TOWARDS PERFORMANCE BASED DURABILITY STANDARDS FOR WOOD IN CONSTRUCTION – PART 1: DELIVERING CUSTOMER SERVICE LIFE NEEDS


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ABSTRACT

There is an increasing need for consideration of performance classification for wood products in construction, as evidenced by the European Construction Products Regulation, and by warranty providers and end user demands for information. As a consequence this requires radical consideration how test methods to determine wood durability (in particular biological durability) can inform on service life and how they might be translated into a performance classification system. This paper describes the changes that have occurred in the past 5-10 years in Europe and how the trajectory of standards development is now on a different pathway. The collaborative European project PerformWOOD is described. It is one of the main responses to the classification and service life demands and is considering key issues such as material resistance, moisture risk and adaptation of existing standards. The current thinking on how to bring together these critical issues to inform end users of performance classification, and ultimately on service life, will be discussed in detail.

1 INTRODUCTION

The building sector is strongly requested to improve its cost effectiveness, quality, energy efficiency and environmental performance. At the same time the use of non-renewable resources needs to get reduced. In this respect wood and wood-based products can play a key role since they are generally low in embodied CO2 and can be gained from sustainable forest resources. Wood has numerous further advantages compared to other building materials such as a high strength-weight ratio, good thermal insulation, and appealing aesthetics. However,
its durability against different biological agents is limited and requires consideration when wood is exposed to moisture and thus favourable conditions for decay.

There is an increasing need for consideration of performance classification for wood products in construction, as evidenced by the European Construction Products Regulation, and by warranty providers and end user demands for information. A key issue for the competitiveness of wood is the delivery of reliable components of controlled durability with minimum maintenance needs and life-cycle costs. The development of performance-based design methods for durability requires that models are available to predict performance in a quantitative and probabilistic format. The relationship between durability during laboratory and field testing and the performance under in-service conditions needs to be quantified in statistical terms and the resulting prediction models need verification and adaptation according to performance in real life.

Research on the performance of wood and treated wood ranges from early predictive methodology [1], predictive models [2], service life prediction research [3-5] to current advanced modelling [6] and research [7-11]. There is a considerable wealth of existing research and knowledge [12].

The majority of existing durability test standards was developed for the assessment of wood preservatives. Now there are numerous additional ways of enhancing durability of a wood product (e.g. wood modification, water repellents, coatings, design). The tests are collectively used to determine if a treatment is fit for purpose in a specific end use, but they are in many cases ill fit to accommodate novel treatments and modifications of wood. More recent activity in the PerformWOOD project has concentrated on an accelerated programme of activity to tackle:

- Material resistance and classification, where the on-going revision of EN 350 [13] has enabled consideration of including permeability to water moving closer towards material resistance [14].
- Moisture dynamics and time of wetness, where on-going work seeks to gather considerable new data on moisture regimes in wooden test specimens [15-17].
- Data handling and variability, as different statistical tools are applied to biological test data to begin understanding best way to present variability and distribution data [18-20].
- Modelling and estimation of service life approaches, considering engineering approaches and combinations of key parameters [12, 21, 22].

2 MATERIAL RESISTANCE

The existing classification system for wood durability in Europe is based on EN 350 [13], where five classes between ‘very durable (DC1)’ and ‘non-durable (DC 5) are distinguished. The classification is based on relative values, e.g. the service life of specimens in field tests relative to non-durable references, or the relative mass loss of specimens in laboratory decay tests. However, from the standard it is so far not clear where the classification was derived from. An ongoing revision of EN 350 [13] aims at increasing the transparency of the classification system by indicating the respective data source. Besides ‘pure’ resistance against wood-degrading organisms the revised standard will also consider the ability of wood to withstand wetting (wetting ability). Within the PerformWOOD project, Round Robin tests are focussing on laboratory test methods to determine the wetting ability of wood.
Based on the idea of the factor method [23] set values have been used for service life calculation for different wood-based materials by Thelandersson et al. [9]. Therefore material resistance classes had been defined and assigned to resistance indices (Table 1). This idea has been followed by Isaksson et al. [24] for an improved design guideline, where various factors to be considered for PSL have been quantified using performance models and data from long term field monitoring. Material resistance classes as consequence of durability against organisms and resistance against wetting are consequently foreseen for a new concept of performance classification within the PerformWOOD approach (see Figure 1).

Table 1. Resistance classification of selected wood materials and corresponding design resistance index \( I_{Rd} \) (taken from the WoodExter Design Guideline, [9])

<table>
<thead>
<tr>
<th>Material resistance class</th>
<th>Examples of wood materials</th>
<th>( I_{Rd} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Heartwood of very durable tropical hardwoods, e.g. Afzelia, Robinia (Durability class DC 1) Preservative-treated sapwood, industrially processed to meet requirements of use class 3</td>
<td>10.0</td>
</tr>
<tr>
<td>B</td>
<td>Heartwood of durable wood species, e.g. Sweet chestnut (DC 2)</td>
<td>5.0</td>
</tr>
<tr>
<td>C</td>
<td>Heartwood of moderately and slightly durable wood species, e.g. European larch and Scots pine (DC 3 and 4)</td>
<td>2.0</td>
</tr>
<tr>
<td>D</td>
<td>Slightly durable wood species having low water permeability, e.g. Norway spruce</td>
<td>1.0</td>
</tr>
<tr>
<td>E</td>
<td>Sapwood of all wood species (and where sapwood content in the untreated product is high)</td>
<td>0.7</td>
</tr>
</tbody>
</table>

3 MOISTURE RISK IN WOODEN COMPONENTS

Apart from in-ground exposures, where adverse moisture conditions can be assumed to exist at any time, a further distinction of fungal hazard is made regarding the respective moisture conditions and corresponding potential decay organisms. This has been done for defining use classes [25] as well as for the differentiation of climate-induced decay hazards [e.g. 26]. However, the variety of existing above ground test methods – representing very different moisture regimes - is also linked to limited comparability of the obtained results. Moisture content measurements could therefore serve as cross linking element between test methods, test sites and other boundary conditions for comparative studies. However, they are still sparsely used, and especially for real assemblies and commodities [e.g. 16, 27] moisture data are rare.

A second aspect of wood moisture content and its dynamics is its contribution to wood resistance. Besides biocidal ingredients of wood, hydrophobic substances and anatomic peculiarities have a significant impact on the moisture dynamics of timber and thus on its durability. Furthermore, impregnating timber with water repellents as well as modifying the wood cell wall aims on reducing the water uptake [28]. The capability of a wooden material to take up and accumulate moisture must consequently be seen as a second component of wood resistance (maybe the more important one). At least for the less severe UC 2 and UC 3.1 [25] moisture performance tests in the field might be seen as appropriate and time-saving
alternative to long-term decay tests. The ‘time of wetness’ concept will therefore serve as key element in a dosimeter approach for performance classification in a revised EN 460 standard [29].

4 DATA HANDLING AND VARIABILITY

Paying attention to variability in test methodologies and data analyses is essential, especially for heterogeneous biological materials such as wood [18]. Increasing the number of test specimens usually improves the reliability of test results, but also increases their cost. Therefore it is important to optimize the amount of delivered data and to select the most relevant approaches making the characterization of the products possible, without presenting unnecessary cost burdens on those procuring the tests.

The variability which is often observed in the results of durability tests results from the variability of both the operators and the tested material itself. Variability among laboratories and/or technicians performing the same tests is frequently reported [e.g. 30, 31]. Although the same standards and protocols are used, their levels of complexity and the fact that the assessment criteria are often qualitative, and thus more subjective than quantitative criteria, explain why different results may be obtained. The variability of the tested material can be due to sampling, but also due to its intrinsic characteristics, which are influenced by the origin and the age of the tree and the position the test samples are taken from within the tree. When selecting a set of samples to be as similar as possible, the variability of the test is accounted for, but cannot be fully prevented. On the other hand a certain number of sources (assortments) should be considered to assure representativeness of the test results.

The classification of natural durability or biocidal efficacy is generally based on the mean or median values of the recorded data. However, the spread of individual values is sometimes wide, which makes the interpretation of the data complicated. Expressing the results in a way that will provide customers with relevant information regarding the level of natural durability is one major challenge for the future. The major risk of underestimating the importance and the impact of high variability, and thus of neglecting implementation of robust statistical approaches, is that manufacturers, users and authorities may be supplied with data whose reliability is doubtful. The statistical approach in CEN/TC 38 standards is being strengthened in order to deliver robust methodologies to the laboratories performing durability tests and, consequently, deliver more reliable information on wood-based products to the market.

5 PERFORMANCE MODELS

For service life planning and performance classification of buildings, building assets, and building products well-functioning ‘performance models’ are absolutely essential. The term ‘performance model’ is ambiguous in a double sense: On the one hand ‘performance’ needs to be carefully defined, because it can have very different meanings depending on the respective type of material, product, commodity and its application. On the other hand the general meaning of ‘model’ is the ‘schematic description of a system, theory, or phenomenon that accounts for its known or inferred properties and may be used for further study of its characteristics’, but it is not settled which factors will describe the command variable. Building components that are exposed outdoors to the weather are mainly affected by moisture and temperature related effects. In addition moisture and temperature can also play an important role indoors and in the building envelope. In particular for bio-based building materials such as wood biological agents require consideration for predicting their service
lives. In contrast, other degradation processes such as corrosion, erosion, and hydrolysis play a minor role.

Efforts in developing performance models for both fungal decay and mould growth have been intensified in recent years. Various approaches have been followed and different models have been proposed to be implemented in design guidelines [12]. However, a high heterogeneity among these attempts became visible and different strategies have been followed.

The modelling attempts can be roughly distinguished according to the following criteria:

- Objectives: precise service life estimation (ideally in years) or comparative evaluation (to quantify effects, e.g. of design details; to compare alternatives, e.g. materials or design solutions)
- Command variables: mass loss, strength loss, remaining strength, decay ratings, decay depth, service life according to different limit states, aesthetic appearance, etc.
- Data sources: laboratory test data, field test data, survey data, expert opinion, reality checks, multi-source approaches, etc.
- Level of accuracy/reliability: Use and durability classes, dosimeter approaches, combined approaches

Furthermore from an engineering point of view decay and biological degradation in general are only part of the overall performance of wooden structures. A comprehensive engineering model can therefore be dominated by the effect of crack formation, ageing, UV degradation, corrosion of fasteners, or building physical phenomena.

With respect to the objectives of PerformWOOD it became clear that a lot of approaches for modelling service lives and performance of wood and wood products are already available. Many approaches have been implemented into design guidance documents already. Consequently, a framework of how exposure, dimension, design details, and the material-intrinsic ability to take up and release water can be linked to model the moisture risk in wood products is in principal available. In particular, the various dosimeter models could serve as reliable tools to quantify the effects of different construction details.

6 QUASI-CONTINUOUS CONCEPTION OF EXPOSURE DOSE - PERFORMANCE MODEL

The future sustainable use of the European forest resource lies with enhancing durability with environmentally improved and targeted systems to meet service life expectations. Work is progressing to take the first steps towards meaningful performance classification for wood products so end users can be assured that wood is a reliable and thus low impact material. The outcomes of the project PerformWOOD are essential in moving forward to:

- Confirm a material resistance measure
- Confirm a moisture risk measure
- Kick start refinements to TC 38 standards and improve test methods
- Provide a draft standard (EN 460 [29]) for consideration of service life
As a major challenge we identified the complex task to unify a continuous approach for quantifying exposure dose and material resistance on the one hand and to provide guidelines that meet the user expectations on the other hand. The latter comprises a scheme with well-defined performance classes which can be applied during daily practice in the building trade. Therefore a quasi-continuous concept has been proposed, as illustrated in Figure 1. Dose and resistance are both considered to be continuous without defining static limit states. Nevertheless, discrete levels of performance can be defined and used for practical planning of buildings and constructed assets. For timber and wood-based building materials this requires considering exposure separately for the different potential degrading agents such as fungi, insects, termites, marine borers and wetting.

![Figure 1: Conceptual chart for determining 'performance classes' for a combination of material and exposure parameters.](image)

### 7 CONCLUSIONS

Project PerformWOOD has formalised and drawn together the on-going research to focus on generation of a material resistance factor for performance classification and alongside developing the first moisture dynamic test protocols in the history of CEN TC 38. A draft standard (EN 460) for consideration of performance classification of wood in construction is underway and relies on concepts that are being road-tested with industry, construction professionals, researchers and the general public. The work in the Working Groups of CEN TC 38 now really begins to continue to revise and sharpen the tests and methods needed to support such a performance classification framework as well as build the technical reports to underpin the future EN 460.

### 8 ACKNOWLEDGEMENTS

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REFERENCES


[29] EN 460 ‘Durability of wood and wood-based products - Natural durability of solid wood - Guide to the durability requirements for wood to be used in hazard classes’ European Committee for Standardization, Brussels, 1994.
