Service life of wooden constructions outdoors above ground - Guidance on design and selection of material

Instituto Eduardo Torroja de Ciencias de la Construcción
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Jöran JERMER – short presentation

Present positions

- Section leader SP Sustainable Built Environment, ”Biobased Materials & Products”
- Head of SP Sustainable Built Environment Stockholm Branch
- Secretary-General of the Int’l Research Group on Wood Protection IRG
- Working Group leader European Standardisation Organisation CEN (stepping down from this position in early 2016)

Previous positions

- Director Swedish Wood Preservation Institute
- Chairman and Secretary-General of the Nordic Wood Preservation Council NTR-NWPC (at different periods)

SP Sveriges Tekniska Forskningsinstitut

Aim and contents of the presentation

To report the major outcome of two recently terminated European projects:

- WoodExter (a WoodWisdom-Net project)
- PerformWOOD (7th Framework Programme)

….and to encourage discussion on how to deal with service life issues for wood in

- Regulations for structural components (e.g. EN 1995)
- Guidelines for non-structural components, e.g. cladding

….with an ”engineer’s approach”.

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How long?

A key issue for the competitiveness of wood is the possibility to control durability, service life, maintenance and life cycle costs for constructions and components where wood is used

Regulations and requirements on service life

Basically two major types of constructions to consider:

1. Structures as covered by Eurocodes

Regulations and requirements on service life

2. End-uses where other aspects than the structural integrity are in focus

Regulations and requirements on service life

Any requirements related to service life/durability must be related to possible consequences in terms of injuries, deaths, economic losses as well as costs and measures necessary to achieve a certain service life.

- **For structures these are related to the measures needed to consider the requirements on load-bearing capacity and applicability.**
- **For other end-uses *expectations* on service life, aesthetic and economical requirements, such as maintenance, are more adequate to consider.**

Durability design

Traditionally, durability design of wooden components and structures is based on a mixture of experience and adherence to good building practice, sometimes formalised in terms of implicit prescriptive rules.

A modern definition of durability is:
The capacity of the structure to give a required performance during an intended service period under the influence of degradation mechanisms.

Conventional durability design methods for wood do not correspond to this definition.

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WoodExter –key objective

Thus, the key objective of the WoodExter project was to take the first steps towards the development of **performance based engineering design in practice** for wood and wood-based building components in outdoor above ground situations which resulted in:

The first technical Guideline in Europe for design of wooden constructions with respect to durability and service life.

Free download at www.kstr.lth.se

The Guideline

The Guideline is focusing on constructions above ground (use class 3 according to EN 335), mainly decking and cladding – two commodities where wood is abundantly used, at least in the Nordic countries, but also other above ground end uses, e.g. bridges, noise barriers.

Basic philosophy behind the Guideline

Thus, the key issue was then how to express a design condition for durability, *familiar to engineers*, in a mathematical way.

The approach chosen was to try to use a similar procedure as for structural design, where the design condition is expressed as

”load effect” < “load-bearing capacity”

..and a limit state associated with collapse or other forms of structural failure.

Basic philosophy behind the Guideline

As the service life/performance of a wooden construction is affected by various factors with respect to:

a) **The exposure/**geographical location, local climate, sheltering, distance from ground, detail design, use and maintenance of coatings

and

b) **The resistance to decay/**different materials have different resistance against decay, e.g. preservative-treated sapwood > larch heartwood> sapwood of all species

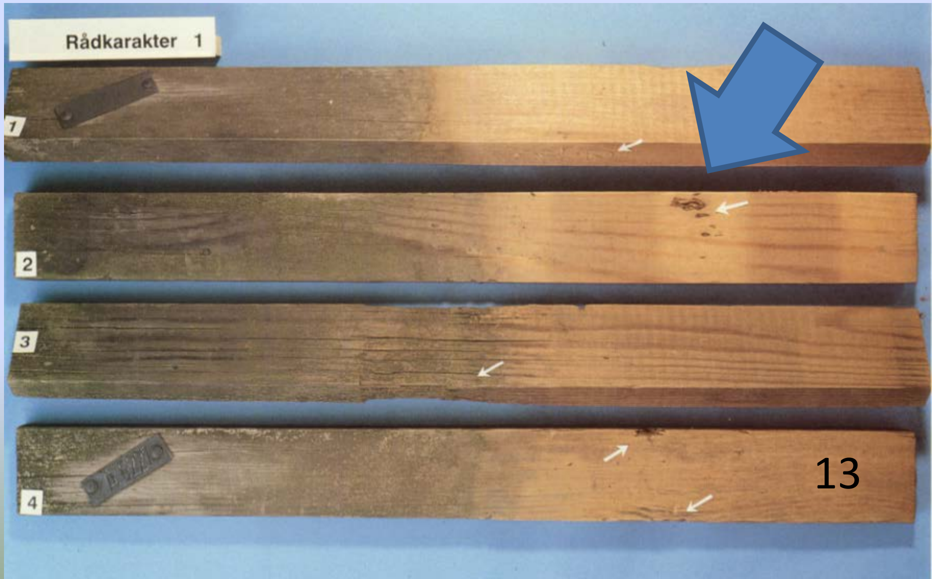
…………………..

Basic philosophy behind the Guideline

……….a design condition for durability based on ”Exposure” and ”Resistance to decay” is proposed accordingly:

The exposure (”load effect”) ≤ The resistance (“load-bearing capacity”)

and a limit state expressed as onset of decay (rating 1 according to the stake test standard EN 252) during a reference service life of 30 years.



Interpretation

In practice, this means:

•When the limit state **is not** reached, **the construction is likely to last 30 years without decay attack =** Performance**.**

•When the limit state **is** reached, **the construction is likely to be attacked by decay before 30 years =** Non-performance**.**

Thus, when using the Guideline the output shall be either

Performance (OK)* or *Non-performance (not OK)

This approach is familiar in structural design!

Design condition and mathematics

Mathematically, the design condition

The exposure ≤ The resistance

….can be expressed as:

$$I_{Sd} = I_{Sk} \cdot \gamma_d \leq I_{Rd}$$

where:

I_{Sd} = exposure index

I_{sk} = characteristic value of exposure index

I_{Rd} = resistance index

γ_d = factor for consequence class (depends on the severity of consequences in case of non-performance)

Exposure index I_{Sd}

The characteristic value of the **exposure index** can mathematically be expressed as:

$$I_{Sk} = k_{s1} \cdot k_{s2} \cdot k_{s3} \cdot k_{s4} \cdot I_{so} \cdot c_a$$

where

I_{so} = basic exposure index to account for geographical location

k_{s1} = factor to account for local conditions

k_{s2} = factor describing effect of sheltering (protection from rain)

k_{s3} = factor describing effect of distance from ground

k_{s4} = factor describing effect of detail design

c_a = calibration factor to be determined by reality checks

Components of the Exposure index I_{Sd}

Substantial work was devoted to assign realistic values to the various factors, $I_{so,}$ k_{s1} **etc, of the Exposure index.**

At this early stage the work was based partly on physical and empirical data and partly on expert judgements.

Let's have a closer look at some of the factors!

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Basic exposure index to account for geographical location I_{so}

Reference condition depending on geographical location

With the help of meteorological data and a software called Meteonorm a basic value I_{so} can be calculated for any location for a reference configuration consisting of a horisontal, free member (no moisture traps) exposed to outdoor temperature, humidity and rain.

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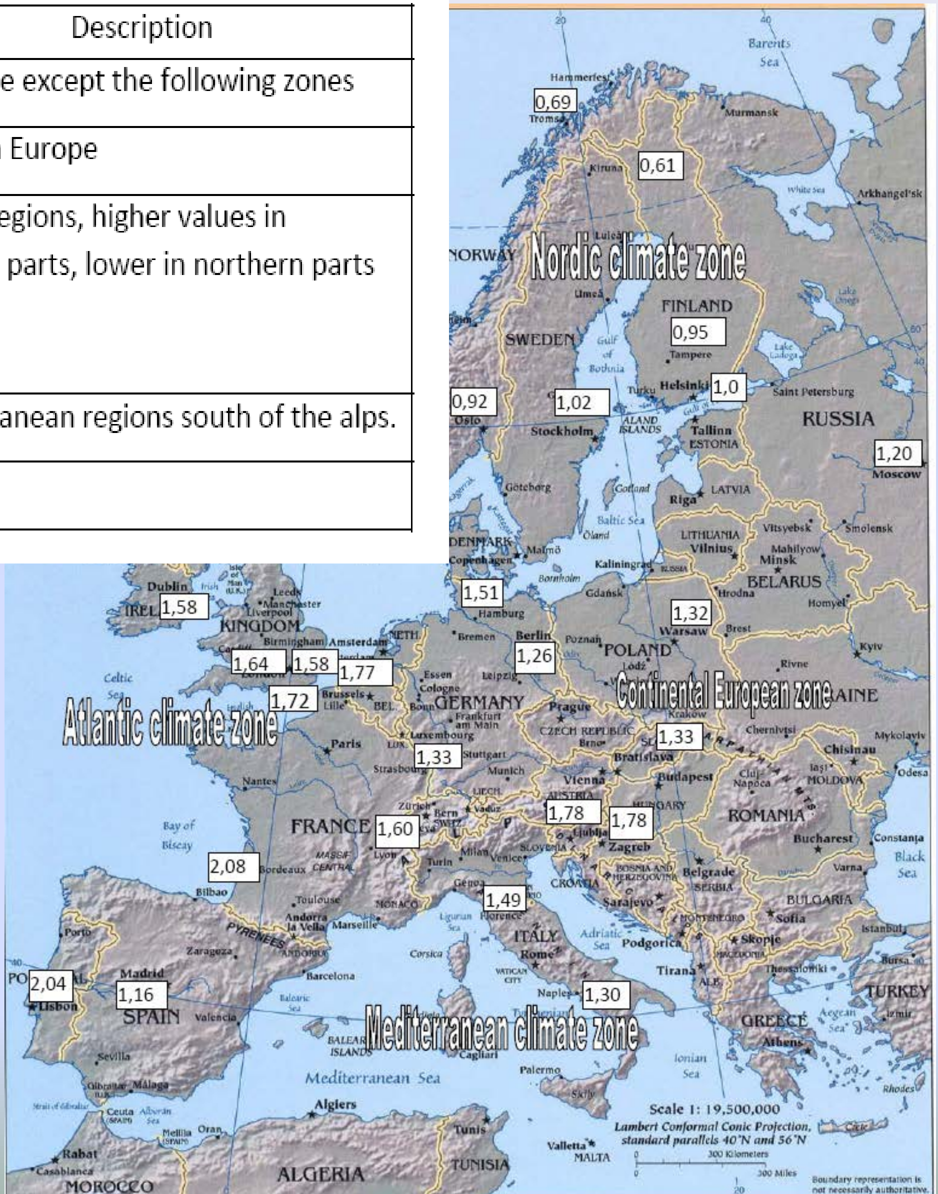
Exposure index, I_{so}, for different geographical sites

Climate Zones	I_{so}	Description
Continental Europe	1,4	All Europe except the following zones
Nordic Climate zone	1,0	Northern Europe
Atlantic Climate zones: • South of latitude 50 • Latitude 50-55 • North of latitude 55	 2,0 1,7 1,4	Coastal regions, higher values in southern parts, lower in northern parts
Mediterranean climate zone	1,5	Mediterranean regions south of the alps.
Altitude effect: altitudes above 500 m, reduce factor by 0,3		



Results for European sites with Helsinki as reference.

Increased decay hazard with increased I_{so} which is logical.

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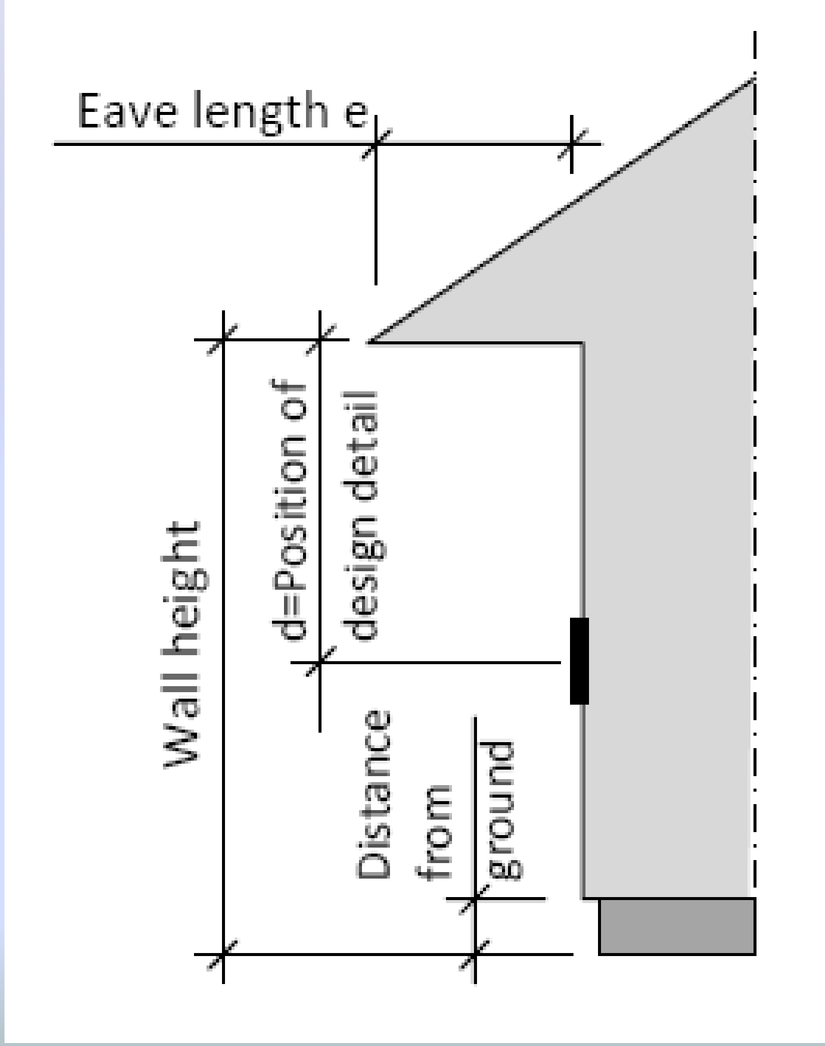
Effect of sheltering overhang, k_{s2}, and distance from ground, k_{s3}

Sheltering: eave to detail position ratio e/d	k_{s2}
e>0,5d	0,7
e=0,15d-0,5d	0,85
e<0.15d (directly exposed to rain)	1,0

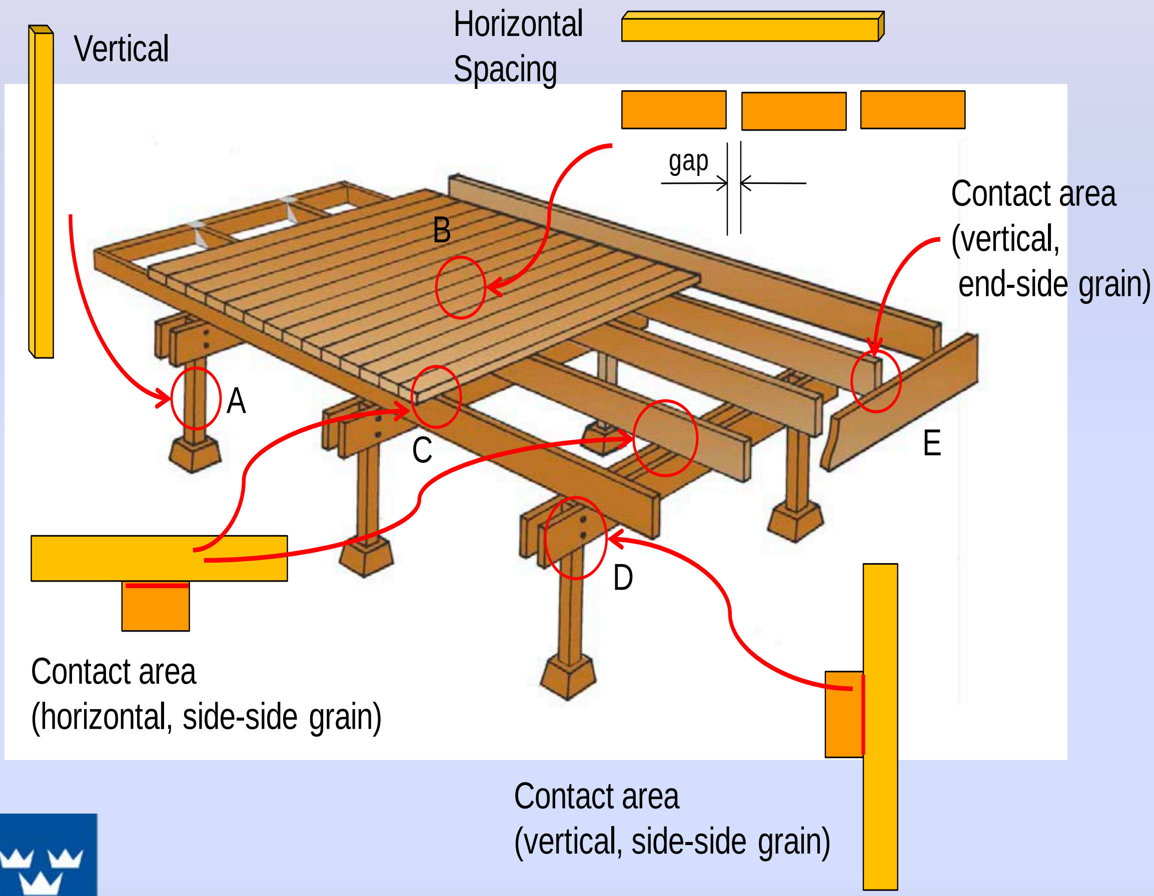
Distance from ground	k_{s3}
>300 mm	1,0
100 – 300 mm	1,5
<100 mm	2,0



Based on subjective judgements

Examples

Example: Rating of details for decking k_{s4}



Detail	Rating	k_{s4}
A	1. Excellent	0,9
B	2. Good	1,0
C	4. Fair	1,4
D	4. Fair	1,4
E	5. Poor	1,6

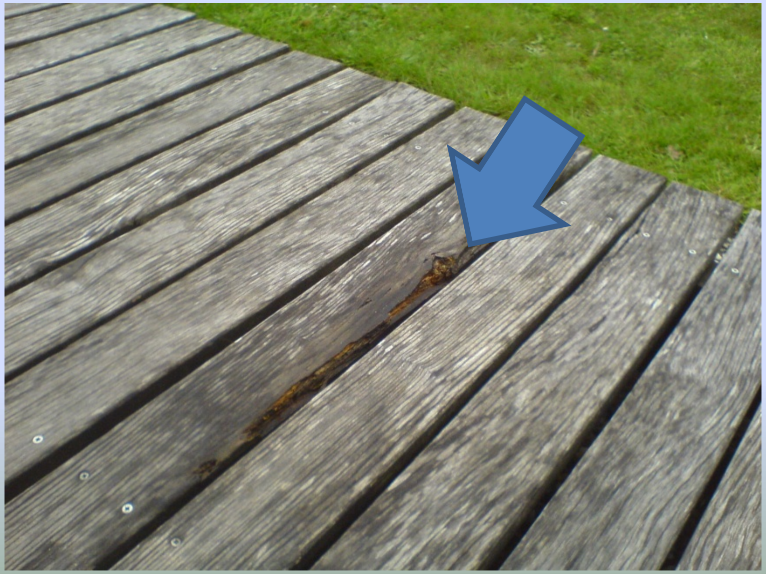
Figure: Courtesy: Timber Decking Association, UK

Resistance index I_{Rd}

I_{Rd} means a rating of materials with respect to resistance to decay

After long discussions and subjective assessments by wood durability experts, a rating was agreed based on

- Durability class data (natural durability) according to EN 350-2
- Test data, mainly from field trials
- Data on treatability and permeability for wood species
- Experience from use in practice



Characteristic resistance index I_{Rd}

Resistance class	Examples of wood materials	I_{Rd}
A	Heartwood of very durable hardwoods, e.g. afzelia, robinia (durability class 1 according to EN 350-2) Preservative-treated industrially processed to meet requirements of use class 3 according to EN 335	**10,0**
B	Heartwood of durable wood species e.g. sweet chestnut , Western Red Cedar (durability class 2)	**5,0**
C	Heartwood of moderately and slightly durable wood species e.g. larch and Scots pine (durability class 3 and 4)	**2,0**
D	Slightly durable wood species having low water permeability, e.g. Norway spruce (*Picea abies*) which is selected as reference material corresponding to I_{Rd} = 1,0	**1,0**
E	Sapwood of all wood species (and where sapwood content in the untreated product is high)	**0,7**

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Rating is not always so easy!
For example, how to rate……

- Preservative-treated wood which often is a mix of treated sapwood and untreated heartwood?

- Untreated wood with a mix of perishable sapwood and naturally durable heartwood?
- Modified wood? (Durability often dependent on process used, in particular concerning TMT, Thermally Modified Timber)

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How to use the Guideline – An example

- **Object: Cladding** on southern facade on family house built in 1979

- **Consequence class:**
  - Small (γ_d =0,8)
- **Exposure:**
  - Nordic climate zone (I_{so}=1,0)
  - Local cond. Medium-Heavy (k_{s1}=1,2)
  - No sheltering (k_{s2}=1,0)
  - 100-300/>300 mm above ground (k_{s3}=2,0/1,0)
  - Medium detail design (k_{s4}= 0,9)
- **Material:**
  - Spruce (resistance class D=1,0)

How to use the Guideline – An example

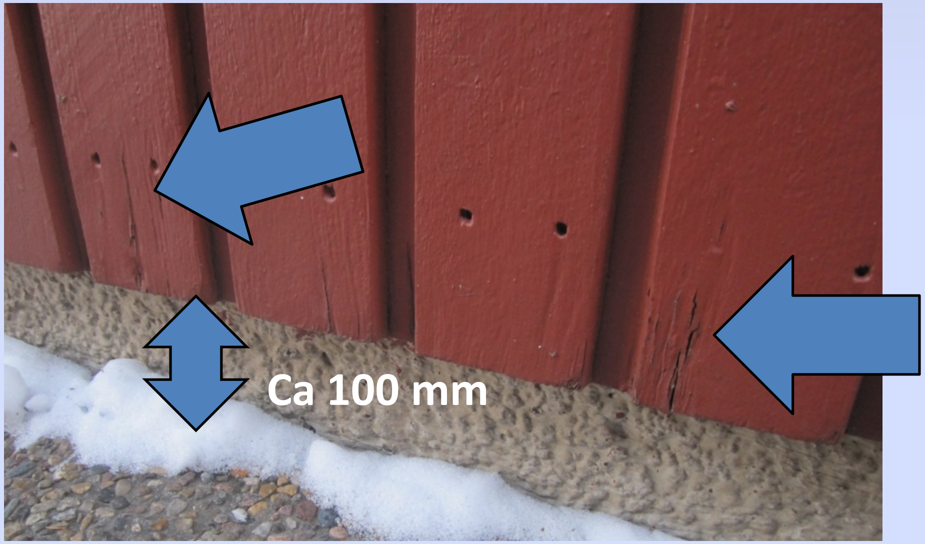
- **Question:**
- Will the cladding last 30 years without onset decay?

- By using the WoodExter software tool, we can find the answer.

How to use the Guideline – An example

- Thus, the answer is: NO!

- Decay was observed after 15-20 years on severely exposed parts of the southern facade with poor sheltering!



Excel tool

Summarizing how to use the Guideline:

The Guideline is used accordingly:

1. Select consequence class to determine γ_d
2. Determine the basic exposure index I_{so} corresponding to the geographical location
3. Determine the correction factor for the local climate
4. Determine the factors related to the design (protection against rain, distance from ground, detail design)

Steps 2-4 give the Exposure index

5. The selected material will give a value for the Resistance index I_{Rd}
6. Check whether the chosen design/material will comply with

$$I_{Sd} = I_{Sk} \cdot \gamma_d \leq I_{Rd}$$

7. If not: reconsider mainly steps 4 and 5

Main advantages of the Guideline

The user will have

- a quantitative tool for decision making that is applies in the same way as other tools used in building design
- a method to distinguish between sites with different climate conditions
- a check list creating awareness of appropriate detailing solutions
- to think about the consequences of violation of the limit state

Conclusions and next steps

- The output from the design tool agrees reasonably well with experience from practice but more reality checks are needed
- Quantification of exposure seems to give reasonable results but has to be further developed
- Quantification of resistance is still difficult for many products/species. Further work needed. How to deal with insects, e.g. termites?
- To find the right balance of risk is a challenge due to large variability of material response as well as exposure
- A major challenge is to encourage specifiers and architects to use the Guideline and give feedback for improvements

Project PerformWOOD (2012-2014)

The main over-all project objective “was to kick-start the development of new standards to enable the service life specification of wood and wood-based materials for construction”

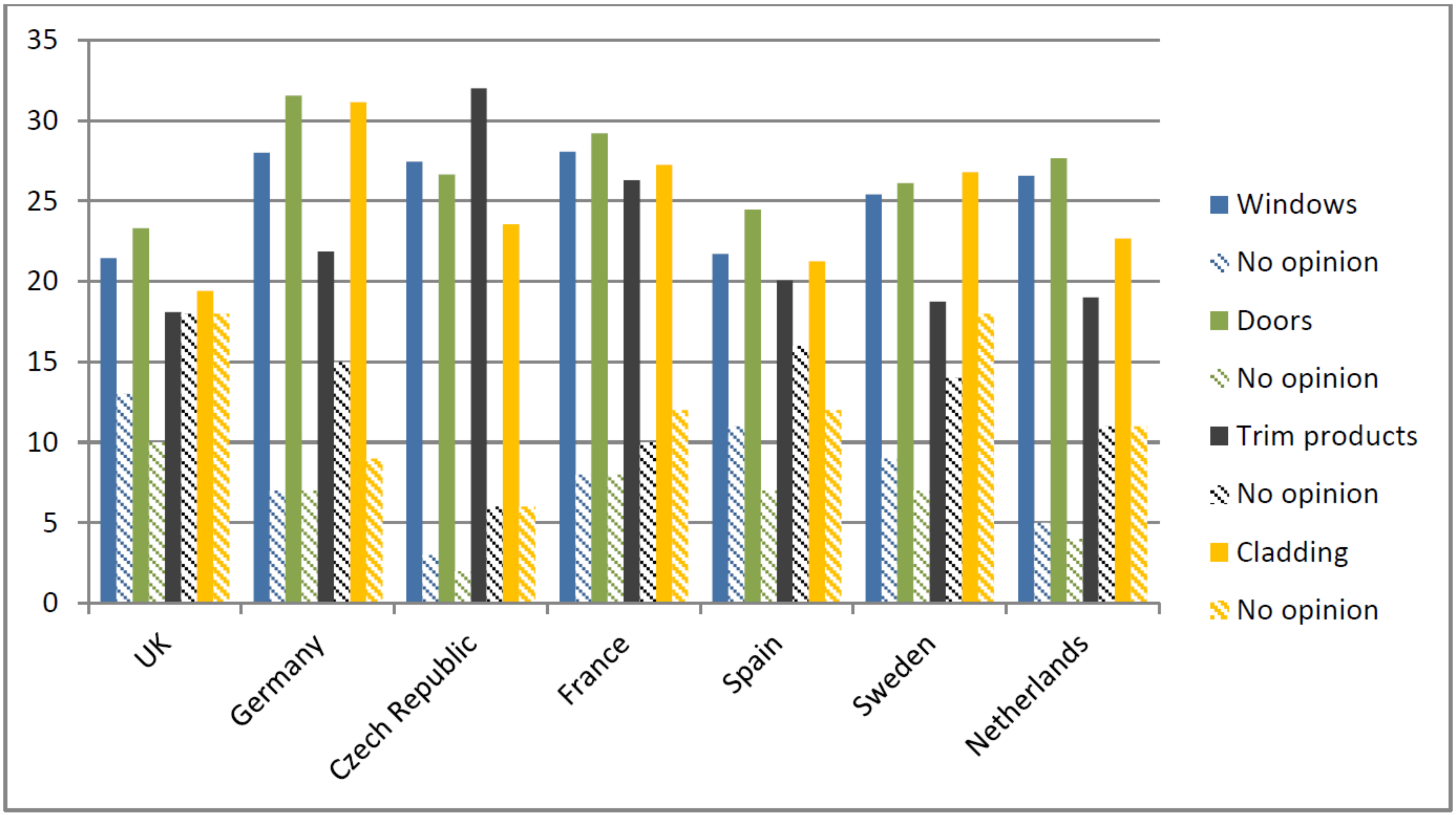
Some important achievements

- **Compilation and analysis of user expectations for service life**

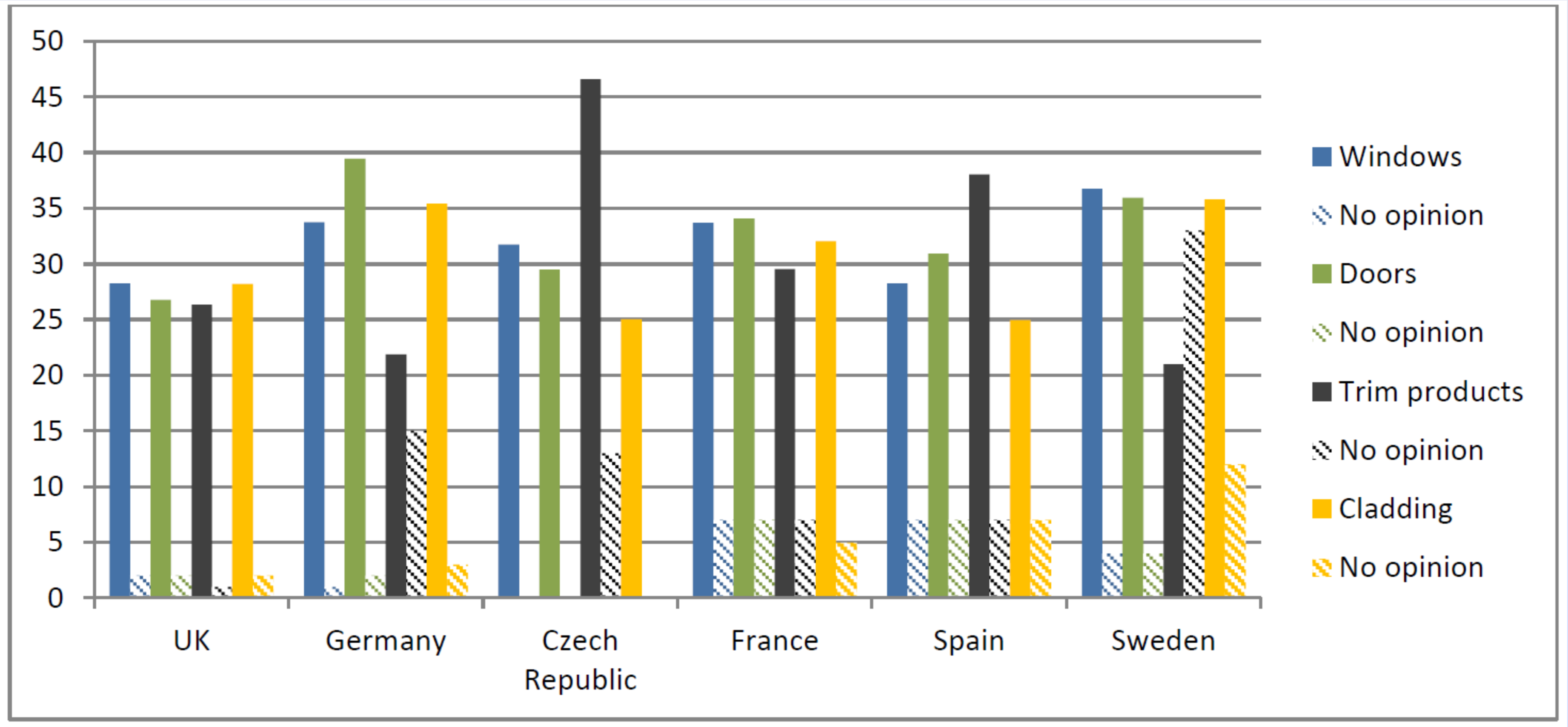
For the first time a comprehensive survey of service life expectations and guarantees for wood and wood based products has been gathered from European construction professionals and citizens.

This is vital information for future shaping of EN 460 (the European Standard that gives guidance on the selection of wood for different use classes defined in EN 335) and national interpretive documents to connect to user needs.

Service life expectations - homeowners



Service life expectations - professionals



Some important achievements

- **A draft European standard (prEN 16818) on measurement of moisture dynamics ("wetting ability") in wood and wood-based materials has been activated as a work item in CEN/TC 38 WG 28**

Discussions in PerformWOOD suggested that the decay durability classification of different wood materials should consider not only

-the resistance to decay (as determined by biological tests), but also

-the "wetting ability" as determined by prEN 16818

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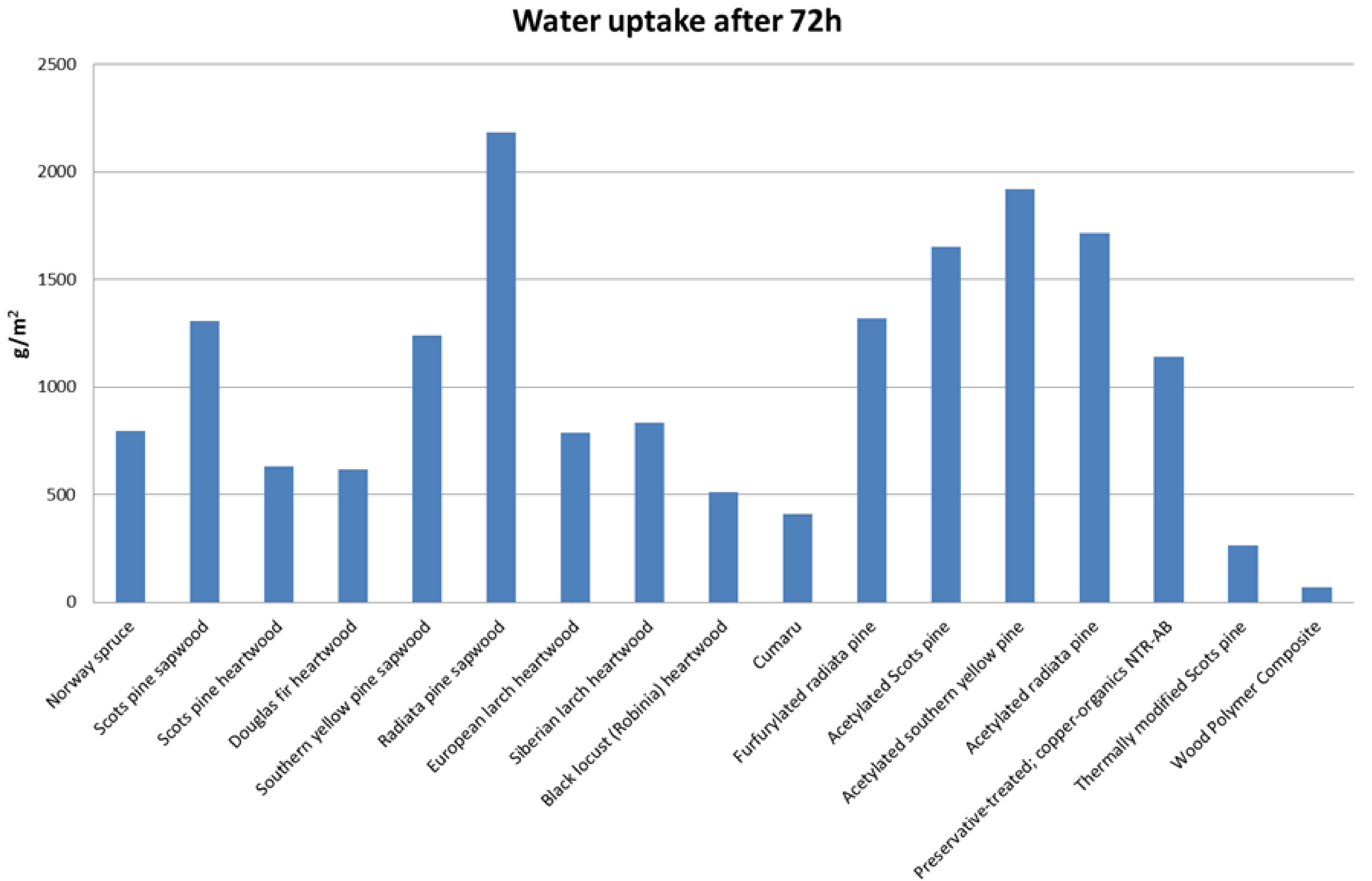
Results from submersion test EN 927-5



Some important achievements

- Thus, the new approach is to introduce also a factor for the ”wetting ability” to determine the resistance I_{Rd} accordingly:

$$I_{Rd} = D_{crit} \times k_{wa} \times k_{inh}$$

D_{crit} = critical dose corresponding to decay rating 1 (slight decay) according to EN 252 (stake test)

k_{wa} = wetting ability factor

k_{inh} = inherent resistance factor

- This approach has been successfully applied in an updated WoodExter guideline prepared in the Swedish project WoodBuild, but only for native wood species and not for preservative-treated wood, modified wood or wood-plastic composites (WPC).

Some important achievements

- **A proposition for a user friendly interface EN 460 based on performance classification of wood has commenced as a work item in CEN/TC 38 WG 28 – massive step towards integrating performance classification into mainstream specification of wood!**

A revised EN 460 is proposed to be shaped accordingly:

- Consequence of failure
- Material resistance
- Exposure dose
- Critical biological hazards
- Performance classification

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New, revised EN 460

- Consequence of failure (COF)

  Input: What is the product? Where is it used? If COF are unacceptable then higher material resistance or techniques to reduce dose need to be selected

- Material resistance

  Will be further elaborated with respect to inherent durability, biological agents and wetting ability

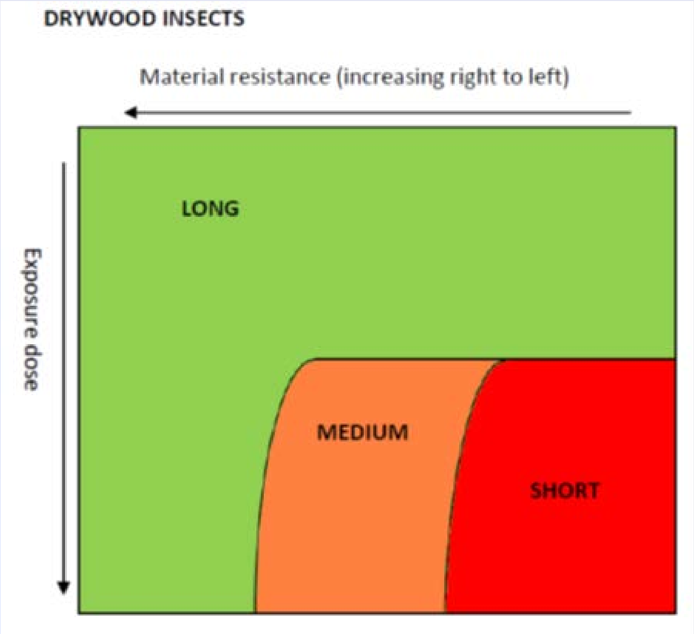
- Exposure dose

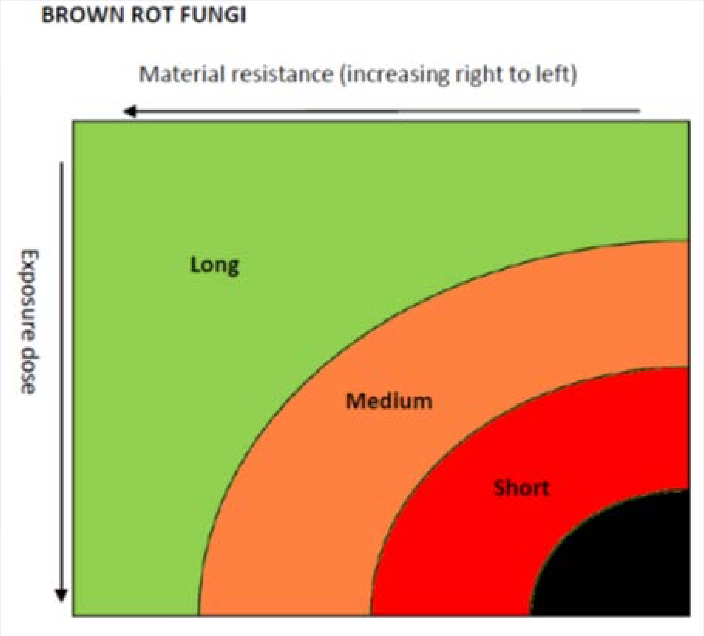
  New concept introduced that will deal with for example prediction of moisture content development in wood based on climate, size, uptake properties and design

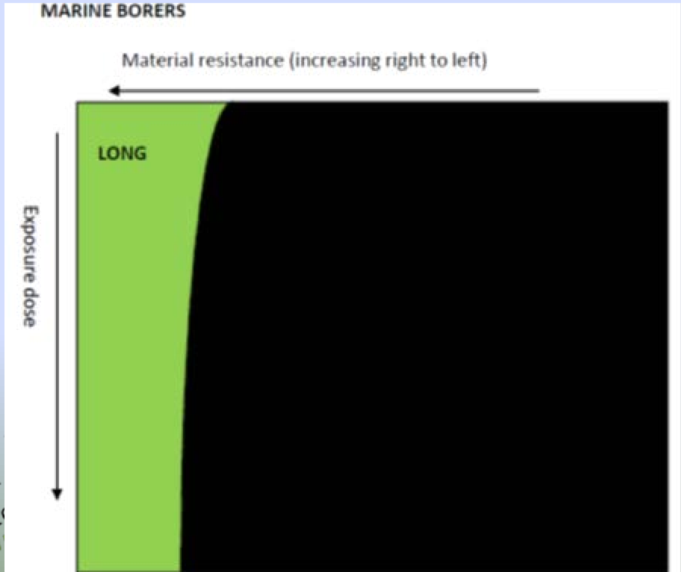
- Critical biological hazards

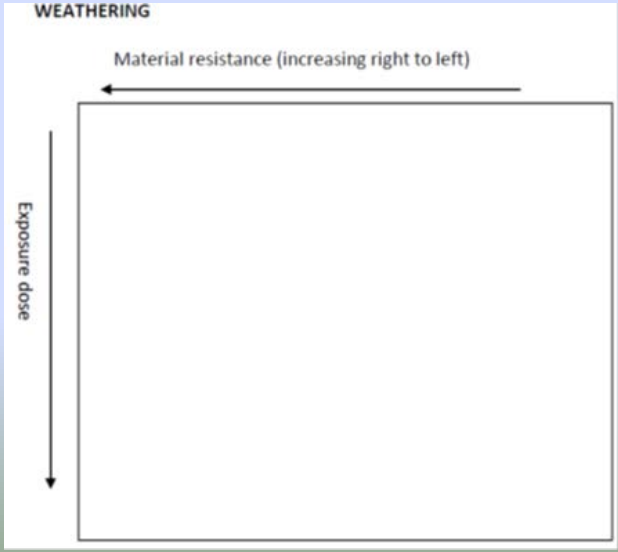
  What is the product? Where is it used? Determine the biological (and other) hazards (fungi, drywood insects, termites, marine borers, weathering)

Critical biological hazard (CBH) charts









Determine performance class (EN460)

Finally, using only the CBH charts for the specific end application and the Material resistance and Exposure dose parameters to see which performance class is attained.

Comment

It is a real challenge to re-draft EN 460 as described. A key issue is to make it simple for the end-user (specifiers, architects etc) in order to encourage its application in practice.

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Next Annual Meeting of the Int'l Research Group on Wood Protection

iRG47

47th Annual Meeting of the **International Research Group** on Wood Protection

Lisbon • LNEC • 15–19 May 2016

Welcome!

Thank you for your attention!
Any questions or comments?