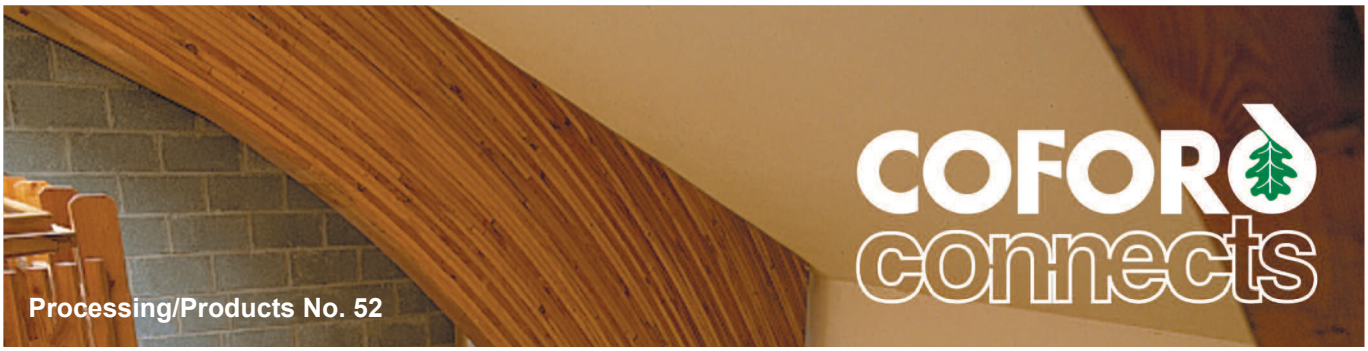

- ***The WoodProps Programme has been characterising the properties of timber species in Ireland, participating in the development of standards for timber structures, and exchanging knowledge with the Irish timber industry.***
- ***The research showed no evidence of decline in the properties of Irish timber during the last 40 years.***
- ***Irish-grown Douglas fir, larch and Scots pine were found to produce high quality timber, and could contribute to diversifying the timber supply. Machine grade settings for Douglas fir and larch were developed.***
- ***Some secondary wood properties are not well known for Irish-grown spruce. Sitka spruce was shown to produce a high yield of T11 for tension parallel to the grain.***
- ***Irish interests were represented through participation in the development of European standards, ensuring no negative consequences from their content.***
- ***Knowledge engagement with the timber industry was carried out to contribute to development of the sector.***
- ***The Timber Information Resource Centre has been developed as a free source of scholarly and technical documents. (https://www.nuigalway.ie/terg/activeprojects/woodprops/)***

COFORD
Department of Agriculture, Food and the Marine, Agriculture House, Kildare Street, Dublin 2, Ireland.
Email: fsd@agriculture.gov.ie
http://www.coford.ie

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Overview of the WoodProps Programme 2017-2020 Wood Properties for Ireland

David Gil-Moreno, Conan O'Ceallaigh, Dan Ridley-Ellis, Annette M. Harte

1. Introduction

Wood Properties for Ireland (WoodProps), funded by the Forest Sector Development Division of DAFM, is a joint Programme between the Timber Engineering Research Group (TERG) at NUI Galway (NUIG) and the Centre for Wood Science and Technology at Edinburgh Napier University. This COFORD Connects Note summarises the work carried out in WoodProps on:

- Characterisation and grading of Irish-grown timber as structural material for better utilisation and diversification of the forest resources.
- Work on European Committee for Standardisation (CEN) standardisation committees to support and protect Irish timber interests.
- Exchange of knowledge related to timber quality, innovation in wood products and providing updates on standards with the forestry and processing industries.
- Providing updates of information and resources in support of timber construction in Ireland.

2. Structural timber quality of Irish grown timber

2.1 Monitoring sawn timber structural properties

Changes in silvicultural management of forests can affect future timber quality. For example, the structural wood properties may decline as the result of improving other aspects of wood production like growth rate. It is therefore important to monitor potential changes in the existing sawn resource to guarantee the quality of the timber supply. Timber quality is defined in terms of grade determining properties (GDPs) described further in Box 1. Previous studies (IITU, 2017) compared the GDPs of Irish-grown spruce from several studies between 1983 and 2016 and found no significant difference. To supplement this work, WoodProps examined data from more than 12 million boards of spruce graded by Balcas Timber Ltd between April 2011 and September 2019, possibly the longest series of wood properties data generated in the island at the time. Although the time series is relatively short, an indication was found that the quality of timber has improved over this timescale, although this could be the result of Balcas implementing improvements in the sawmill's practice. Data showed that the

median density increased from about 410 kg/m^3 to about 460 kg/m^3 (Figure 1). In the same period, the median stiffness (calculated from the grading machine) increased from about 8.0 kN/mm^2 to about 9.5 kN/mm^2.

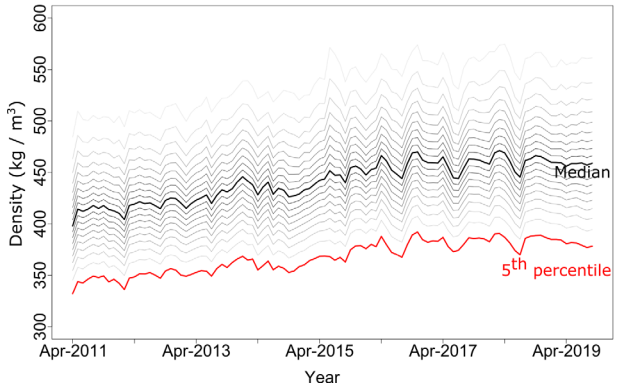

Figure 1: Change in density percentiles over time (lines in increments of 5%).

Box 1. Fundamentals of strength grading of timber

Structural timber is typically graded by species and growth areas to the strength classes defined in the standard EN338, a common framework of grades with specific values of wood properties. The grade determining properties (GDPs), are strength and stiffness, measured in bending or tension parallel to the grain, together with density. The grades are defined by the so-called characteristic values, the mean stiffness and the lower fifth percentiles of strength and density. Irish-grown timber is typically graded to C16, a bending grade with characteristic values of 8 kN/mm^2 stiffness, 16 N/ mm^2 strength and 310 kg/ m^3 for density. The allocation of pieces to grades relies in the prediction of the GDPs, by either machine or visual grading, based on a non-destructive assessment and its relationship, previously determined by testing (Figure 2), with each GDP. Machine grading is based on the statistical relationship between the GDP and one or more indicating properties (IPs). X-ray and longitudinal resonance are two of the most common technologies for measuring IPs. Different IP thresholds for a machine (the 'settings'), assign the timber pieces to strength classes. A population of timber achieves lower yields as the settings increase to satisfy the requirements of higher strength classes.

Visual grading is based on a set of rules assessing timber IPs, typically knots, ring width, and slope of of grain. Compared to machine grading, visual grading produces lower yields because the IPs measured are less powerful predictors and because the normative requirements differ and include reduction factors to account for human fallibility.

2.2 Structural properties of minor conifer species

Sitka spruce (*Picea sitchensis* (Bong) Carr.) forms the main raw material supply for the Irish forest sector, with a small percentage of Norway spruce, (*Picea abies* L). For grading purposes, the two combined are known as British spruce. In order to increase resilience against pests and diseases and to respond to climate change, it is advisable to diversify the timber resource. Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco) (Figure 3) and larch (*Larix* spp). are the second and third most common conifer species

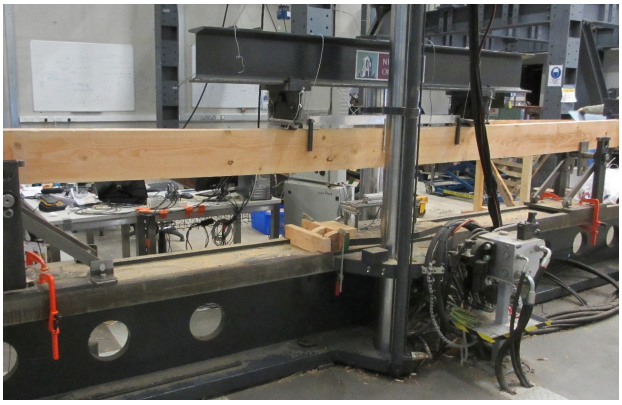

Figure 2: Destructive bending test on Douglas fir specimen at NUIG.

Figure 3: Douglas fir forest in Co. Tipperary.

in Ireland. As part of the WoodProps programme, machine grading settings were developed for these two species for the growth area formed by Ireland and the UK. The work comprised sampling, processing, conditioning, non-destructive assessment, testing, analysis and modelling of hundreds of pieces from the two countries. In April 2018 and May 2020, respectively, the grading settings for Douglas fir and larch were approved by the European Task Group CEN TC124/WG2/TG1 for 13 machines (Gil-Moreno et al., 2019 and Ridley-Ellis et al., 2022).

The GDPs of Scots pine (*Pinus sylvestris* L.) were also investigated. The current stocked area is relatively small to undertake the development of grading settings, and only one subsample was investigated, but this can be used to develop grading settings in bending when more material becomes available. The GDPs in tension were measured using a smaller subsample. Table 1 shows a summary of the GDPs of the three minor species studied. Sitka spruce, which typically produces near 100% yields for C16, is listed here showing yields for C18 for comparison. The yields represent the grading with an ideal machine with a perfect correlation between the values of the GDPs predicted and those measured in the laboratory (optimum grading). Overall, larch produced the highest timber quality. Douglas fir produced higher yields than Sitka spruce, with larger differences for higher quality requirements. Scots pine also achieved higher values than Sitka spruce, although the trees sampled were 77 years old and the typical rotation length for Sitka spruce is 35-45 years.

Table 1: Mean values, coefficient of variation and optimum grading yields (with EN384 k_h factor) of the properties investigated. CPA: compression parallel to the grain; CPP: compression perpendicular to the grain.

Species	Test	Pieces	Strength N/mm² (CoV)	Stiffness kN/mm² (CoV)	Density kg/m³ (CoV)	Optimum Grading yields
Douglas fir	Bending	704	38.0 (42%)	10.6 (31%)	495 (14%)	C18 99%
Larch	Bending	956	40.0 (30%)	9.81 (25%)	504 (12%)	C22 100%
Scots pine	Bending	158	38.2 (39%)	9.50 (29%)	524 (10%)	C20 95%
Spruce[1]	Bending	~2000	30 to 33 (30%)	7.5 to 8.5 (30%)	380 to 410 (10%)	C18 92%
Scots pine	Tension	81	22.8 (43%)	9.02 (30%)	516 (9%)	T11 90%
Spruce	Tension	153	24.7 (24%)	8.71 (21%)	420 (11%)	T12 90%
Spruce	CPA	153	30.1 (15%)	10.9 (19%)	418 (11%)	NA
	CPP	153	2.57 (20%)	0.29 (34%)	420 (11%)	NA

[1]GDP by Ridley-Ellis et al. (2022) and yields by Moore et al. (2013).

2.3 Determination of secondary structural properties of Irish spruce

In addition to the GDPs, so-called secondary properties are required for design calculations for timber structures. They include compression strength parallel and perpendicular to the grain as well as, in the case of the bending grades, tension parallel to the grain. The limited information on these properties for Irish spruce relates to the tension properties (Raftery and Harte, 2014, Gil-Moreno *et al*., 2019). Secondary properties are typically estimated using the equations in the standard EN384. These equations were derived using grades higher than C16, the most common strength class used in Ireland, and so may underestimate the performance of Irish spruce. Testing showed that Irish spruce achieves at least T11 strength class in tension (100% yield for optimum grading), with a characteristic strength of 11 N/mm². Further, the relationship between the characteristic strength values in bending and tension was investigated using more than a thousand pieces previously tested in bending at NUIG and almost 200 pieces in tension. Following the approach used to develop the equations in EN384, it was possible to develop an equation that represents the performance of C16 Irish-grown spruce under tension better than the EN384 equation, resulting in higher tensile strength values. It must be noted that the sample size was relatively small, and a larger study is recommended to support a proposal to change the equation in EN384. More details can be found in (Gil-Moreno et al., 2022).

In addition, compression tests parallel to the grain determined a characteristic strength of 24.6 N/mm² which is higher than the value of 17.2 N/mm² given in EN384 for grade C16. On the other hand, the compressive stress perpendicular to the grain was 1.75 N/mm², which is lower than the value of 2.2 N/mm² calculated using EN384. The number of pieces was relatively small (153) and a larger study is advised to examine this behaviour further.

3. Participation in National and European standards committees

The use of timber for construction is largely dependent on national and international standards, and decisions taken by CEN standardisation committees can have very significant consequences for industry. Through WoodProps, Ireland was represented on the European committees CEN TC124/WG2: Solid timber; CEN TC124/WG2/TG1: Grading; Assignment to strength classes (the researcher at NUIG David Gil-Moreno was elected as the secretary of the group) and CEN TC124/WG1: Test methods. A total of 15 meetings of the CEN TC124 groups and one CEN TC124 plenary meeting were attended. The information from these meetings was circulated to the National Committee NSAI/TC 008 and sawmills by e-mail, published on the WoodProps website, and used to recommend a national position for the open ballots in these committees.

Most of the work aimed at improving the comprehension of the text for the correct application of different standards. To a lesser extent, technical amendments were also addressed. One of the most relevant activities for CEN TC124 is the ongoing

revision of the visual grading standard EN1912. Information on the source of the material and evidence of the test data used for the visual assignments in EN1912 was requested by the CEN TC124/WG2 to National Committees (NSAI in Ireland) in order to maintain the current assignments in the new version. As part of the work in WoodProps, the requested information was compiled and submitted that will support the visual assignments "General Structural" (GS) and "Special Structural" (SS) as equivalent to C14 and C18, respectively, for spruce using the IS127 visual grading rules. Furthermore, on behalf of the NSAI, the WoodProps member proposed the addition of the source UK and species combination British spruce as material to which the Irish visual rules can be applied (Table 2), and based on the equivalence of the national softwood grading standards IS127 and BS4978 to extend the assignments of BS4978 to apply to IS127. The resolution is pending as part of the revision of the standard and is contained in the current working draft of EN1912.

Table 2: Current and proposed assignments in EN1912

Strength Class	Grading rule Publishing country	Grade	Current assignment		Proposed assignment	
			Species commercial name	Source	Species commercial name	Source
C18	Ireland	SS SS	Norway spruce Sitka spruce	Ireland	Norway spruce Sitka spruce British spruce	Ireland & UK
C14	Ireland	GS GS	Norway spruce Sitka spruce	Ireland	Norway spruce Sitka spruce British spruce	Ireland & UK

4. Knowledge exchange with forestry and processing industries

The WoodProps team undertook knowledge exchange activities with the wood processing industries through site visits, presentations and online resources. The aim was to share industry-academia knowledge and to support the industry needs with scientific evidence. WoodProps members carried out site visits and attended and hosted events to engage, and discuss topics with sawmills, board manufacturers, engineers, architects, growers, and tertiary institutions on timber quality, innovation in wood products and updates on standards. This facilitated subsequent engagement with different stakeholders to collaborate, discuss and answer technical enquiries that included consultations through emails and by phone. The WoodProps website (https://www.nuigalway.ie/terg/activeprojects/woodprops/) was developed at the start of the programme and regularly updated to host information on standardisation, news, events publications, etc. An additional source of engagement was the TERG twitter account @TERG_NUIG that facilitated engagement with the wider public.

5. Provision of information and resources on timber construction

Increased emphasis on a net-zero carbon economy has led to an increased interest in timber as a structural material (Figure 4). The development of new engineered wood products has enabled timber construction to compete with steel and concrete in multi-storey buildings. Ireland has been cautious to adopt modern timber construction methods, due in part to a lack of expertise in timber design and a lack of awareness among those involved in regulating the construction sector. To address this, WoodProps developed an online source of collated scholarly and technical documents to inform developers, engineers, product manufacturers, architects and other industry stakeholders on all aspects related to timber engineering and design of timber structures. This Timber Information Resource Centre (Figure 5), http://www.nuigalway.ie/terg/knowledge/, includes Irish and worldwide building case studies, guidance documents for timber design, product suppliers, information on fire performance, building regulations, forestry material, structural design tools, etc. It is updated frequently to keep pace with a fast moving and innovative industry. Input from industry stakeholders has been a key factor in formulating the relevant information categories and suggestions for content are continuously welcomed. Since its formation, the Centre has provided interested stakeholders with evidence and expertise related to the performance of wood-based products and building systems and has demonstrated the benefits of using timber products as a carbon store in the fight against climate change.

Figure 4: Mass timber construction in County Wexford.

A survey carried out by the WoodProps team (O'Ceallaigh et al., 2021) examined the way timber is perceived as a construction material by stakeholders, the willingness to adopt timber in construction and the training needs of the industry. In relation to the selection of timber as a structural material, architects were found to be significant contributors (40%), even more influential than the client (24%). The two largest issues impeding the use of timber in construction projects in Ireland was "poor knowledge of timber among designers" and "lack of wood culture among designers and clients" highlighting the need for continued education and support for building professionals seeking to build more sustainable structures. Encouragingly, 97% of participants were interested in learning about the use of timber in construction.

Figure 5: Timber Information Resource Centre on WoodProps' website.

6. Conclusions

- The key structural properties of Irish-grown spruce timber have not declined the last 40 years.
- Machine grading settings have been developed for Irish-grown Douglas fir and larch, producing higher yields than spruce. Scots pine has also been shown to be a promising species for structural timber production.
- Sitka spruce in Ireland can produce high yield of structural grade T11 in tension parallel to the grain. There is also strong indication that calculating this property using the equation in EN384 underestimates the performance for C16 Irish-grown spruce.
- Exchange of knowledge with the timber industry and participation in CEN Committees was undertaken to represent and protect Irish interests and facilitate industry involvement in standards development.
- WoodProps contributed to increased interest in timber construction with the delivery of technical activities, seminars and the creation of *Timber Information Resource Centre*

Acknowledgements

The WoodProps programme is funded by the Forest Sector Development Division of the Department of Agriculture, Food and the Marine, Ireland. The authors gratefully acknowledge the support of Coillte, Murray Timber Group, Balcas Timber Ltd, ECC Timber Products, and Microtec s.r.l. – GmbH. The contribution of NUI Galway staff who one way or another helped to complete this programme is appreciated. The work also draws on data from other projects at NUI Galway and the SIRT project at Edinburgh Napier University, and the authors are also grateful to its funders and research partners.

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