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The timber resource in G.B. - more species for new challenges

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ABSTRACT

Timber in Great Britain is mostly produced from Sitka spruce (*Picea sitchensis*). Biotic threats have led tree growers to consider the planting of a wider range of species to offer a more resilient forest. There is little information on how this will impact on domestic timber production, and the future supply of graded structural timber. Samples from some of the candidate species were tested according to standard procedures and assessed against current timber grades. Results showed that it is possible to produce timber suitable for use in construction from these species.

1. INTRODUCTION

In order to design structures, engineers and architects require to know the forces and stresses experienced by a structure, and, correspondingly the mechanical and physical properties of the material they work with.

All construction materials are inherently variable, and timber, being a natural material, is particularly so. The characterisation of construction timber is achieved by grades. In Europe, a construction timber grade, with values for use in design, is known as a strength class. Those values correspond to the population of timber assigned to that grade, and not the properties of individual pieces. Table 1 shows the first five general strength classes for softwood in Europe as described in EN338 (CEN, 2016b).

In order to examine the potential grade of a population of timber, a representative sample of timber (from trees grown under similar conditions to the timber that will be graded) must be assessed. The three properties used to determine grades are: bending strength (or modulus of rupture, MoR), bending stiffness (or modulus of elasticity, MoE) and density. Grading for these three properties is established by testing, and measurements are standardised. All other properties of the strength class are estimated from these three properties using established equations in EN384 (CEN, 2016a).

The important values for MoR and density are the lower 5th percentiles, while values for MoE refer to the mean. The strength classes define minimum requirements for these (referred to as characteristic values) for the population graded, after adjustments for statistical confidence and other considerations. Typically, one of these three properties will limit the timber to a strength class.

Contrary to the popular opinion that wood density is that limiting property in G.B.; previous research has shown that it is generally stiffness that limits the grading of British timber to a particular strength class.

Table 1. Characteristic values for strength classes C14 to C22

Wood property	Characteristic values				
	C14	**C16**	**C18**	**C20**	**C22**
Bending strength (N mm^{-2})	14	16	18	20	22
Modulus of Elasticity* (kN mm^{-2})	7	8	9	9.5	10
Density (kg m^{-3})	290	310	320	330	340

* the characteristic value for MoE must equal or exceed 95% of the value given in table 1.

The majority of wood produced in G.B., particularly for construction, comes from Sitka spruce, a species that has been grown for this purpose since around 1920. Many years of research and industrial experience have characterised the wood properties of this species. However, recent outbreaks of pests and diseases in the UK have highlighted the potential threats to a species monoculture; diversifying the species being grown is one way to manage the risk and ensure that there is a wood supply for future generations.

There are differences in wood properties between species and in order to provide guidance on which species are likely to be useful for timber, we need to collect some evidence. The environment plays a big role in shaping the timber that a tree produces therefore we need to examine trees in the regions in which are likely to be grown.

This study investigates the wood properties of four conifer tree species that currently form a minor component of the wood resource in G.B. but may play a more important role in the future.

2. Material and methods

Material obtained for studying came from three even-aged pure species plantations, representing growing regions at three different latitudes (Figure 1).

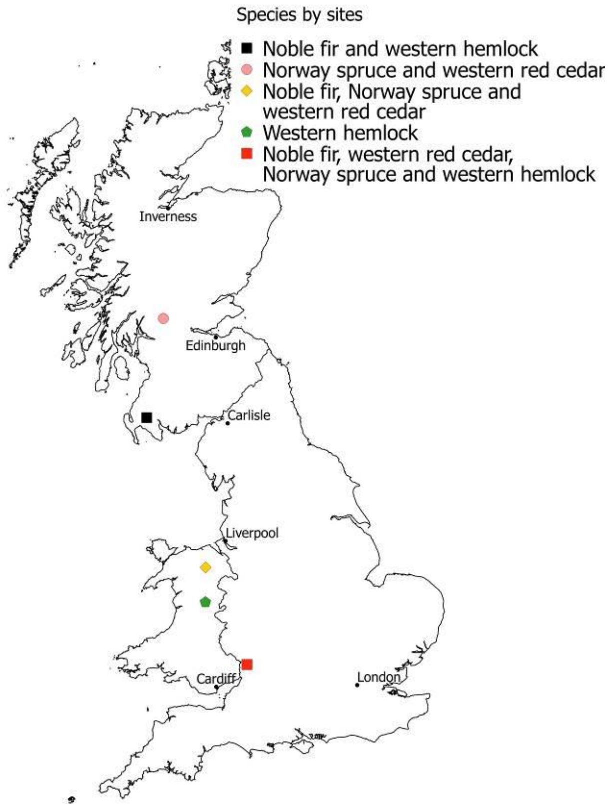

Figure 1. Location of sampled sites.

The four species investigated in this paper are: Norway spruce (*Picea abies*), noble fir (*Abies procera*), western red cedar (*Thuja plicata*) and western hemlock (*Tsuga heterophylla*). A total of 109 trees (28 for western hemlock and 27 for the rest of species) were felled.

Figure 2. Collection of sampled logs in the forest.

Timber specimens of 50x100 mm nominal size were cut following radial transects (Figure 3), with annual ring numbers being identified in the battens to ensure material was comparable with trees of a similar age.

Figure 3. Sawmilling of a log.

Battens were kiln dried and stored in a controlled environment prior testing in a four point bending test (Figure 4) according to EN 408:2010 (CEN., 2012). Values of MoR and both global and local stiffness (MoE_G and MoE_L) were obtained from the tests. MoE_G is determined over a longer span than MoE_L, which is based on the deflection of the central section tested, and therefore considered shear-free. An empirical relationship between MoE_G and MoE_L was examined to obtain “pure bending” MoE (MoE_{PB}). Density was measured afterwards from samples cut from each batten, and oven dried to obtain the moisture content, so that wood properties measured can be adjusted to a standard 12% moisture content as indicated in the standard EN384 (CEN, 2016a).

Figure 4. Bending test of a batten.

A total of 126 structural sized specimens of noble fir were tested and analysed, 128 of Norway spruce, 115 of western red cedar and 138 of western hemlock. Material was included up to 45 years old, which is the typical rotation length of a Sitka spruce plantation in G.B.

3. Results

Table 2 summarises the wood properties for the whole sampled population studied at an age of 45 years (Gil-Moreno et al., In press),

Table 2. Characteristic values (in bold), mean values, grade and standard deviations (in parentheses) by species restricting the material to 45 years (Gil-Moreno et al., In press).

	Wood Properties	Norway spruce	Western hemlock	Noble fir*	Western red cedar
MoE	**$E_{0,mean}$ (kNmm^{-2})**	8.6 (1.7) C18	8.3 (2.0) C16	7.7 (2.3) C16	7.4 (1.7) C14
Density	ρ_{mean} (kg m^{-3})	378 (36.6)	444 (38.8)	358 (36.7)	365 (30.3)
	ρ_k (kg m^{-3})	345 C22	385 C30	324 C18	318 C16
MoR	f_{mean} (N mm^{-2})	31.1 (9.0)	34.5 (10.7)	31.1 (13.1)	30.1 (8.0)
	$f_{m,k}$ (N mm^{-2})	19.1 C18	18.2 C18	14.8 C14	16.3 C16
Strength class**		C18	C16	C14	C14

* Noble fir material is comparatively younger due to difficulties in finding more mature plantations.
** for 100% yield

For allocation of timber to a certain strength class, the three properties must achieve the required values. Table 2 shows that stiffness is the main limiting property of the four species studied: the MoR and density satisfy values of higher strength classes.

The given characteristic values in Table 2 define the minimum strength class achieved for the whole population (100% grading yield). Grading allows to sequentially remove the worst material so that the remaining population achieves a higher strength class for more mechanically demanding construction. So, at the expense of reducing the yield (percentage of the population graded to a certain strength class), higher strength classes can be achieved. Table 3 shows how the yields decrease for the material studied as the requirements increase.

Table 3. Yields achieved for a rotation length of 45 years, with a perfect grading machine (Gil-Moreno et al., In press).

	C14	C16	C18	C20	C22
Norway spruce	100%	100%	100%	84%	65%
Western hemlock	100%	100%	94%	80%	65%
Noble fir	100%	96%	77%	62%	49%
Western red cedar	100%	96%	58%	41%	27%

As part of the wider study we are investigating how non-destructive testing can help us segregate material (Gil-Moreno and Ridley-Ellis, 2015) early in the timber production process to make the best possible use of the resource.

4. Conclusions

Our research demonstrates that the four species investigated are potentially capable of producing high yields of C16 (the basic customary strength class used in the United Kingdom) for a rotation length of 45 years. Norway spruce and western hemlock can also produce high yields of C18, though this grade is not in a large demand in G.B.

Further research could explore the manipulation of desirable wood properties in these species through forest management practices or tree breeding.

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