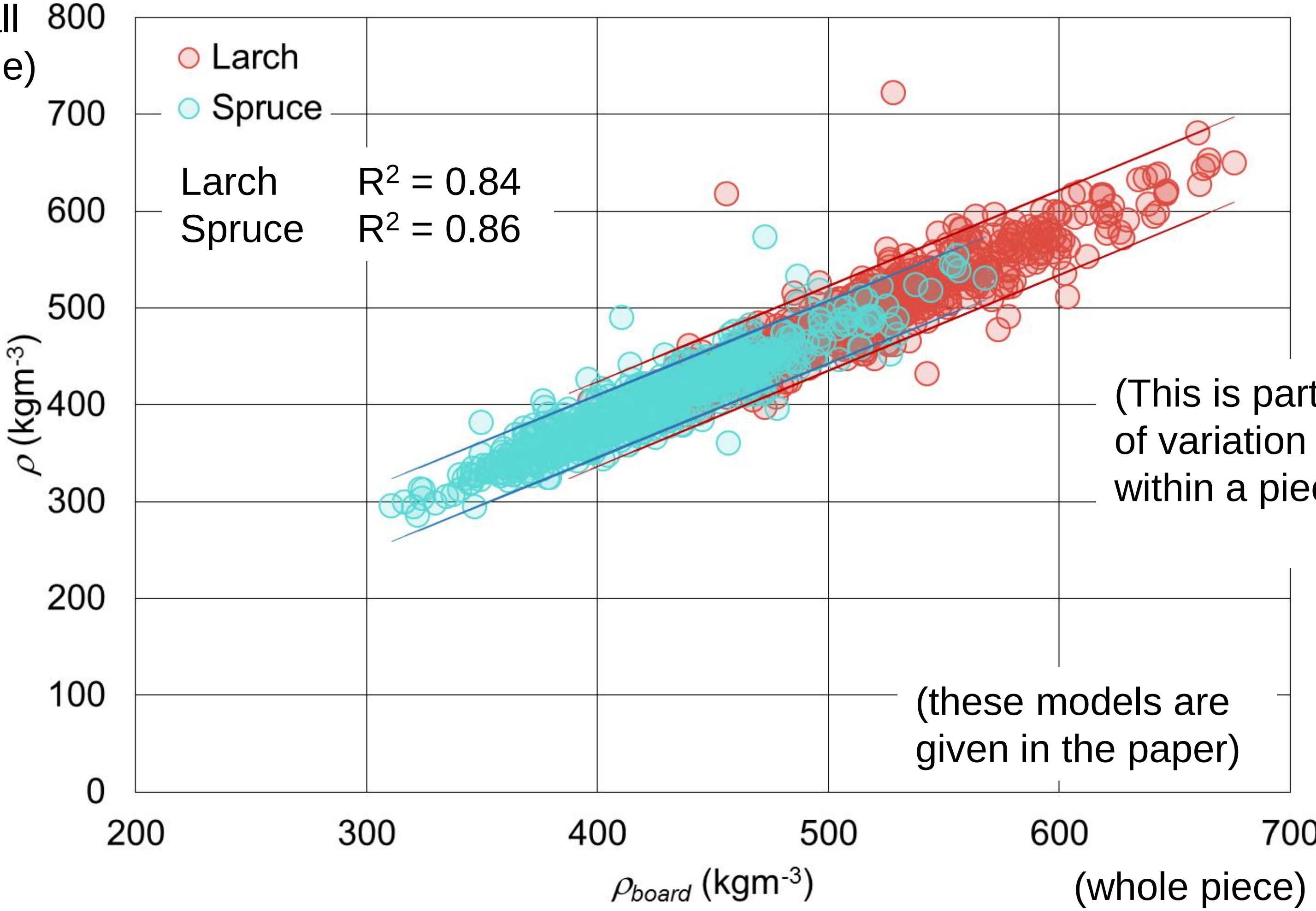
Models for bending stiffness



Note: this does not include the 22×47 dimension as they are unusually small

Models for density

(small sample)



(This is partly because of variation in density within a piece)

(these models are given in the paper)

(whole piece)

Note: this does not include the 22×47 dimension as they are unusually small

Models for bending strength

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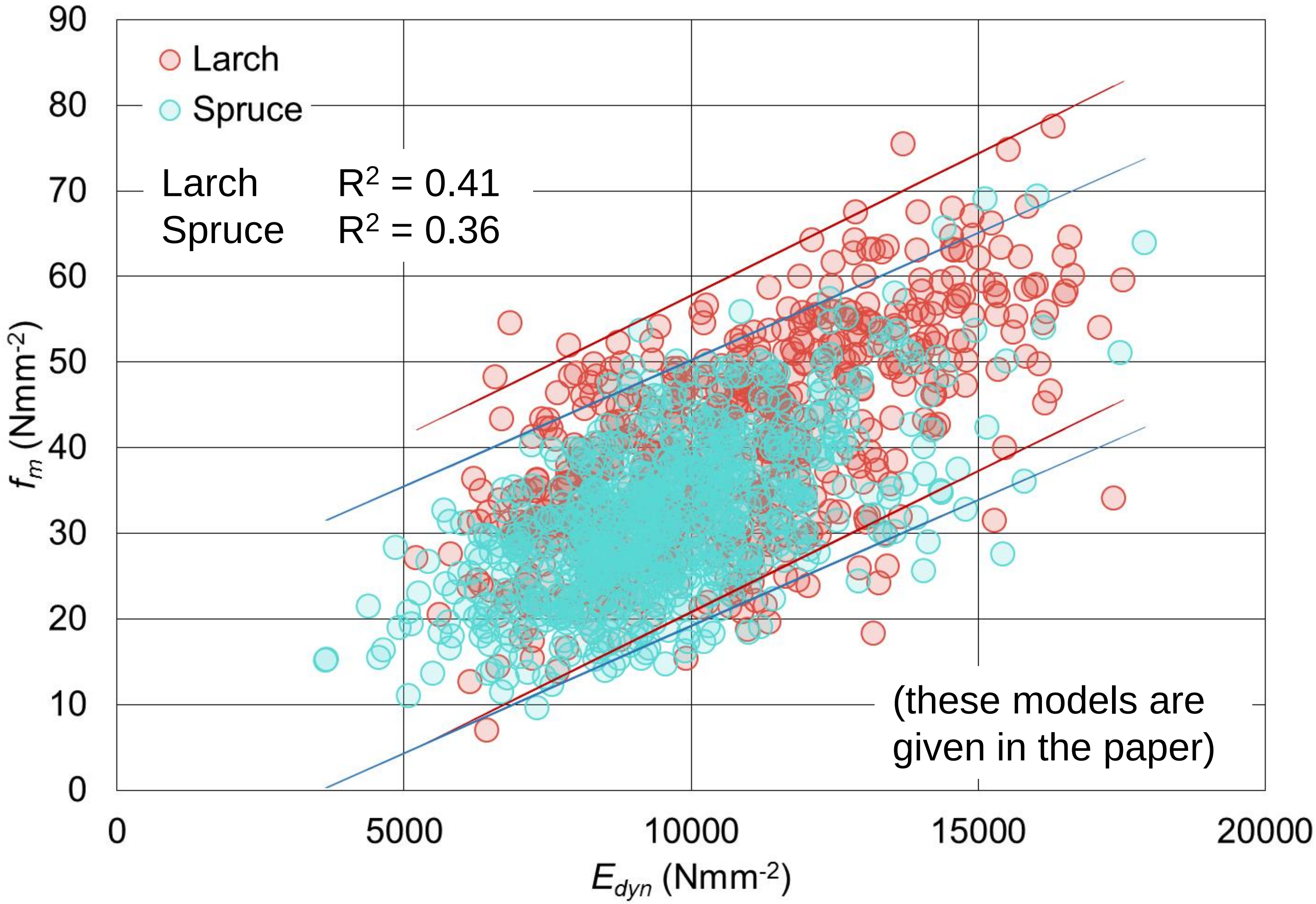

Note: this does not include the 22×47 dimension as they are unusually small
The k_h factor in EN 384 has not been applied

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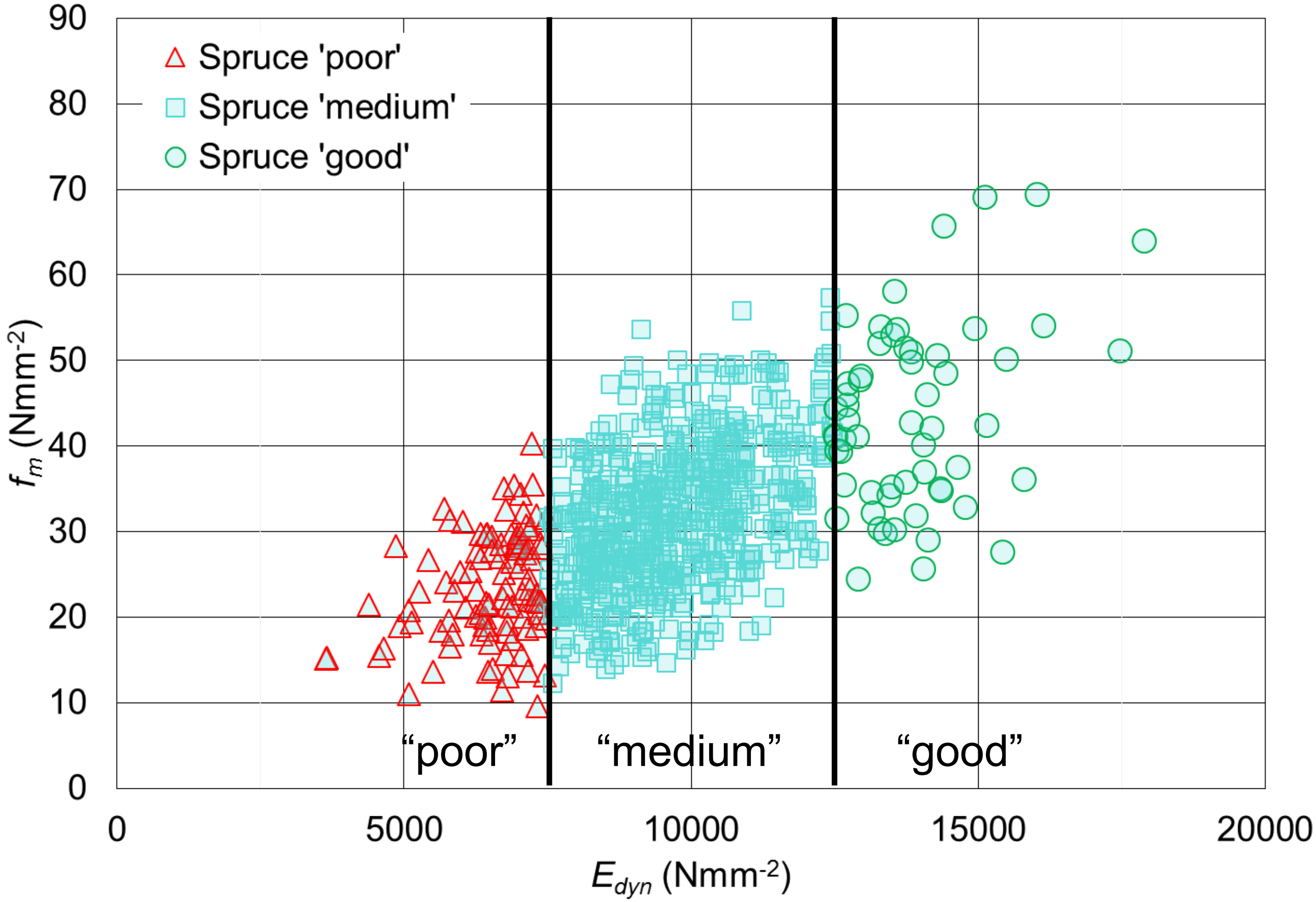
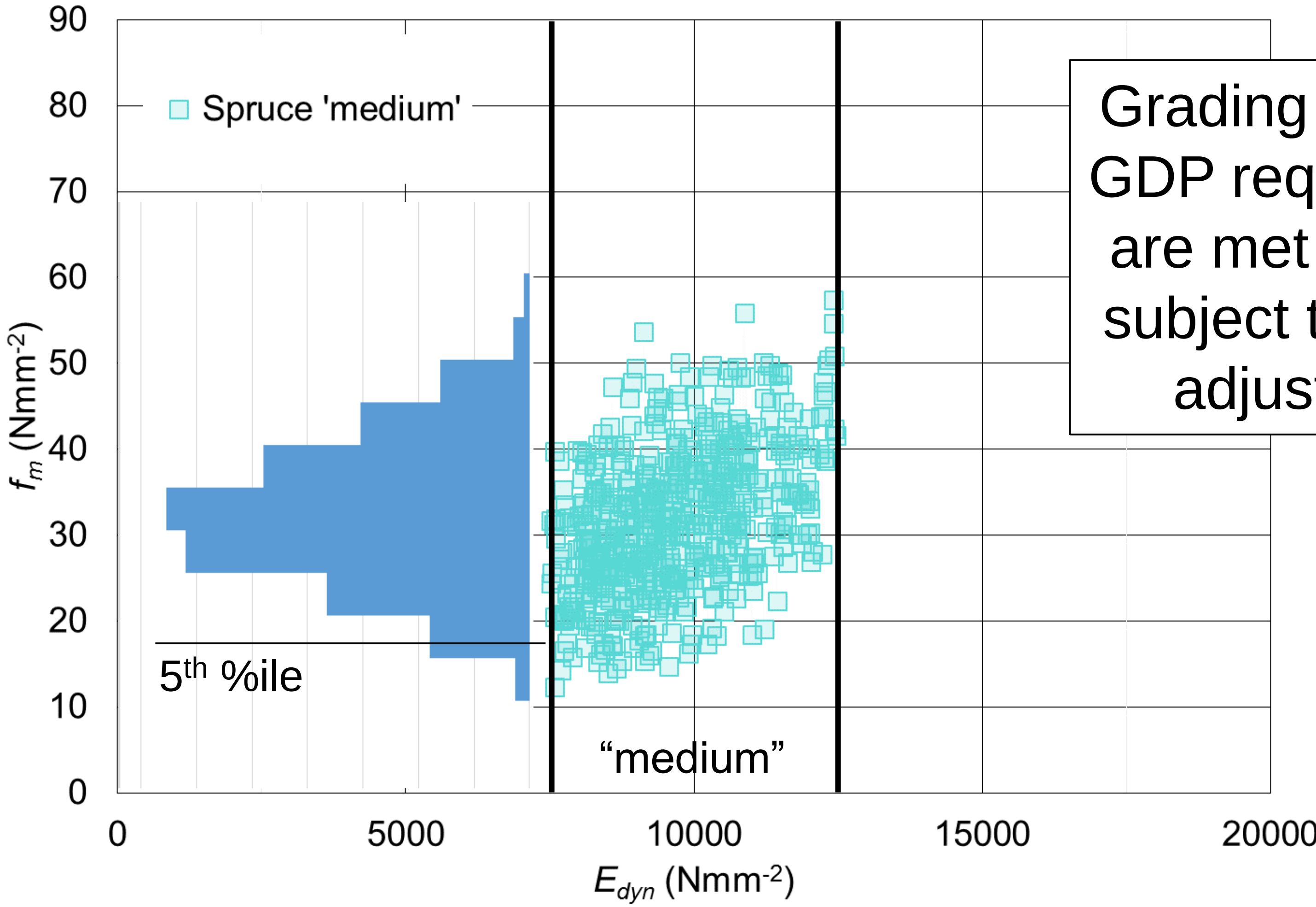
Grading – IP boundaries



Grading – IP boundaries



Grading aims that GDP requirements are met (at least) subject to various adjustments

Means that…

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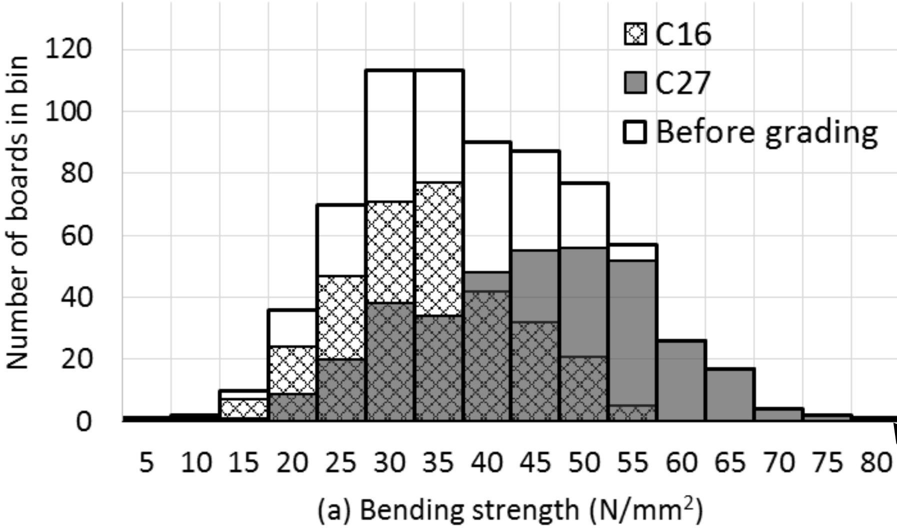
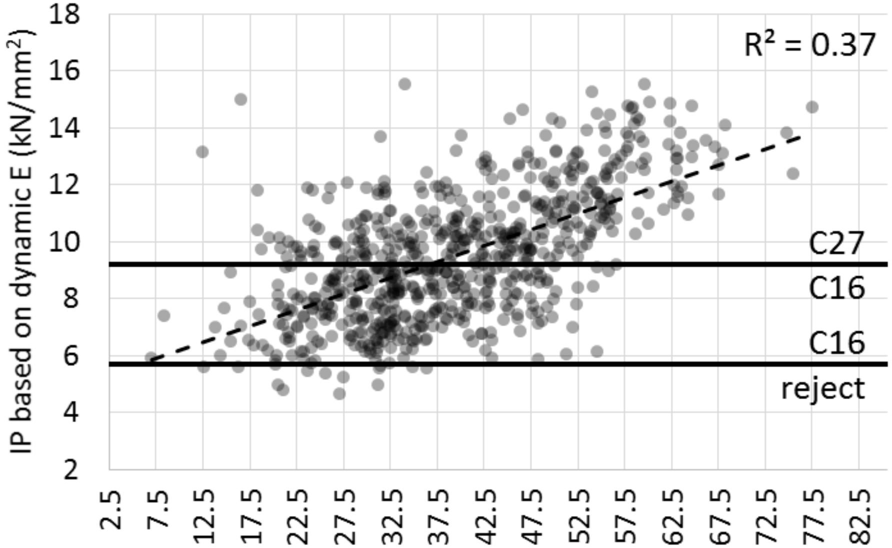
- Grading not about properties of individual pieces
- Often only one of the GDPs is limiting
- Sometimes none of them are
- So quite usual for some properties to exceed what is stated for the strength class
- Especially true of the secondary properties

- Having the same strength class does not make pieces equal! (or even sets of pieces)

UK larch with mtgBATCH 962

(EN14081-2:2010+A1:2012)





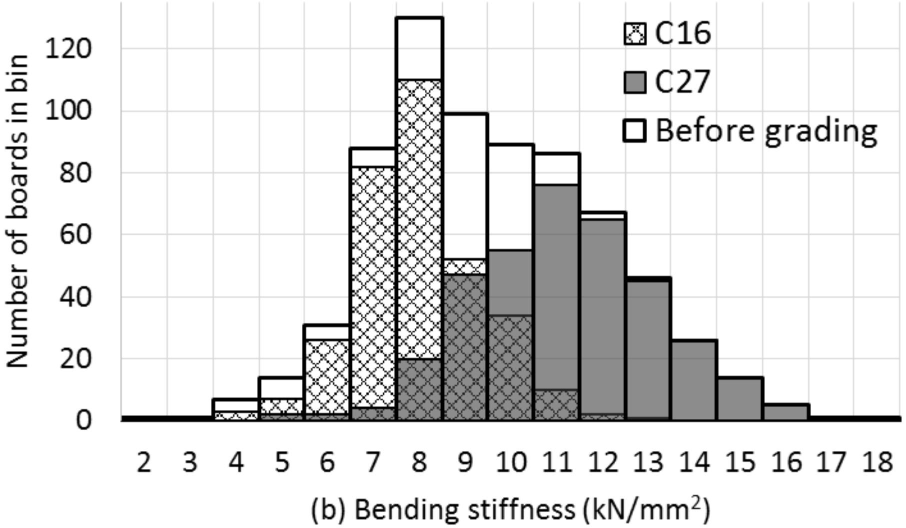
	% of required		
	Bending strength	Bending stiffness	Density
Class	%	%	%
C16	143% ✓	105% ✓	129% ✓
C27	100% ✓	103% ✓	122% ✓

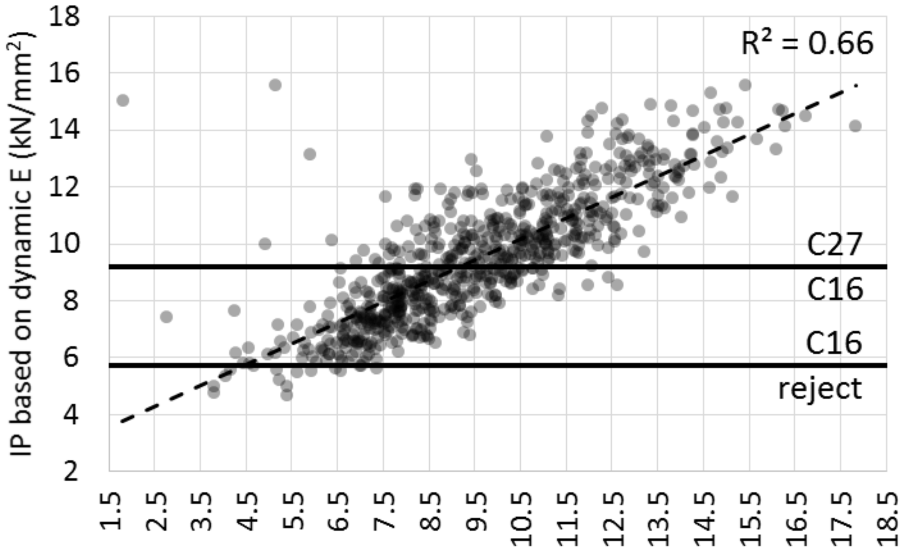
Strength

Note there is still a large variation within the grades – the difference is we now have characteristic values

UK larch with mtgBATCH 962

(EN14081-2:2010+A1:2012)



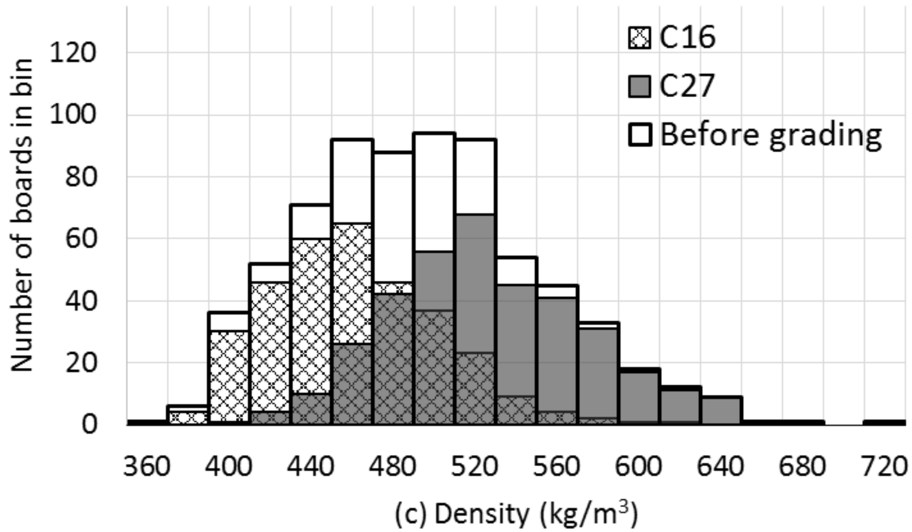


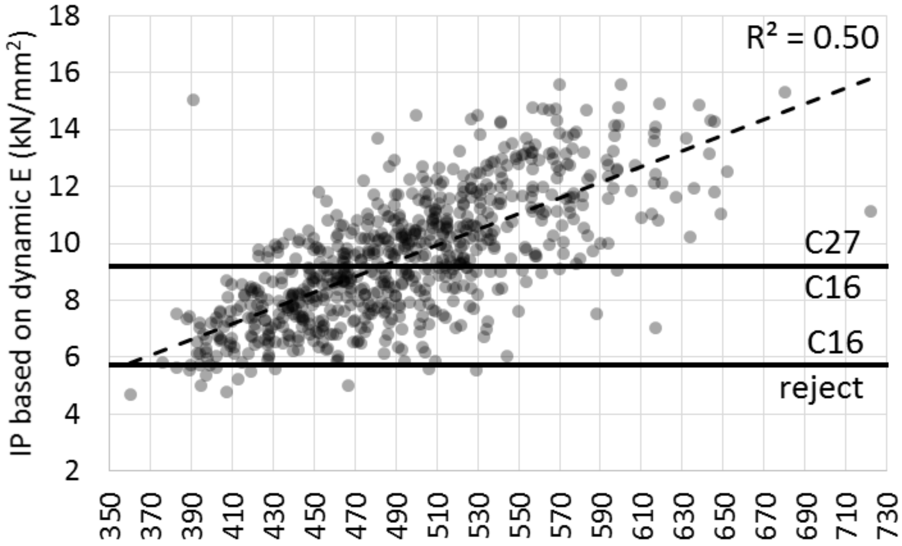
	% of required		
	Bending strength	Bending stiffness	Density
Class	%	%	%
C16	143% ✓	105% ✓	129% ✓
C27	100% ✓	103% ✓	122% ✓

Stiffness

UK larch with mtgBATCH 962

(EN14081-2:2010+A1:2012)





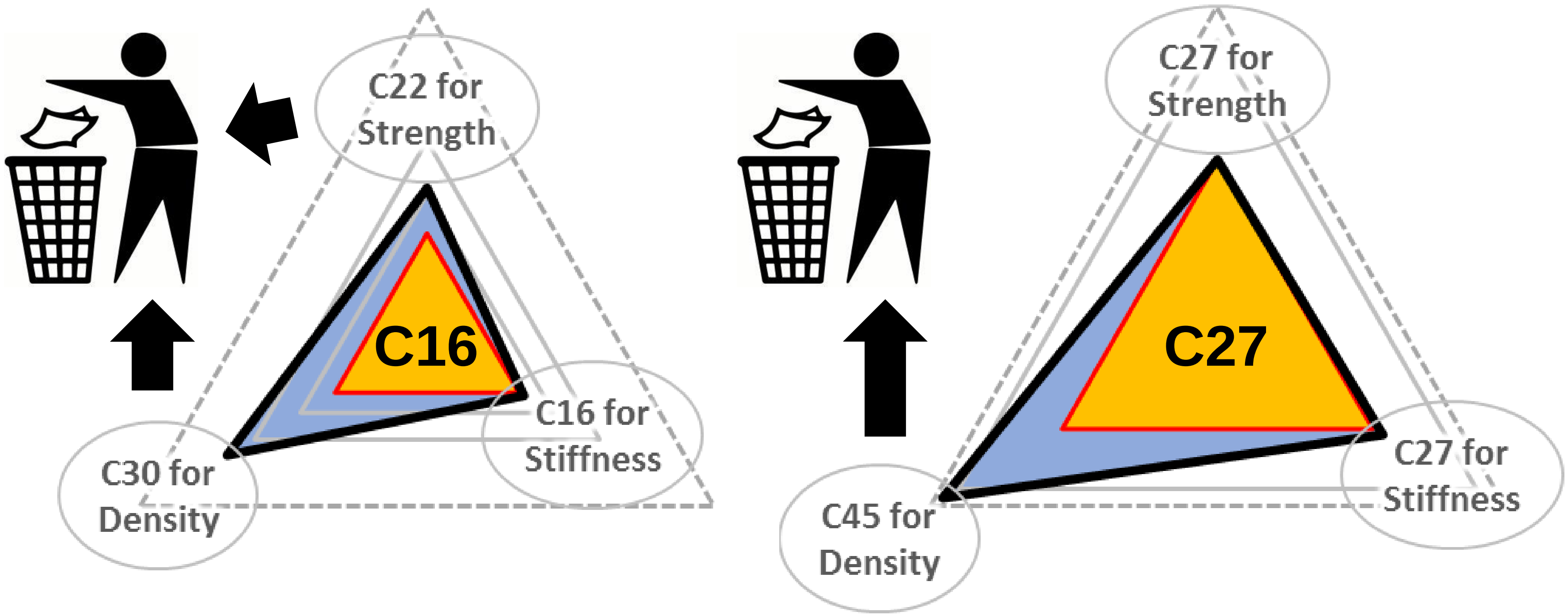
	% of required		
	Bending strength	Bending stiffness	Density
Class	%	%	%
C16	143% ✓	105% ✓	129% ✓
C27	100% ✓	103% ✓	122% ✓

Density

Using E_{dyn} as IP for density because it's not critical. Simpler this way – no point using density from weight (which has R^2 = 0.85)

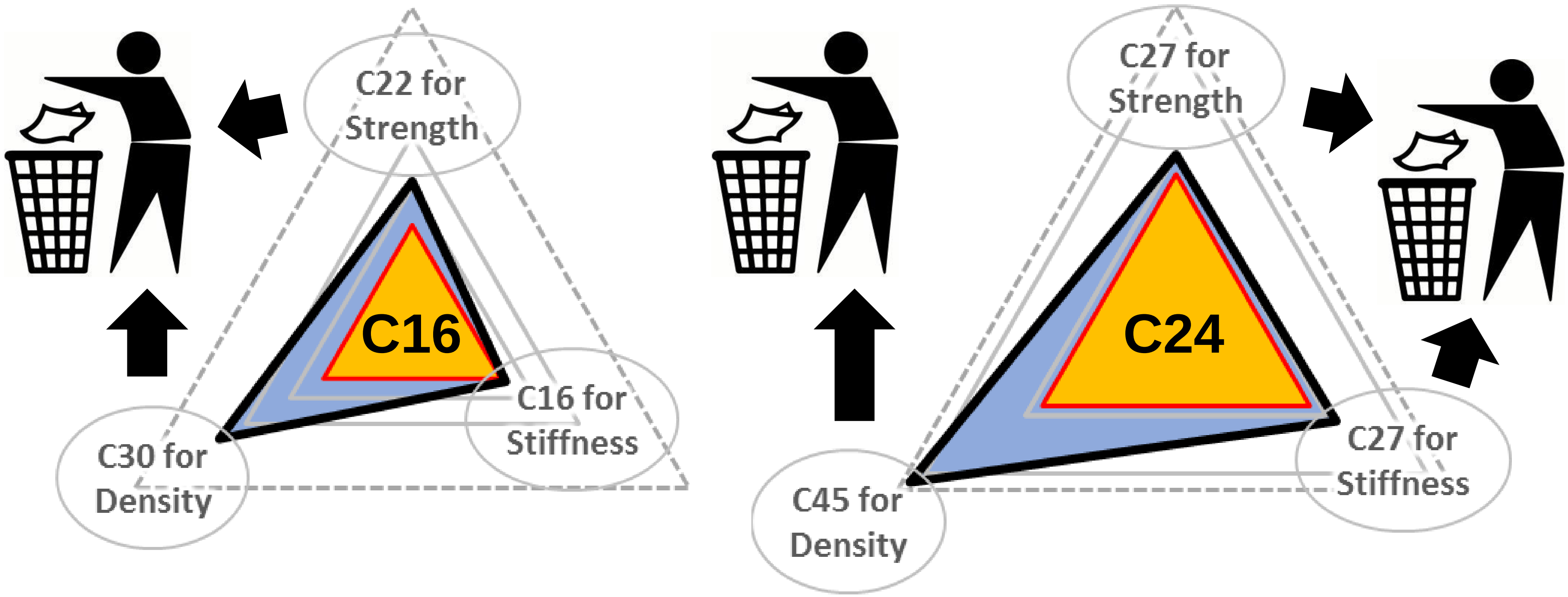
Discarding performance

UK larch with mtgBATCH 962



Discarding performance

UK larch with mtgBATCH 962



Might actually choose to discard even more!
C27 is not a common grade in the UK…so a producer may decide to mark the C27 as C24
(because the C16 with C24 combination doesn't work in this case)

Advantage of usual grades

- When placing timber on the general market
- Familiar
- Design can be done before timber obtained
- Easier for more general visual grading assignments and machine settings
- Don’t need to know specific end use when grading
- But…this is at the expense of properties (although this often doesn’t matter much in practice)

But strength classes not the only way
- they are just a convenience

Compared to target values

Spruce (for the previously listed grading machines and datasets)

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Class	% of target bending strength	% of target bending stiffness	% of target Density
C14	110 to 126	112 to 116	114 to 115
C16	100 to 116	105 to 109	107 to 111
C18	100 to 104	100 to 105	105 to 110
C20	101 to 106	100 to 108	101 to 110
C22	101 to 124	102 to 113	100 to 110
C24	101 to 114	100 to 111	107 to 111

Note: this includes k_h and k_v factors

Note – this is the range seen even in a single dataset, using similar machines

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Compared to target values

Larch (for the previously listed grading machines and datasets)

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Class	% of target bending strength	% of target bending stiffness	% of target density
C14	127 to 164	107 to 124	136 to 138
C16	128 to 144	105 to 119	128 to 130
C18	-	-	-
C20	107 to 107	106 to 106	123 to 123
C22	100 to 109	101 to 104	119 to 123
C24	100 to 111	100 to 103	119 to 126
C27	100 to 110	102 to 110	118 to 129
C30	101 to 110	103 to 114	115 to 129

Note: this includes k_h and k_v factors

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Situations for different thinking

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- Grading of in-situ timber
  - Think about predicting the properties of actual pieces
  - Even if describing collective properties of several timbers, there is little reason to limit the description to EN 338 strength classes
- Grading timber for a specific building
  - (When the timber is known before the design)
  - Not placing on general market (so why discard properties?)
  - Can even think about sorting pieces for the different components (end use is not unknown)

Situations for different thinking

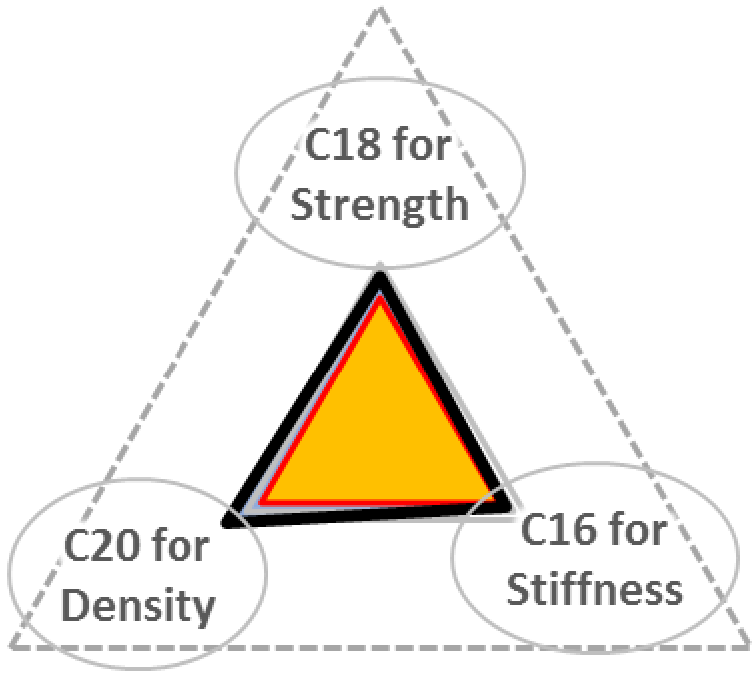
- Grading timber by a fabricator
  - E.g. timber framer, glulam manufacturer
  - Not placing on general market (so why discard properties?)
  - Can fit to resource
  - Can fit to application
  - Can fit design more closely to actual properties
  - Mass production ∴ discarding potential more of a problem
- Grading by a sawmill for certain market
  - Market may accept a different strength class
- Grading by a sawmill for general market
  - Still some things that can be done

Things you can do

- Don't use EN 14081 (if you don't have to)
- Don't use an EN 338 strength class
  - Direct declaration of properties (easier for visual grading)
  - Define your own strength class that works better
  - Use a different standard strength class (e.g. TR26)
- Use an EN 338 strength class
  - Directly declare secondary properties (based on tests)
  - Note that hardwoods can now be graded to C-classes

Simple e.g. British spruce

- Usually want near 100% yield
- ∴ Grading C16/reject
- Typical market is studs
  - where bending stiffness is not as important as the strength



But grading to C16 means discarding strength and density because of relatively low stiffness!

"C16+"

C16+ is a user defined UK grade for studs. Its primary characteristic values are:

$f_{m,k}$ = 18.5 N/mm²

$E_{0,mean}$ = 8000 N/mm²

ρ_k = 330 kg/m³

Would be fine if treated as C16

Other characteristic values can be calculated from the equations given in EN 384.

(Strength > C18, and density of C20)

Summary

- Although convenient, the standard strength classes are not the only way
- Sometimes the cost in 'lost' properties is considerable
- Sometimes it may be better to do things differently – especially:
  - When grading in-situ timbers, or for a specific building
  - When grading within a fabrication process
- And remember – strength classes are not good descriptions of *actual* wood properties (it's just a statistical lower bound)

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By the way…

The definition of strength classes can (and does) change

EN338:2016 compared to 2009 version														
	Hardwood													
	D18	**D24**	D27	**D30**	D35	**D40**	D45	**D50**	D55	**D60**	D65	**D70**	D75	D80
Strength														
● Bending	0%	0%		0%	0%	0%		0%		0%		0%		
Tension parallel	0%	0%		0%	0%	0%		0%		0%		0%		
Tension perpendicular	0%	0%		0%	0%	0%		0%		0%		0%		
Compression parallel	0%	0%		4%	0%	4%		3%		3%		6%		
Compression perpendicular	-36%	-37%		-34%	-33%	-34%		-33%		0%		-11%		
Shear	3%	-8%		-3%	2%	5%		13%		7%		0%		
Stiffness														
● Mean MoE parallel	0%	0%		0%	0%	0%		0%		0%		0%		
5% MoE parallel	0%	-1%		0%	0%	0%		0%		0%		0%		
Mean MoE perpendicular	0%	0%		0%	0%	1%		0%		0%		0%		
Mean G	0%	2%		0%	0%	0%		0%		0%		0%		
Density														
● 5% density	0%	0%		0%	0%	0%		0%		0%		-11%		
Mean density	0%	0%		0%	0%	0%		-1%		0%		-11%		