Performance-based Specification of Wooden Components

Christian Brischke ¹
Andreas O. Rapp ²

ABSTRACT
The need for a unified and harmonised system for performance classification and specification of wood and wood-based products in Europe emanates from requirements of users and the European Construction Products Directive (CPD). A road to a feasible specification system is outlined. Exposure-related performance prediction was worked out as a key task on the way to product specification. Therefore suitable tools, field test methods as well as short-term/laboratory test methods, are sought to allow the determination of reference service lives for different exposure categories. On the one hand, performance factors, which derive from service lives in field tests, allow the specification of wood products. On the other hand, the calculation of inter-site factors may allow the modelling of service lives and the drawing of hazard mappings.

KEYWORDS
Wood, Commodity, Field tests, Service life prediction, Performance factors

¹ Leibniz Universität Hannover, Institute of Vocational Sciences in the Building Trade (ibw), Hannover, D-30419 Germany, Phone +49 762-5829, Fax +49 762-3196, brischke@ibw.uni-hannover.de
² Leibniz Universität Hannover, Institute of Vocational Sciences in the Building Trade (ibw), Hannover, D-30419 Germany, Phone +49 762-4595, Fax +49 762-3196, rapp@ibw.uni-hannover.de
INTRODUCTION

A unified and harmonised system for performance classification and specification of wood and wood-based products in Europe is still lacking. At the same time the need for such a system becomes more and more obvious. Users and consumers have a strong interest in reliable information on the expected performance of wooden products. They are the decision makers in the market place and will particularly decide, if wood-based products or substitute building materials will be used.

For the user, the only valuable product information needs to be based on a performance characterisation. For example when attempting to chose among different products, is not very helpful to the user to determine the relative protective effectiveness of a wood preservative as is done according to different European standards, e.g. EN 113 (1996), ENV 807 (2001). For potential customers it is essential to have useful information in a form that helps assess whether the product will meet its performance requirements (i.e. the desired service life). Ideally what is needed for this purpose is a reliable service life estimate, but at the very least, a product specification having performance classes would be useful information for a consumer to make an informed choice. Furthermore, such a system should not be limited for a particular group of wood products only, but universally applicable for all wood-based products including, for example:

i. Wood treated with classical wood preservatives
ii. Wood treated with new organic preservatives
iii. Natural durable wood
iv. Modified wood
v. Wood-based composites.

Secondly, the need for performance classification emanates from the European Construction Products Directive, CPD (1988) on the approximation of laws, regulations and administrative provisions of the member states relating to construction products. The CPD requires in particular "products fit for an intended use", which may be translated as meaning, “a sufficient level of performance” over a particular time period – the time period of the intended use.

Thus, for the wood industry, as well as for wood scientists, three important needs may be derived from the CPD:

1. Provide data that are applicable for performance estimations of wood-based products
2. Deliver suitable test methods to assess the performance over time of wood-based products
3. Establish a European-wide harmonised classification and specification system.

The objectives of this work were to identify the necessary steps towards a feasible performance classification system and to provide a roadmap for the specification of wood-based products. The approach presented in the following should be seen as a proposal and a base for the discussion about different aspects related to wood product specifications. Valuable comments and subjects of the discussion, which took place in the frame of COST Action E37 “Sustainability through new technologies for enhanced wood durability”, were considered in this paper.

ROADMAP FOR THE SPECIFICATION OF WOOD AND WOOD-BASED PRODUCTS

2.1 General Aspects

A roadmap for the specification of wood and wood-based products to be drawn in this paper can be defined by its start and ending point. The starting point of this road is the expectancy regarding a specification system by the user of wood-based products and the CPD (1988) as described in Section 1. As is shown in Figure 1, a feasible product specification is the final destination at the end of the road intended to meet user requirements. From the beginning it is clear that the end of this road can only be reached by performance prediction, which somehow need to be realized. In the following
sections, the different stopovers on the roadmap to developing a useful product specification will be described and discussed that focus on the steps necessary to achieve performance prediction.

![Roadmap](image)

**Figure 1.** Start and ending point of a road towards the specification of wood and wood-based products.

2.2 Necessary Number of Reference Service Lives

To predict the performance of a wood-based product means nothing else than to predict its service life. The service life of a product ends, when the performance level becomes lower than the performance requirements, whether they are functional, static, or aesthetic. Therefore performance prediction can be equated with service life prediction, and the principles of service life planning as given by the ISO standard 15686 should be considered. According to ISO 15686-1 (2000) a service life can be estimated by considering a reference service life and different modifying factors as follows:

\[
\text{Estimated service life (ESL)} = \text{Reference service life (RSL) \cdot modifying factors,}
\]

whereby the modifying factors include all conditions that deviate from defined reference conditions, e.g. climate, design measures, or maintenance intervals.

From the laws of error propagation it can be seen that the more unknown variables considered in an equation, the higher the total statistical error to be expected. Therefore, it is obvious, that working with only a single RSL is no solution. Thus, the question arises as to how many different RSLs need to be considered to obtain a reliable service life estimate, and how can these RSLs be determined (i.e. what are suitable test methods?). Different wooden commodities, even if they are made from the same material, can perform very differently. Depending on the exposure situation different service lives will be obtained. Consider, for example, wooden poles in ground contact or the same material used as beams in a roof construction. Table 1 shows information on the relation between commodities, exposure situations, and the expected performance for related use classes described in EN 335-1.

Different commodities can be merged into commodity groups having similar expected performance. At the same time, different exposure categories can be defined and related to the different commodity groups. However, a simple equalisation of exposure and commodity is not possible, as for window joinery, which is usually coated, the same exposure situation is given compared to a cladding, but a completely different performance of these two commodities can be expected. In this case one needs to distinguish between coated and uncoated commodities within the same exposure category "above ground". A second example for the need of a more discerning classification of commodity/exposure groups is the hazard of termite attack. This regionally occurring special hazard concerns nearly all commodities and requires therefore a separate category.
Table 1. Different exposure categories with related use classes according to EN 335-1 (2006), commodities and potentially suitable test methods.

<table>
<thead>
<tr>
<th>ID</th>
<th>Related to use class</th>
<th>Exposure category</th>
<th>Commodity group</th>
<th>Close to reality Test method</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>Interior</td>
<td>Roof beams, rafters</td>
<td>Not known, Not available</td>
</tr>
<tr>
<td>B</td>
<td>2</td>
<td>Above ground covered</td>
<td>External walls, ground floor joist</td>
<td>Not known, Not available</td>
</tr>
<tr>
<td>C</td>
<td>3.1</td>
<td>Above ground coated</td>
<td>Window joinery</td>
<td>L-joint EN330</td>
</tr>
<tr>
<td>D</td>
<td>3.2a</td>
<td>Above ground slight</td>
<td>Cladding, fence rails</td>
<td>Not known, Not available</td>
</tr>
<tr>
<td>E</td>
<td>3.2b</td>
<td>Above ground severe</td>
<td>Decks</td>
<td>Double layer / multiple layer</td>
</tr>
<tr>
<td>F</td>
<td>4</td>
<td>Ground contact</td>
<td>Poles, posts, sleepers</td>
<td>EN 252</td>
</tr>
<tr>
<td>G</td>
<td>5</td>
<td>Sea water contact</td>
<td>Ships, wharfs</td>
<td>EN 275</td>
</tr>
<tr>
<td>H</td>
<td></td>
<td>Termite hazard</td>
<td></td>
<td>Not known, Not available</td>
</tr>
</tbody>
</table>

Some exposure categories are identical with the use classes described in EN 335-1 (2006) and may be taken over. However, the range of use class 3 seems to be unacceptably broad and needs therefore to be subdivided. In Table 1 coated and uncoated commodities are first distinguished, and thereafter, slight and severe hazards are distinguished for uncoated materials. The need for further differentiations should be discussed.

To summarize, the essential finding is that the agreement on a certain classification of exposure categories, which represent different commodities close to reality, gives the necessary number of RSLs to be considered for service life prediction. The rule should hence be to distinguish between as many categories as necessary, but as few as possible. Thus, the first stopover "Necessary exposure categories" is reached, as given in Figure 2.

Figure 2. Roadmap for the specification of wood and wood-based products.
2.3 Determination of Reference Service Lives with Appropriate Field Test Methods

Once a certain number of exposure categories are agreed on, the next task is to determine RSLs for all of them. Therefore, suitable test methods, which represent the different exposure categories, and commodity groups respectively, need to be determined. Table 1 gives some examples for field test methods, which may be helpful to determine RSLs for the particular categories. For example, the EN 252 (1989) test for in-ground exposure and the L-joint-test (EN 330, 1993) for coated window joinery are well-established methods, and a lot experience with these tools exists.

For other exposure categories suitable tools are still missing and the adoption of existing methods or the development of new methods should be the next stopover on the map ("Appropriate field tests", Fig. 2).

2.4 Determination of Reference Service Lives with Adopted Laboratory Tests

Appropriate test methods for the determination of RSLs are not necessarily only field test methods. The wood industry in particular, but also scientists and testing laboratories, are seeking short-term methods that take less time to conduct, not at least to allow a sufficiently rapid approval of a product for specific applications. However, as a starting point in the development of such methods, is that these should replicate in-use conditions as close to reality as possible. These are typically conducted, in general and apart from in-service performance, as field trials.

Some guidance on how to incorporate short-term tests into performance classification is given by the ISO standard 15686-2 (2001). An extract of the systematic methodology for service life prediction of building components, adopted and closely related to wood products is given in the scheme provided in Fig. 3.

![Figure 3. Systematic methodology for service life prediction of building components (according to: ISO 15686 -2 (2001)).](image)

Whenever one wants to make use of the results derived from short-term tests, it is indispensable to compare the degradation patterns between long-term and short-term tests. As long as no similar degradation pattern can be observed, the short-term test should be adopted. However, if similar degradation is provided, nothing argues against the inclusion of laboratory short-term tests. Quite the contrary, there are also some exposure categories conceivable, where short-term tests appear as the only suitable solution: For commodities exposed above ground and protected, e.g. external walls, the occurrence of decay will probably take years or even decades. In this case, moisture measurements over a limited period of time may be an alternative to long-term field trials.
However different the test methods, for the roadmap it is essential that for every exposure category, a method having test conditions closely related to in-use conditions should be established to obtain a RSL for each exposure category, as given in Table 1. From this, “Determination of RSL” is the next stopover on the product specification roadmap provided in “Fig. 2. The adoption of short-term test methods may be seen as a side route on the map.

### 2.5 Performance Factors

The results of the different tests, representing the different exposure categories, can be used to predict and classify the performance of wood-based products. Actually, the primary result of every field trial is the service life in years of, on the one hand, a material X to be tested, and on the other hand, a reference material. The reference material can be Scots pine sapwood (*Pinus sylvestris* L.), as it is used in many existing European standards, but may be also different for a particular test method. At this stage it is particularly important to note that the service life of a reference material or reference product (SLreference) is different from the reference service life (RSL) of a certain material X determined at a particular test site. Thus, two main results arise from each field test:

\[
\text{SL}_{\text{material X}} = \text{service life of a material X to be tested} \\
\text{SL}_{\text{reference}} = \text{service life of the reference}
\]

To become independent from the influence of the different test sites it seems appropriate to express the performance of the test material as a factor, the performance factor (PF), given as:

\[
PF = \frac{\text{SL}_{\text{material X}}}{\text{SL}_{\text{reference}}} \quad [\text{y/y}]
\]

In accordance to the classification of exposure situations (Table 1) the performance factors must be related to the different exposure categories. For each exposure category a performance factor needs to be determined as the following example shows:

**Exposure category F: ground contact**

Test method: EN 252 (1989)

\[
\begin{align*}
\text{SL}_{\text{material X}} &= 6.9 \text{ years} \\
\text{SL}_{\text{reference}} &= 3.0 \text{ years} \\
PF_F &= \frac{\text{SL}_{\text{material X}}}{\text{SL}_{\text{reference}}} = \frac{6.9}{3.0} = 2.3
\end{align*}
\]

PF$_F$ = 2.3 $\rightarrow$ 2.3 longer service life than the reference in ground contact (exposure category F)

With the help of performance factors for each exposure category considered, a very detailed and precise characterization for a material to be tested is possible. From the stopover "Performance factor" the final destination is already reachable on the roadmap. In principal, every material can be specified with a certain number of performance factors.

### 2.6 Performance Classes and Performance Regulation

The use of numerous different performance factors may cause confusion during its implementation in practice. Therefore it could be an option to combine performance factor intervals in performance classes, e.g. according to the classification of durability (EN 350, 1994), as schematically shown in Fig. 4. Again the creation of performance classes needs to be done separately for the different exposure categories.

To define, which product may be used for a certain application, is a task for the local authorities. They need to devise requirements related to the different performance classes (example given in Fig. 4). On the roadmap the final destination is reached. The task "performance regulation" appears as a stopover on the road to a "performance-based product specification".
Performance factors → Performance classes → Application

PC 1 PF = 5
PC 2 PF > 3, but = 5
PC 3 PF > 2, but = 3
PC 4 PF > 1.2, but = 2
PC 5 PF = 1.2

Related to exposure categories!

Minimum requirements for certain applications: e.g., “PC 2 or better”

Figure 4. Relationship between performance factors, performance classes, and performance regulation.

2.7 Test-site Relationships

In section 2.5 relating to performance factors, the influence of the test site was not considered. In fact, performance factors were created in order to eliminate the influence of the test site. However, the test site nonetheless has a strong influence on the test results. Testing the same material at different field test sites will inevitably lead to different service lives. Table 2 gives a fictitious example of test results from L-joint tests (EN 330, 1993), carried out at three different test sites, e.g., London, Hamburg, and Bordeaux.

Table 2. Fictitious example for the calculation of performance factors from service lives of a material X to be tested and a reference material determined at different test sites.

<table>
<thead>
<tr>
<th>Test site</th>
<th>SLmaterial X [y]</th>
<th>SLreference [y]</th>
<th>PF3.2a (L-Joint)</th>
</tr>
</thead>
<tbody>
<tr>
<td>London</td>
<td>18</td>
<td>9</td>
<td>2.0</td>
</tr>
<tr>
<td>Hamburg</td>
<td>24</td>
<td>12</td>
<td>2.0</td>
</tr>
<tr>
<td>Bordeaux</td>
<td>30</td>
<td>15</td>
<td>2.0</td>
</tr>
</tbody>
</table>

The material X to be tested revealed different service lives at the three sites as well as the reference material. Ideally, the calculation of performance factors leads to the same performance classification (here: PF3.2.a = 2.0) for all test sites. Certain variations of the performance factors determined at different sites should be expected, but may be in an acceptable range.

The relation between two test sites can be calculated from the service lives of the reference material in terms of an inter-site factor, e.g., between London and Bordeaux:

\[
\text{Inter-site factor } \text{BDX/LON} = \frac{\text{SL}_{\text{reference}}}{\text{SL}_{\text{BDX}}} = \frac{\text{SL}_{\text{reference}}}{\text{SL}_{\text{LON}}}, \text{BDX/LON} = 15 \text{ years} / 9 \text{ years} = 1.67
\]

Another example shows a possible practical use of knowledge related to inter-site relationships. Consider the following:

1. Material X shall be used in Bordeaux
2. Material X is so far tested only in London
A question might be posed as to what the estimated service life (ESL) of material X in Bordeaux would be? With the help of knowing the inter-site factor between London and Bordeaux, the ESL of material X in Bordeaux can be calculated as:

\[
ESL_{\text{material X / BDX}} = \frac{SL_{\text{material X / LON}} \cdot \text{ISF}_{\text{BDX/LON}}}{18 \text{ years} \cdot 1.67} = 30 \text{ years}
\]

To summarize, two important measures can be obtained as a result of different field tests at different test sites: 1.) The performance factor, which is the service life of a certain material relative to a reference, can be used to specify a product. 2.) As a by-product, inter-site factors, which describe the relation between different test-sites by means of their decay hazard, can be used for service life prediction models and hazard mappings.

For the roadmap a second sideway with the stopover "Inter-site factors" resulted from reflecting on the inter-site relationships (Fig. 2). Together with the tasks "product specification" and "performance regulation" it represents the basis for performance based building, which can be seen as a super ordinate aim, when working on performance prediction and product specification.

3 CONCLUSIONS

A strong need for performance classification derives from the user of wood and wood-based products on one hand, and is required by the CPD on the other hand. On the way to fulfilling these requirements service life prediction can be seen as the link between "user needs" and a feasible "product specification". The results from service life prediction are always numbers in years and consequently satisfy the perceived needs of the user, whereas performance factors, determined for a sufficient number of different exposure categories, can represent the connection between use and hazard classes and durability classes.

The roadmap outlined in this paper shows that all necessary tools for an exposure-related performance specification are, in principal, already available. Different field and laboratory tests need to be adopted to in-service related test situations, but do already exist, as well as the use classes and durability classes, which are adaptable to performance classes. The challenge for the wood industry practitioners and wood scientists is to bring all these single elements together – a proposal is made in this paper. Finally, the cornerstones for a performance-based building can be established on the way to developing a feasible product specification.

4 REFERENCES


EN 252, 1990, ‘Wood preservatives. Field test methods for determining the relative protective effectiveness in ground contact’.


