WoodBuild – key results and thoughts for future work

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WoodBuild – Background

WoodBuild – a Swedish research project – was conducted between 2008 and 2013.

It was financed by the Swedish government research fund VINNOVA and industry partners.

Turnover: ~ 5 MEUR

Research partners:

- **SP Technical Research Institute of Sweden**
- **University of Lund**
- **Leibniz University Hannover**

WoodBuild – overall objectives

Generate new knowledge of exposure and biological attack of wood and wood-based materials to

• identify sustainable, scientifically evaluated building component designs from durability point of view

• improve and develop new methods for testing of resistance against mould and decay for wood and wood based materials

• **develop engineering tools for practical service life design of wood structures and commodities**

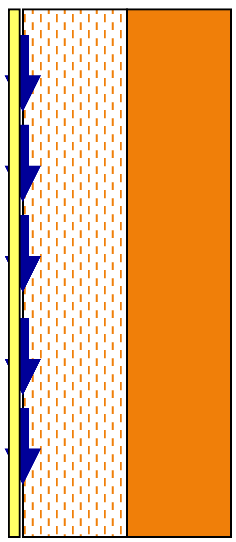
Woodbuild – main applications

Wood in outdoor applications above ground…

..and in the building envelope

Key issues

- **How long will wood last in above ground end uses?**
- **Moisture safe design of the building envelope**



- **Plaster applied direct on insulation**
- **No drainage!**
- **Leakage in joints and cracks !**

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Result – 3 Guides

The New Approach!

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

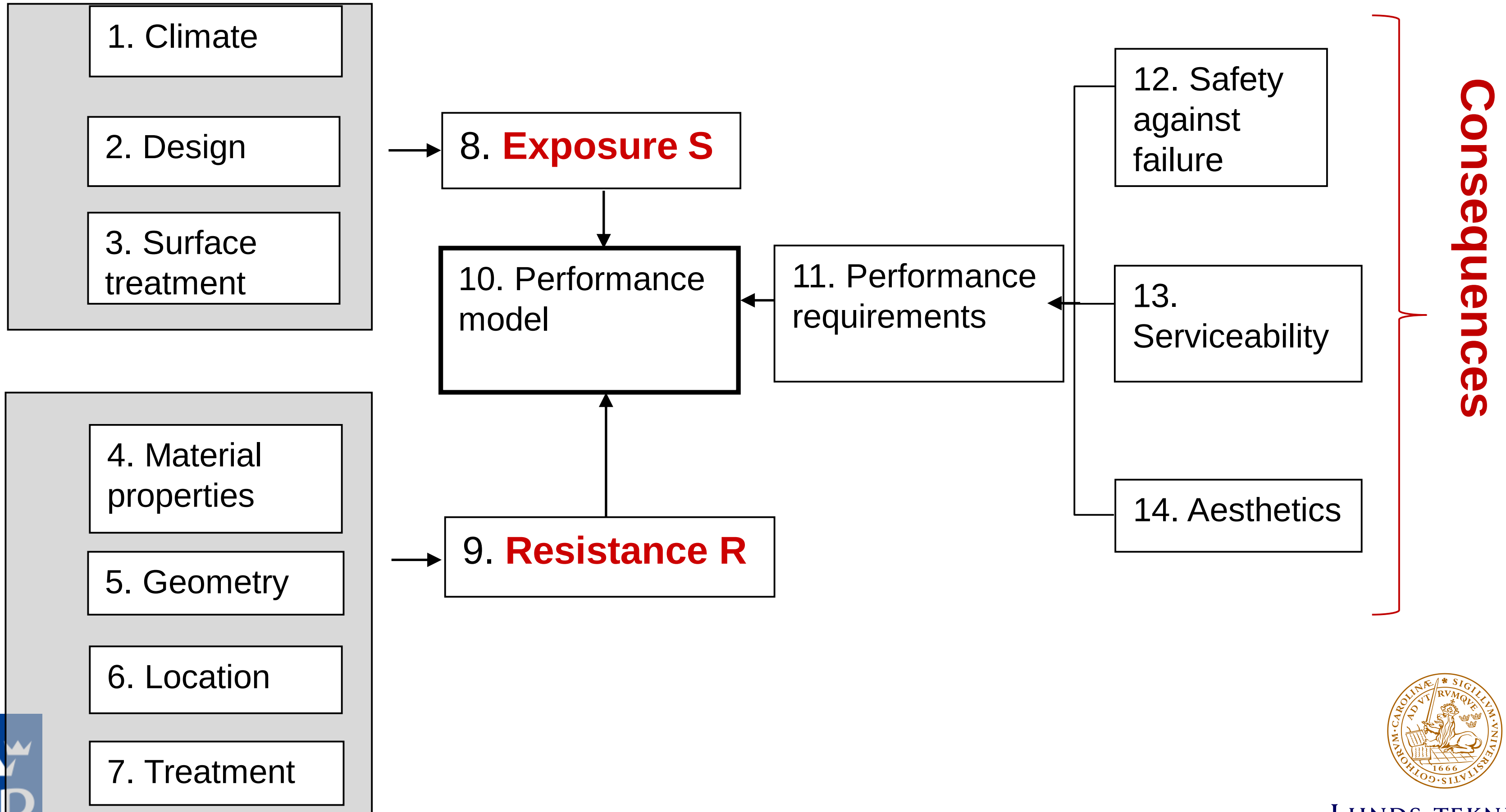
”load effect” < “load-bearing capacity”

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

This approach is familiar to engineers in the building sector.

Exposure and material resistance – key factors for performance

As the service life/performance of a wooden construction is affected by various factors with respect to the exposure conditions and the material resistance to fungal attack…….



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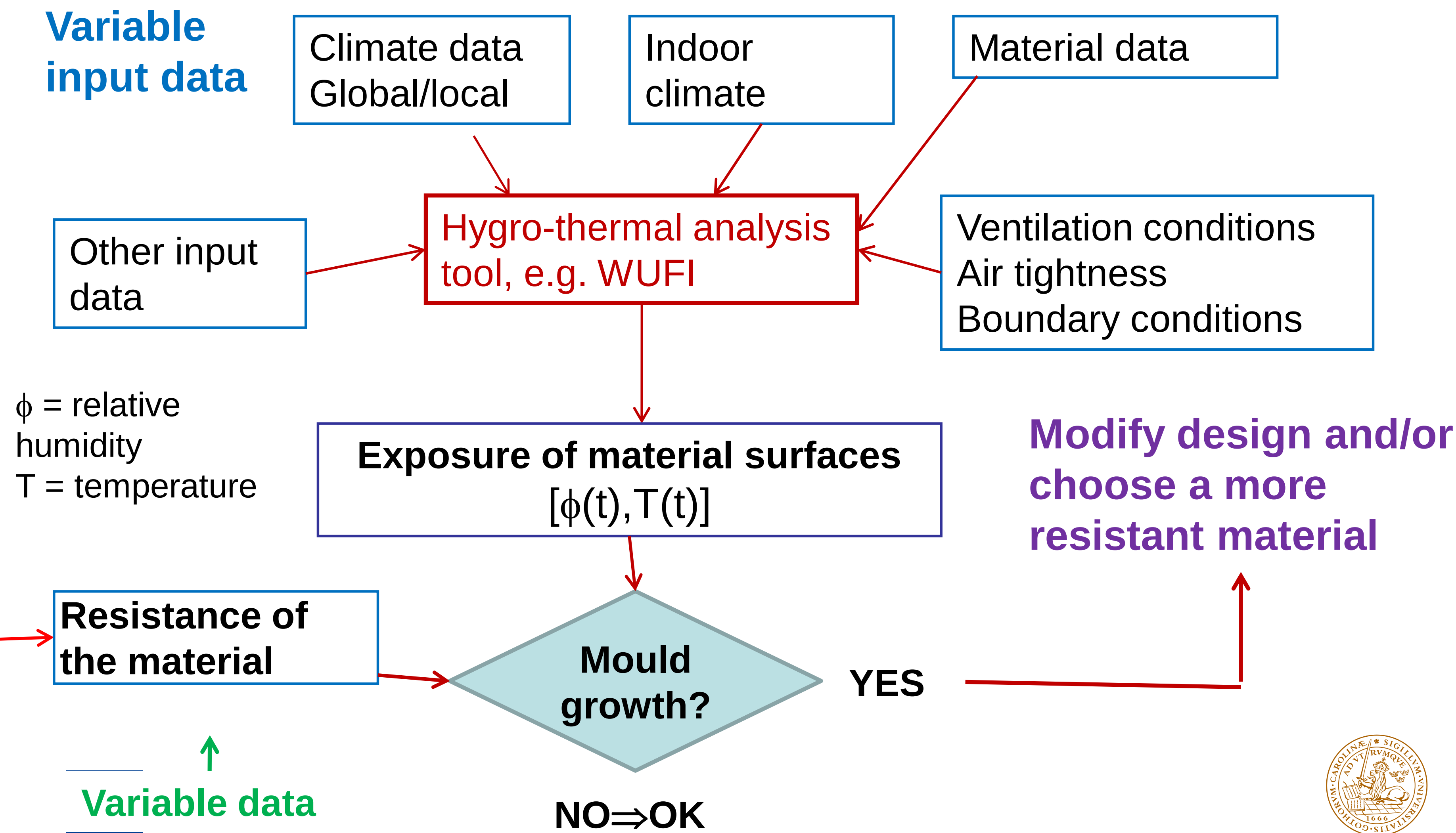
Design condition

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

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

and a limit state expressed as a defined rating of decay attack/mould growth.

Moisture safe design of the building envelope – general principles



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MRD model

In order to handle the input data on exposure and material resistance, a method, called the MRD model (Mould Resistance Design) was developed for evaluation of the mould risk. It is based on a substantial amount of data from e.g:

- **Meteorological measurements from different geographical locations covering several decades**
- **Indoor climate measurements**
- **Laboratory tests for mould growth with different wood-based materials (”ranking” different materials with respect to resistance against mould growth)**
- **WUFI simulations**

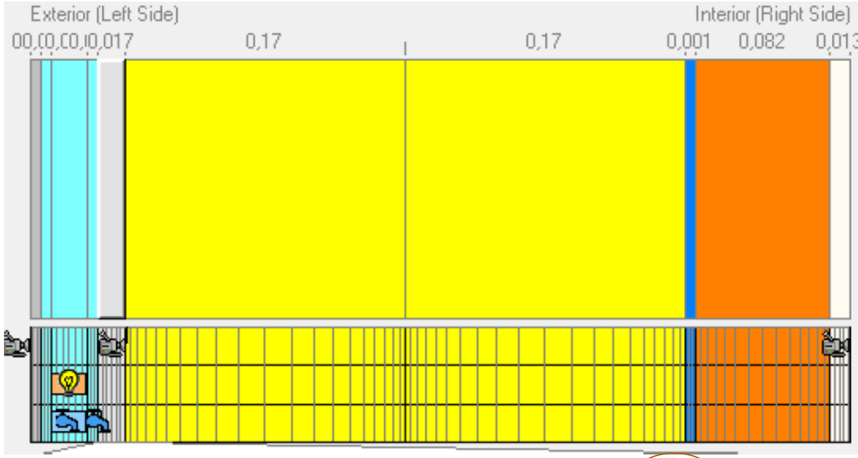
Use in practice

The MRD model can then be used for evaluating the mould risk for e.g. different wall designs

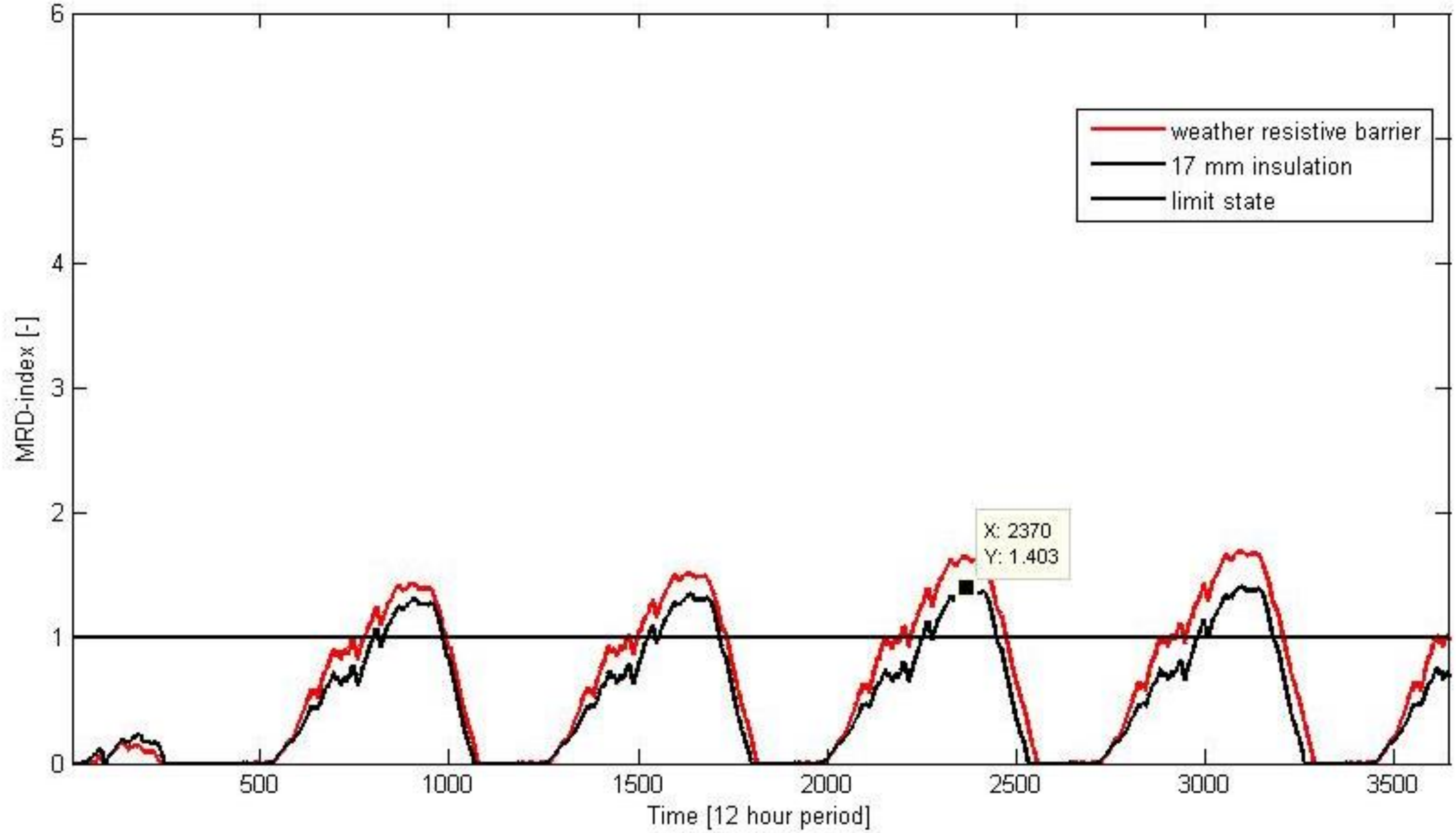
Example: Wall of a passive house

Materials from left to right

Thickness, mm	Layer
8	Fibre cement board
30	Air gap, 40 ACH (Air changes/h)
a) 0 b) 17	Weather resistive barrier, s_d =0,2 m Mineral insulation
170+170	Mineral insulation/ wood studs
1	Vapour retarder
82	CLT-panel, spruce radial
13	Gypsum board



Result –passive house



Effect of replacing weather barrier with insulation negligible. The solution shows a certain risk of growth, might be improved by adding more insulation (analysis by J. Niklewski)

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Possible consequences of violating the limit state
(i.e. consequences of mould growth in the building envelope)

- Adverse smell affecting the indoor environment
- Visible mould growth revealed by inspection
- Emissions from microorganisms leading to adverse health effects for some people in the building (e.g. allergy, enhanced risk for cancer, reduced working capacity etc.)

Primarily of economic nature implying

- need for renovation work which may be expensive
- loss of value of the building when sold

Guide on moisture safety - Conclusions

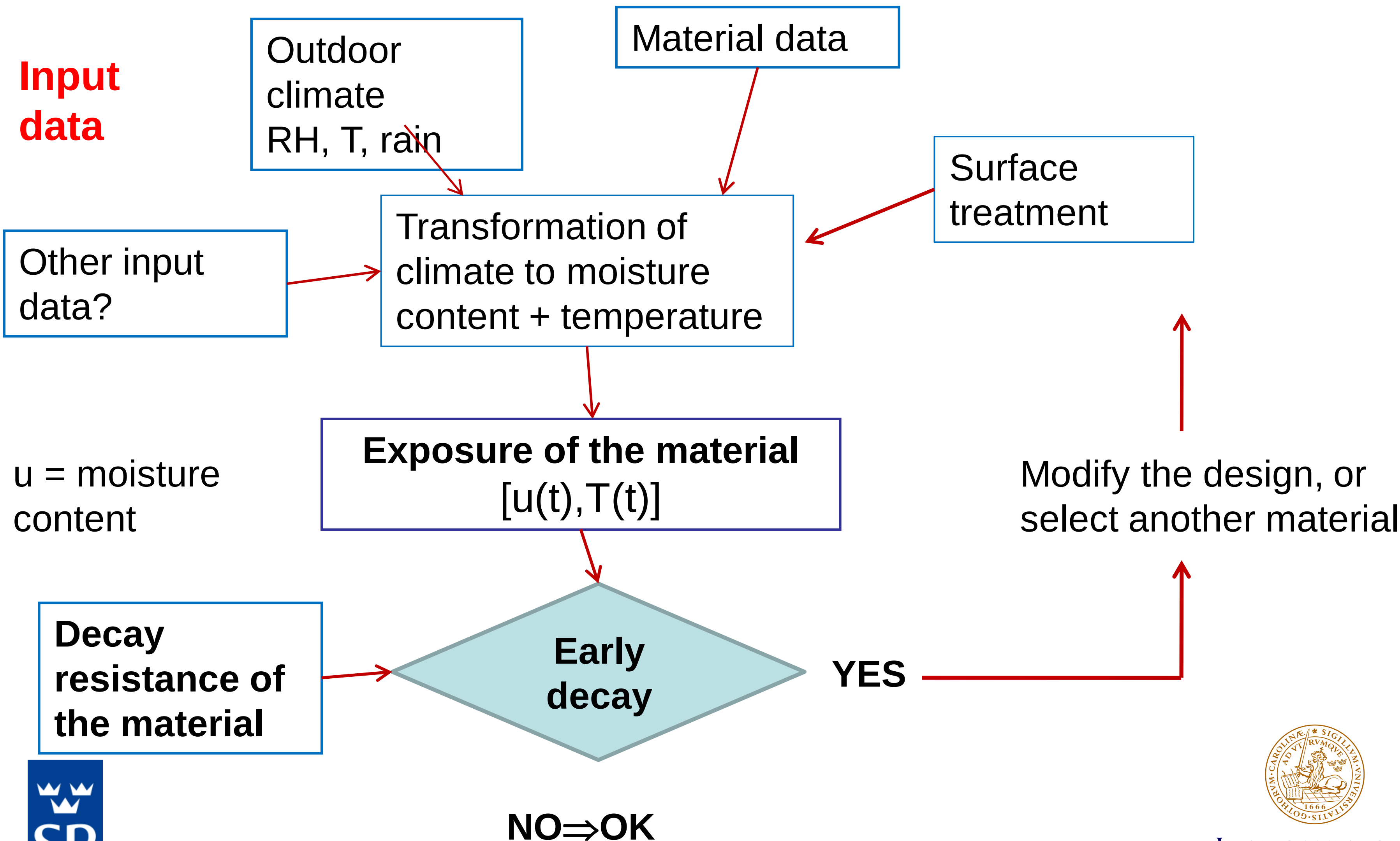
This guide should be seen as a first attempt to handle risks related to moisture saftey and wood materials in a rational and balanced way.

Moisture safety must be evaluated as a function of simultaneous influence of RH and T and their variation with time. This is provided by the MRD model which gives a tool to evaluate the risk of mould growth.

It is not yet possible to quantify all uncertainties that affects the moisture safety. Further research is therefore needed to handle these uncertainties that affects both exposure and material resistance. Calibration needed against well-known design solutions showing adequate moisture safety as well as design solutions which are clearly known to be unsatisfactiory.

A major challenge is to encourage specifiers to use the Guide and give feedback for improvements!!

Design of outdoor wood constructions above ground – general principles



Different approaches:
WoodExter vs WoodBuild

The general design principle was first applied in the WoodWisdom project WoodExter in order to give the answer if the constrution was likely to last at least 30 years without decay attack.

In the WoodBuild project the design principle was further elaborated to make it possible to actually calculate the expected service life in years.

Design condition and mathematics

Mathematically, the design condition

The exposure ≤ The resistance

…. can be expressed as:

$$D_{Ed} = D_{Ek} \cdot \gamma_d \leq D_{Rd}$$

where:

D_{Ed} = exposure index

D_{Ek} = characteristic value of exposure index

D_{Rd} = resistance index

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

Exposure index D_{Ek}

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

$$D_{Ek} = k_{E1} \cdot k_{E2} \cdot k_{E3} \cdot k_{E4} \cdot k_{E5} \cdot D_{E0} \cdot c_a$$

where

D_{E0} = exposure that accounts for the geographical location

k_{E1} = factor to account for driving rain

k_{E2} = factor for local exposure conditions (topography, surrounding buildings)

k_{E3} = factor describing effect of sheltering (protection from rain)

k_{E4} = factor describing effect of distance from ground

k_{E5} = factor describing effect of detail design

c_a = calibration factor to be determined by reality checks

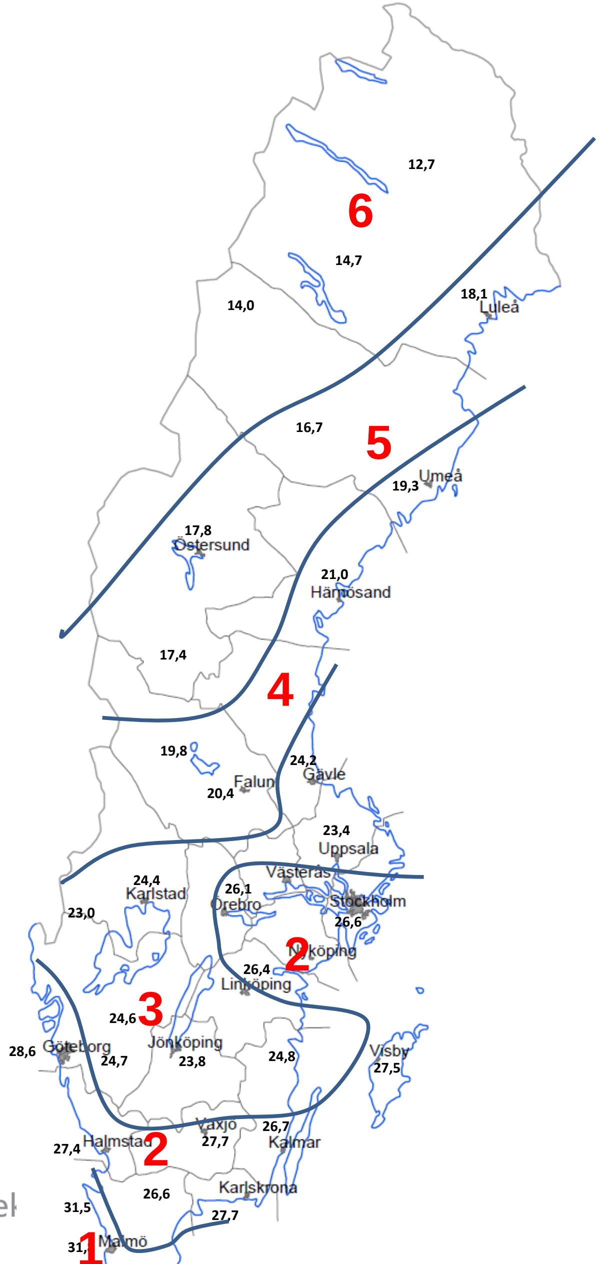
Components of the Exposure index D_{Ek}

Substantial work was devoted to assign realistic values to the various factors, D_{E0}, k_{E1} etc, of the Exposure index.

This work has been based partly on physical and empirical data and partly on expert judgements.

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

Exposure index, D_{E0}, for different geographical sites



D_{E0} for different zones of Sweden	
Zone	D_{E0} **(days)**
1	32
2	28
3	25
4	21
5	18
6	15

Increased decay hazard with increased D_{E0} which is logical.

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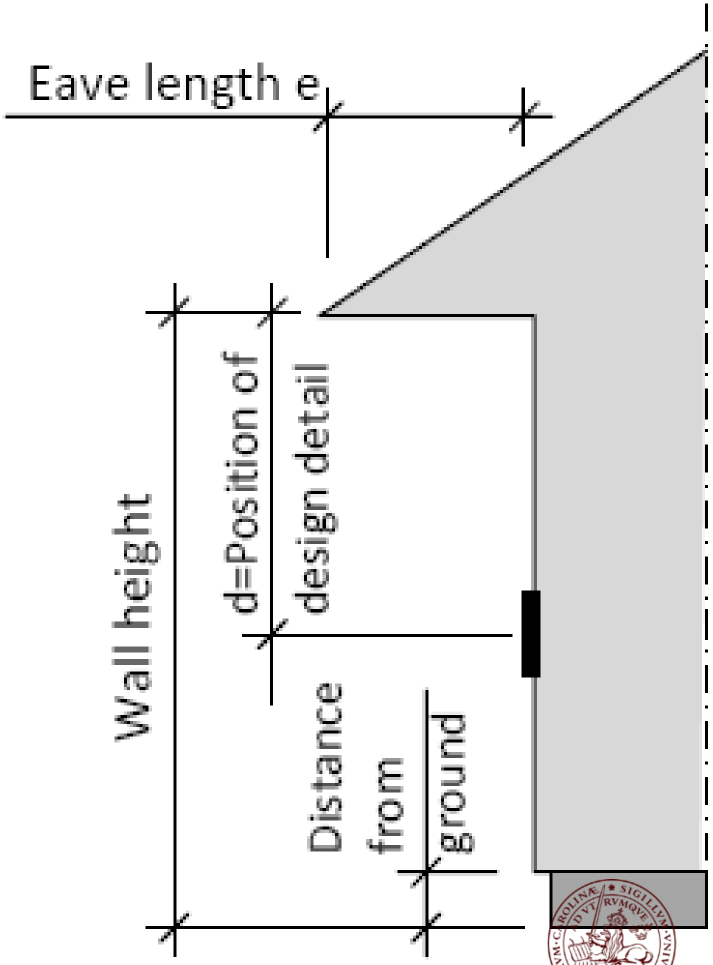
Effect of sheltering overhang, k_{E3}, and distance from ground, k_{E4}

Sheltering: eave to detail position ratio e/d	k_{E3}
e>0,5d	0,7
e=0,15d-0,5d	0,85
e<0.15d (directly exposed to rain)	1,0

Distance from ground mm	k_{E4}
>400	1,0
200	1,65
<100	2,0



Based on subjective judgements

Examples

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Resistance index D_{Rk}

The resistance D_{Rk} for different wood-based materials depends mainly on the resistance to decay but also on the moisture dynamics (wetting ability) and is determined accordingly:

$$D_{Rd} = D_{crit} \cdot k_{wa} \cdot k_{inh}$$

D_{crit} = critical dose corresponding to decay rating 1 (slight decay) according to EN 252 (expressed in days); if no other information is available = D_{crit} = 325

k_{wa} = wetting ability factor

k_{inh} = inherent resistance factor

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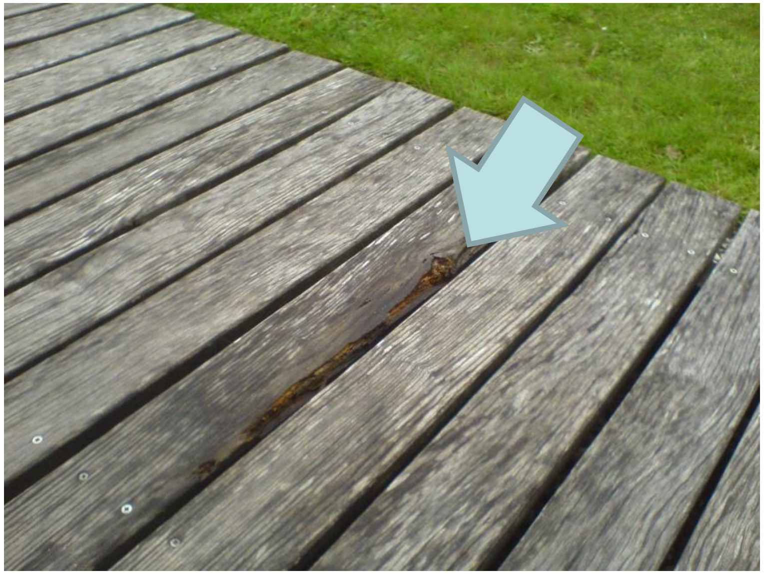
k_{inh} - the inherent resistance factor

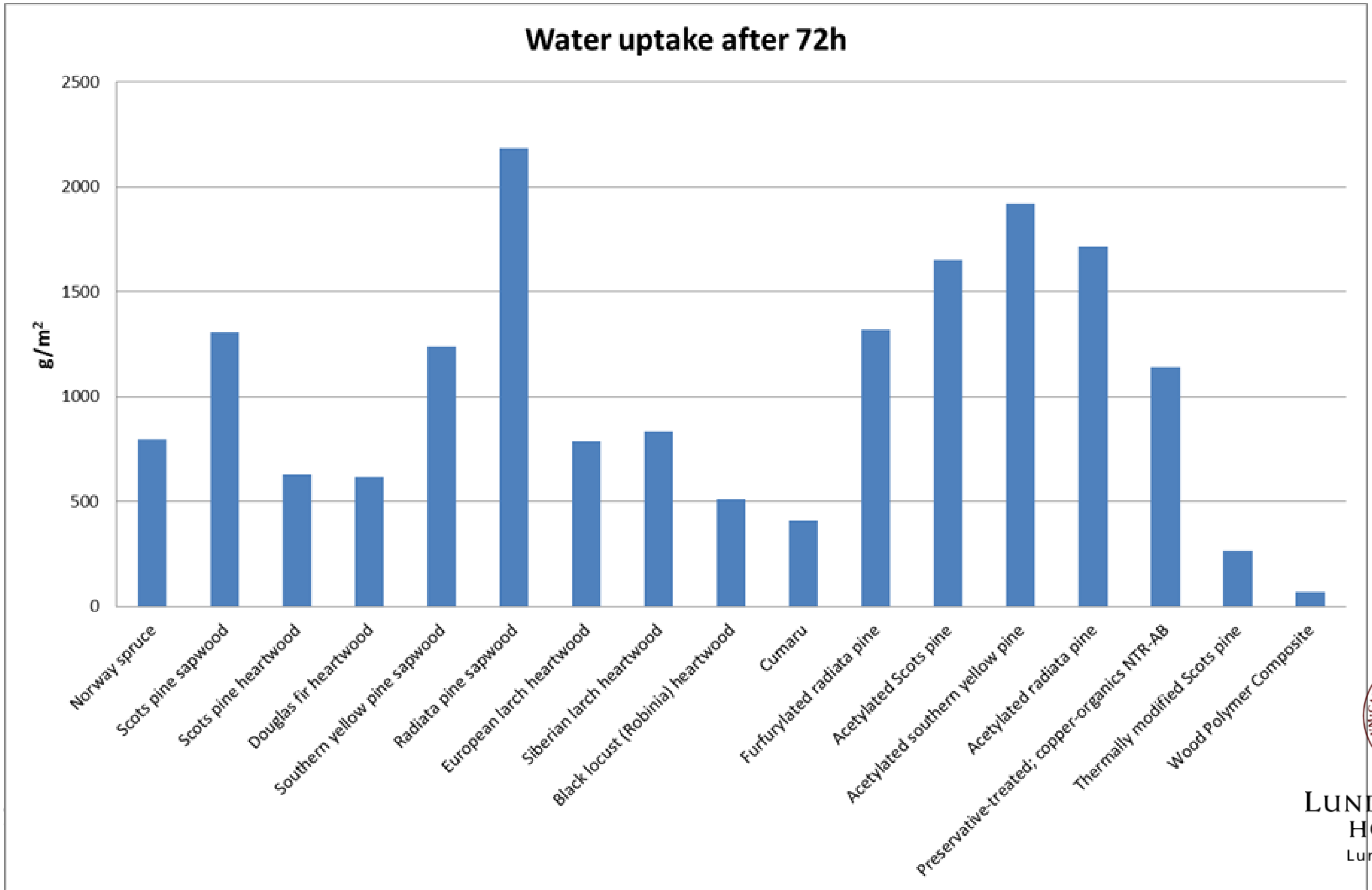
After long discussions and subjective assessments by wood durability experts, k_{inh} was agreed for a number of materials based on

- **Durability class data (natural durability) according to EN 350-2**
- **Test data, mainly from field trials**
- **Experience from use in practice**



k_{wa} – factor for wetting ability

Based on subjective assessments by wood durability experts and floating and submersion tests to measure the residual moisture content as well as submersion according to EN 927-5, k_{wa} was agreed for a number of materials.



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Suggested values for k_{inh} and k_{wa}
Reference: Norway spruce (= factor 1)

Material	k_{wa}	k_{inh}	D_{Rd}	D_{Rd} relative to Norway spruce
Norway spruce	1.0	1.0	325	1.0
Scots pine sapwood	0.8	1.0	260	0.8
Scots pine heartwood	1.5	1.5	731	2.2
Douglas fir heartwood	1.5	1.5	731	2.2
European larch heartwood	1.5	1.5	731	2.2
English oak heartwood	1.0	1.5	487	1.5
Western Red Cedar hw	1.5	**5.0**	2 438	7.5
Acetylated Scots pine	**n/a**	**8.0**	**2 600**	**8**
TMT Scots pine	**n/a**	**2.5**	**813**	**2.5**
Preservative-treated wood UC 3 (NTR AB)	**n/a**	**5.0**	**1 625**	**5**

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). Moisture uptake other than for untreated wood.

Summarizing how to use the WB Guide:

The Guide is used accordingly:

1. Decide about expected service life
2. Select consequence class to determine γ_d
3. Determine the basic exposure index D_{E0} corresponding to the geographical location
4. Determine the correction factor for the local climate (driving rain etc)
5. Determine the factors related to the design (protection against rain, distance from ground, detail design)

Steps 2-5 give D_{Ed} for the exposure

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

$$\text{Expected service life} = D_{Rd} / D_{Ed}$$

8. If not: reconsider mainly steps 5 and 6

Main advantages of the Guide

The user will have

a quantitative tool for decision making that is applied 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 WoodExter design tool agrees reasonably well with experience from practice. We have less experience with the WoodBuild tool. Thus, but more reality checks are needed

Quantification of exposure seems to give reasonable results but has to be further developed, in particular with respect to local climate and design

Quantification of resistance is still difficult for many products/species. Further work needed. So far focus only on decay. How to deal with insects, e.g. termites? Moisture uptake for treated/modified wood/WPC and how to interpret still need to be further investigated

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 Guide and give feedback for improvements

iRG47

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

Lisbon • LNEC • 15-19 May 2016

Welcome!

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Thank you for your attention!
Any questions or comments?