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Review

Modelling the outdoor performance of wood products – A review on existing approaches

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HIGHLIGHTS

- Approaches to reflect biotic and abiotic agents affecting performance of wood-based building materials have been reviewed.
- Efforts in developing performance models for fungal decay and mould growth have been intensified in recent years.
- A framework is available to link exposure, design and the material-intrinsic ability to take up and release water.
- Methods and models have the potential to get implemented in design guidelines and European and international standards.

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ABSTRACT

Service life planning and performance classification are key issues in the building sector. Well-functioning 'performance models' are absolutely essential to predict the service life and functionality of buildings, building assets, and building products over time. Different types of performance models have been established for various building materials, but cannot necessarily transferred to wood-based materials, primarily due to their organic character. For performance modelling of wood products biological agents need to be considered, such as wood disfiguring and degrading organisms.

Different approaches to adequately reflect the influence of biotic and abiotic factors on the performance of wood have been reviewed and evaluated with respect to their usability in the building trade. We found that efforts in developing performance models for both fungal decay and mould growth have been intensified in recent years. A high heterogeneity among the numerous attempts became visible, different strategies have been followed, and were roughly distinguished according to the respective objectives, governing variables (e.g. mass loss, strength loss, remaining strength, decay ratings, service life, aesthetic appearance, etc.), data sources and the resulting level of accuracy.

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. Methods and models have the potential to get implemented not only in design guidelines, but also in European and international standards. In particular, various dosimeter models could serve as reliable tools to quantify the effects of different construction details.

Contents

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1. Background – Modelling the risk for decay

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'. An important issue is to define the governing variables. 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 should be considered in order to predict service lives. In contrast, other degradation processes such as corrosion, erosion, and hydrolysis of wood substance play a minor role.

Wood can be degraded by wood-destroying insects (e.g. beetles and termites), bacteria, fungi, and marine borers. Their occurrence and the risk of infestation respectively depend on the exposure conditions and the geographical position. While for instance the presence of termites in Europe is mainly restricted to the Southern-European countries, and shipworms live only in sea water with certain salinity, wood-destroying fungi are ubiquitous and can occur worldwide. However, there are physiological cardinal points that determine the ability of other organisms to grow and to attack wood. For example, fungi demand wood moisture contents above fibre saturation for transporting their degrading enzymes [1,2]. These deviating living conditions allow a principle differentiation of organism groups referring to the exposure conditions of wooden components. This principle is basically reflected by the use class approach described in EN 335 [3] where six use classes (UC) are defined according to the respective moisture regime and the potential presence of wood-degrading organisms (Table 1).

In particular UC 2, UC 3.1 and UC 3.2 are characterized through the respective moisture conditions, whereby UC 4 ("ground contact") is considered to be permanently wet and therefore equalized with "fresh water contact". Consequently, developing performance models with respect to fungal decay above ground covers a wide range of exposure conditions, wherefore various dosimeter approaches have been applied to address the varying moisture loads impacting on wooden components.

Generally, it becomes evident from the classification scheme of EN 335 [3] that one general model cannot display the whole diversity of exposure conditions; rather a set of models is needed each considering a particular exposure range and group of potentially occurring organisms.

In addition to the so-called 'wood-destroying organisms' which are able to degrade wood substance, and partly also digest and metabolize lignocellulose, 'only' aesthetical damage is caused by 'wood disfiguring fungi' in terms of mould growth and blue stain. Besides the optical impairment moulds have the potential to cause allergic reactions and human health problems. This is an issue especially in indoor environment, where damp water can cause moisture accumulation. Mold and rot fungi are basically different in biology and physiology as well as in their strategy to use wood as a nutrition source. While mould is more or less a surface phenomenon without significant impact on the mechanical properties of wood, rot fungi degrade cell walls in the full volume of a building component. Moisture and temperature minimum thresholds also vary between both groups and require consequently different modelling approaches. A comprehensive review

Table 1
Summary of use classes and their respective harmful organisms of wood and wood products according to EN 335 [3].

Use class	General service conditions[a]	Occurring organisms[b,c]				
		Wood disfiguring fungi	Wood-destroying fungi	Beetles	Termites	Marine organisms
1	Interior, dry	–	–	U	L	–
2	Interior or under roof, not exposed to weather, possibility of condensation	U	U	U	L	–
3	Exterior, without soil contact, exposed to weather If class-divided: 3.1 limited moist conditions 3.2 persistently moist conditions	U	U	U	L	–
4	Exterior, in contact with soil or freshwater	U	U	U	L	–
5	Permanently or regularly immersed in salt water	U[d]	U[d]	U[d]	L[d]	U

U = is spread all over Europe and in the area of the European Union.
L = occurs locally all over Europe and in the area of the European Union.
[a] There are borderline- and extreme cases for the use of wood and wood products. These can cause the result, that a use class will be allocated, which differs from the definition of this standard.
[b] Protection against all listed organisms is not absolutely required because they do not occur under all use conditions and at all geographical locations or they are not economically significant or not able to infest specific wood products due to the specific state of the product.
[c] See Annex C.
[d] The area above water surface of certain wooden components can be susceptible to all stated organisms.