Durability-based design of timber structures – Quantifying design, exposure, and resistance on the basis of dose-response relationships

Linda Meyer-Veltrup, Christian Brischke

Leibniz University Hannover
Faculty of Architecture and Landscape Sciences
Institute of Vocational Sciences in the Building Trade (IBW)

Leibniz Universität Hannover

COST FP1303
Performance of bio-based building materials

COST FP1303 Meeting
28 Feb – 01 Mar 2017
Sofia, Bulgaria

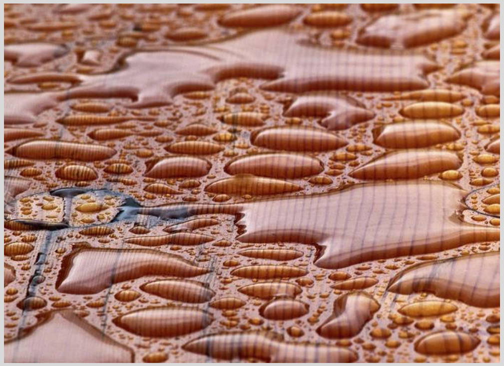
Background

Leibniz
Universität
Hannover

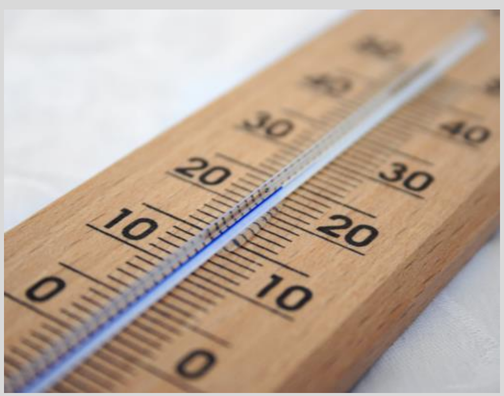
Leibniz Universität Hannover

Background

Exposure



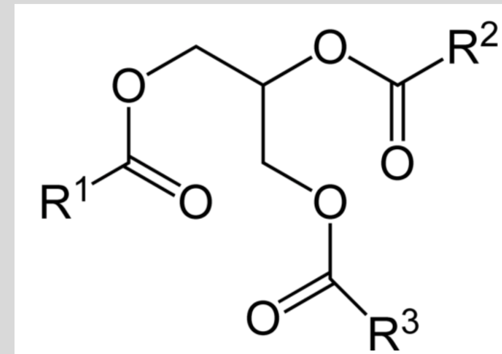
Moisture content



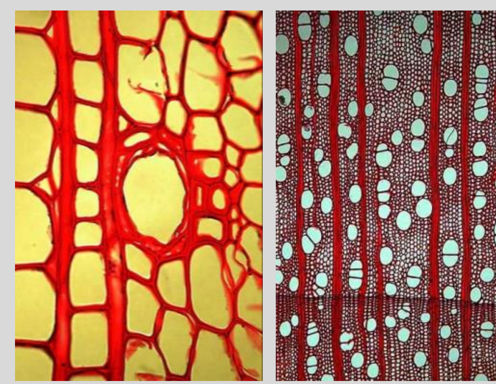
Temperature

Fungal infestation

Resistance

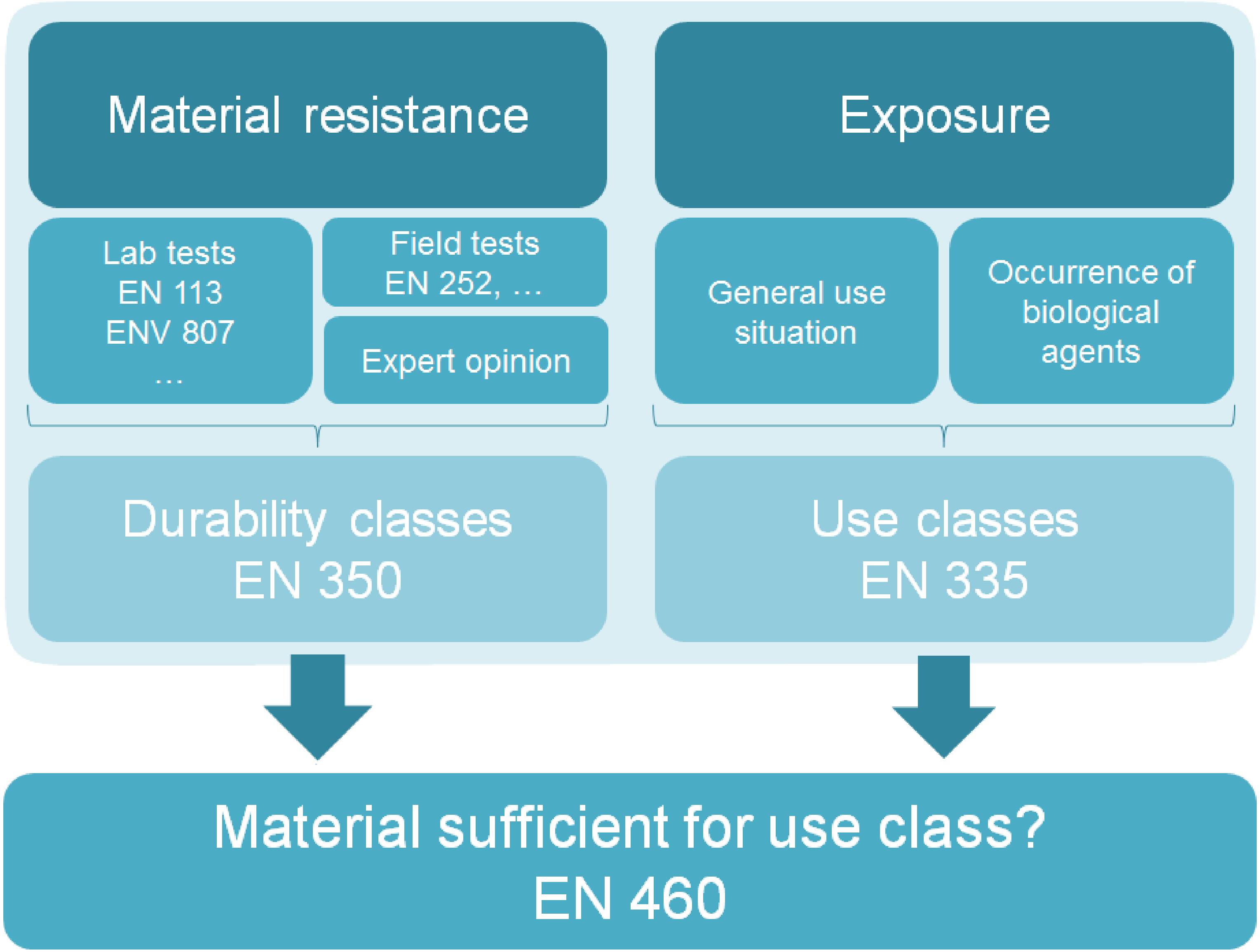


Chemical composition



Anatomical structure

Background


Material resistance
Exposure
Lab tests
EN 113
ENV 807
…
Field tests
EN 252, …
Expert opinion
General use situation
Occurrence of biological agents
Durability classes
EN 350
Use classes
EN 335
Material sufficient for use class?
EN 460

Guidance on durability

Use classes (UC)	Durability classes				
	1	2	3	4	5
	Very	Durable	Moderately	Slightly	Not durable

→ **Non – continuous process**

→ **Results in the conclusion whether a material is suitable for a certain exposure or not**

→ **Gives no information about the service life or performance of a material in a <u>quantitative manner</u>**

(+) = natural durability is normally sufficient, but for certain end uses treatment may be advisable

(+) /(-) = natural durability may be sufficient, but depnding on the wood species, ist permeability, and end use, preservative treatment may be necessary

(-) = preservative treatment is normally advisable, but for certain end uses natural durability may be sufficient

- = preservative treatment necessary

Objectives

Leibniz Universität Hannover

- Current rethinking within European standardization bodies claims

…the development of performance related classification systems for timber products

…delivery of respective performance data

- The first attempts for comprehensive approaches to predict performance: e.g. WoodExter, WoodBuild, PerformWood, DuraTB

Performance-Modelling

→ Design principle

Acceptance for a chosen design, if…

Exposure (D_{Ed}) ≤ Resistance (D_{Rd})*

D_{Ed} = Exposure dose

(based on temperature and wood MC)

D_{Rd} = Resistance dose

(material property)

*Isaksson et al. (2014) & Brischke et al. (2014)

Leibniz Universität Hannover

Performance-Modelling

→ 3 step approach

Exposure-Model → **Decay-Model** → **Exposure ≤ Resistance** ← **Resistance-Model**

Exposure-Model:
- Climate
- Design
- Surface treatment
- …

Decay-Model:
- Fungi
- Termites
- Insects
- Marine organisms
- …

Resistance-Model:
- Inherent protective properties
- Wetting ability
- Susceptibility to cracks
- …

Exposure-Model + Decay-Model → Exposure **dose**

Resistance-Model → Resistance **dose**

Isaksson et al. (2014) & Brischke et al. (2014)

Performance-Modelling

→ 3 step approach

Exposure-Model → **Decay-Model** → **Exposure ≤ Resistance** ← **Resistance-Model**

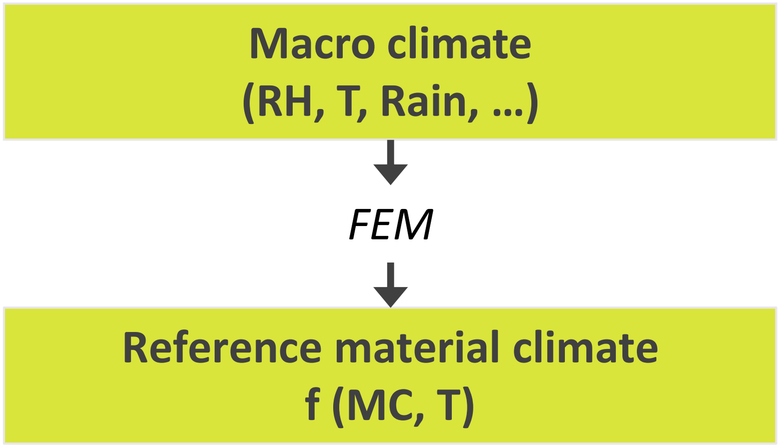
- Climate
- Design
- Surface treatment
- …

- Fungi
- Termites
- Insects
- Marine organisms
- …

- Inherent protective properties
- Wetting ability
- Susceptibility to cracks
- …

Exposure Model

- Starting point: series of macro-climate data
- Derive a reference material climate



Exposure Model

Leibniz Universität Hannover

Building and Environment 97 (2016) 126–136

Contents lists available at ScienceDirect

Building and Environment

journal homepage: www.elsevier.com/locate/buildenv

ELSEVIER

Moisture content prediction of rain-exposed wood: Test and evaluation of a simple numerical model for durability applications

CrossMark

J. Niklewski [a,*], M. Fredriksson [b], T. Isaksson [c]

[a] *Division of Structural Engineering, Lund University, PO-Box 118, SE-221 00 Lund, Sweden*
[b] *Division of Building Materials, Lund University, PO-Box 118, SE-221 00 Lund, Sweden*
[c] *Skanska Sverige AB, Skanska Teknik, SE-205 33 Malmö, Sweden*

ARTICLE INFO

Article history:
Received 15 September 2015
Received in revised form
14 November 2015
Accepted 29 November 2015
Available online 8 December 2015

Keywords:
Moisture content
Decay prediction
Wood

ABSTRACT

Decay prediction models are frequently used to estimate the service life of wooden components. These models require knowledge of how the material climate, i.e. moisture content and material temperature, varies over time. In the present study, the performance of a simple numerical moisture transport model was evaluated for use in decay prediction models. First, a model based on Fick's second law of diffusion was calibrated against laboratory measurements where wooden boards were exposed to artificial rain. Second, the model was tested against field-test measurements on wooden boards exposed outdoors above-ground. The influence of rain was investigated by studying the difference between sheltered and exposed specimens over time. Finally, the model was applied to a number of Swedish climates and two different decay-prediction models were used to evaluate the decay rate. The influence of rain on the moisture content in wooden specimens was reproduced with sufficient accuracy for decay prediction.

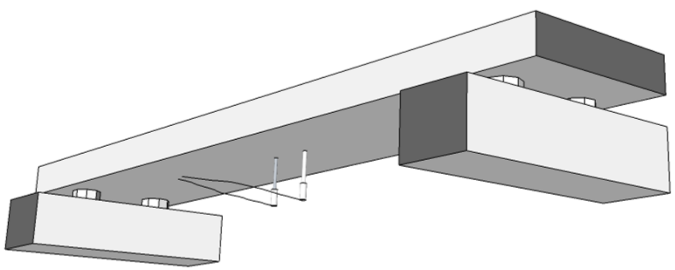
- based on Fick's second law of diffusion
- taking into account RH, T <u>and</u> precipitation

Leibniz
Universität
Hannover

Exposure Model

- Starting point: series of macro-climate data
- Derive a reference material climate

Reference:



Horizontal Spruce board without water traps

Reference location: Uppsala, Sweden

Macro climate
(RH, T, Rain, …)

↓

FEM

↓

Reference material climate
f (MC, T)

↓

Decay model

Performance-Modelling

→ 3 step approach

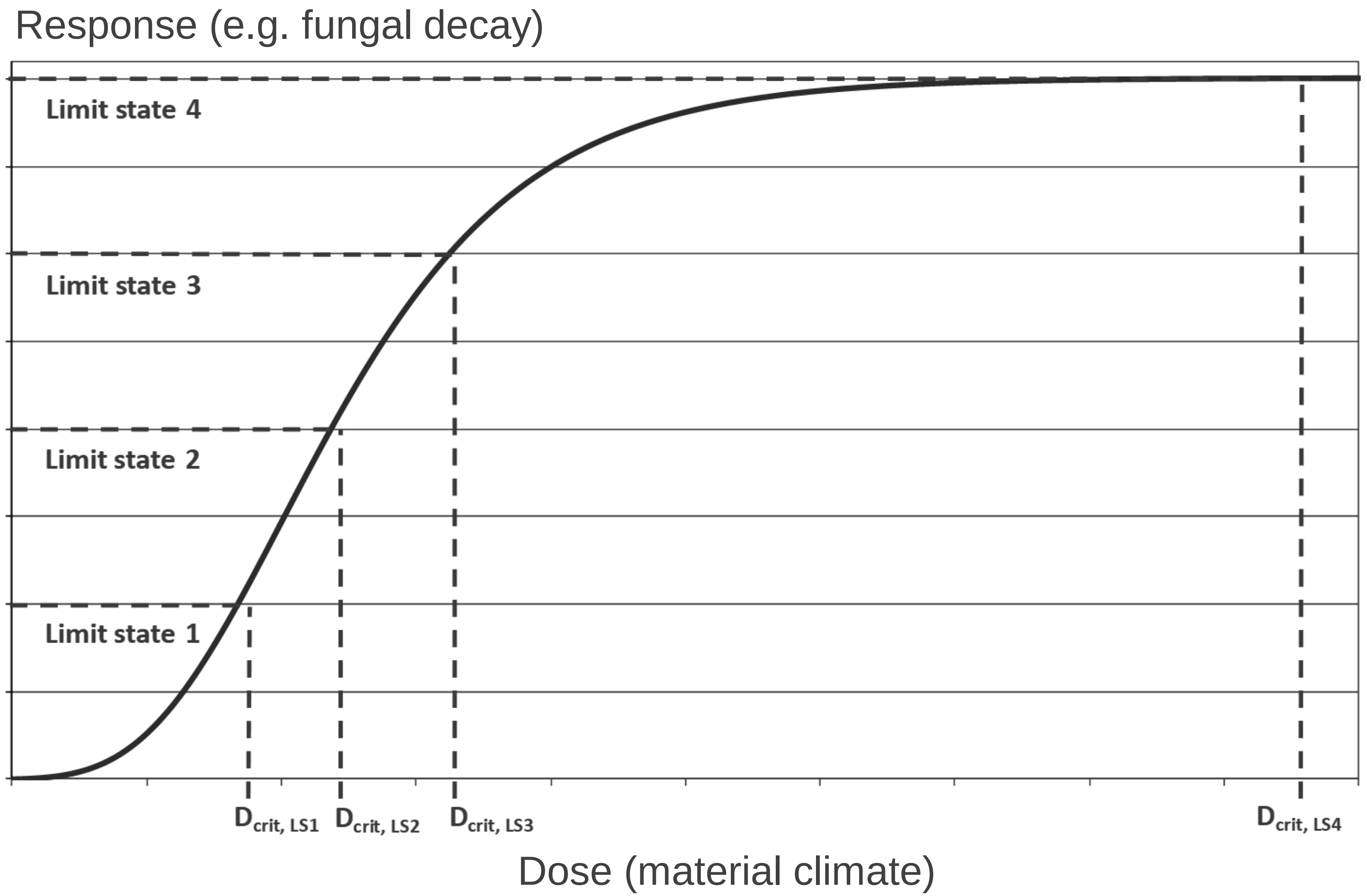
Exposure-Model → **Decay-Model** → **Exposure ≤ Resistance** ← **Resistance-Model**

Exposure-Model
- Climate
- Design
- Surface treatment
- …

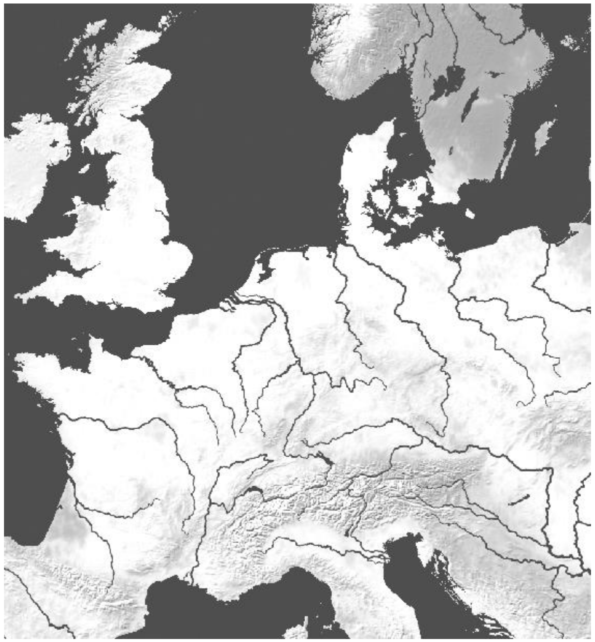
Decay-Model
- Fungi
- Termites
- Insects
- Marine organisms
- …

Resistance-Model
- Inherent protective properties
- Wetting ability
- Susceptibility to cracks
- …

Decay model

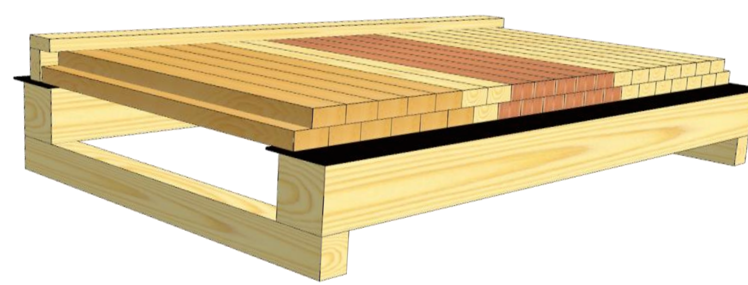

Response (e.g. fungal decay)
Limit state 4
Limit state 3
Limit state 2
Limit state 1
$D_{crit, LS1}$
$D_{crit, LS2}$
$D_{crit, LS3}$
$D_{crit, LS4}$
Dose (material climate)

Decay model



1	Oslo	14	Heilbronn
2	Uppsala	15	Heidelberg
3	Taastrup	16	Dobel
4	London	17	Schömberg
5	Watford	18	Stuttgart
6	Portsmouth	19	Bühlertal
7	Gent	20	Hornisgrinde
8	Bordeaux	21	Oberrottweil
9	Ljubljana	22	St. Märgen
10	Zagreb	23	Hinterzarten
11	Hamburg	24	Freiburg
12	Reulbach	25	Feldberg
13	Essing		

- Horizontal double-layer tests at 25 different sites in Europe
- Daily recording of *T* and *MC*
- *Annual assessment of fungal decay*
- *Exposure: 4 - 8 years*



Decay model

Materials and Structures (2016) 49:3281–3291
DOI 10.1617/s11527-015-0719-y

CrossMark

ORIGINAL ARTICLE

Modelling timber decay caused by brown rot fungi

Christian Brischke · Linda Meyer-Veltrup

Received: 7 July 2015 / Accepted: 21 September 2015 / Published online: 13 October 2015

Abstract Decay models are key elements for service life prediction and performance classification of wooden products and timber structures. Available models differ in terms of data sources used and prevailing decay types considered. Comparative studies on performance models are therefore rare. In this study we applied data sets from field tests dominated ... compared to the previous white and soft rot model for a given dosage.

Keywords Above ground exposure · Durability · Service life prediction · Shading · Soft rot · White rot

1 Introduction

Materials and Structures (2013) 46:1209–1225
DOI 10.1617/s11527-012-9965-4

ORIGINAL ARTICLE

Development of decay performance models for outdoor timber structures

Tord Isaksson · Christian Brischke ·
Sven Thelandersson

Received: 7 March 2012 / Accepted: 17 October 2012 / Published online: 2 November 2012

Abstract Performance based building (PBB) and design is closely connected to various needs and requirements: Performance levels need to be defined, test methods for verification of performance need to be developed, and reliable performance data are needed for materials, products, constructions, and different design solutions. In contrast to other building mate- ... derived from material climatic data and corresponding decay development in the field. Different dose–response models are proposed and evaluated for predicting onset (and progress) of decay when wood is exposed to a dynamic and arbitrary climate exposure described in terms of time series of coupled temperature and moisture content. A logistic dose–response ...

Construction and Building Materials 66 (2014) 384–397

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

ELSEVIER

Construction and Building MATERIALS

Review

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

CrossMark

Christian Brischke [a,*], Sven Thelandersson [b,1]

[a] Leibniz University Hannover, Faculty of Architecture and Landscape Scape Sciences, Institute of Vocational Sciences in the Building Trade, Hannover, Germany
[b] Lund University, Faculty of Engineering, Division of Structural Engineering, Lund, Sweden

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.

Wood Sci Technol (2008) 42:507–518
DOI 10.1007/s00226-008-0191-8

ORIGINAL

Dose–response relationships between wood moisture content, wood temperature and fungal decay determined for 23 European field test sites

Christian Brischke · Andreas Otto Rapp

Received: 30 August 2007 / Published online: 3 April 2008

Abstract Scots pine sapwood (*Pinus sylvestris* L.) and Douglas fir heartwood (*Pseudotsuga menziesii* Franco) specimens were exposed in double layer field trials at 23 different European test sites under different exposure conditions (in total 27 test sets). The material climate in terms of wood moisture content (MC) and wood temperature was automatically monitored over a period of up to 7 years and compared with the progress of decay. The overall aim of this study was to establish dose–response relationships between climate factors and decay as a basis for the

Performance-Modelling

→ 3 step approach

Exposure-Model → **Decay-Model** → **Exposure ≤ Resistance** ← **Resistance-Model**

Exposure-Model:
- Climate
- Design
- Surface treatment
- …

Decay-Model:
- Fungi
- Termites
- Insects
- Marine organisms
- …

Resistance-Model:
- Inherent protective properties
- Wetting ability
- Susceptibility to cracks
- …

Site specific decay hazard

Decay hazard

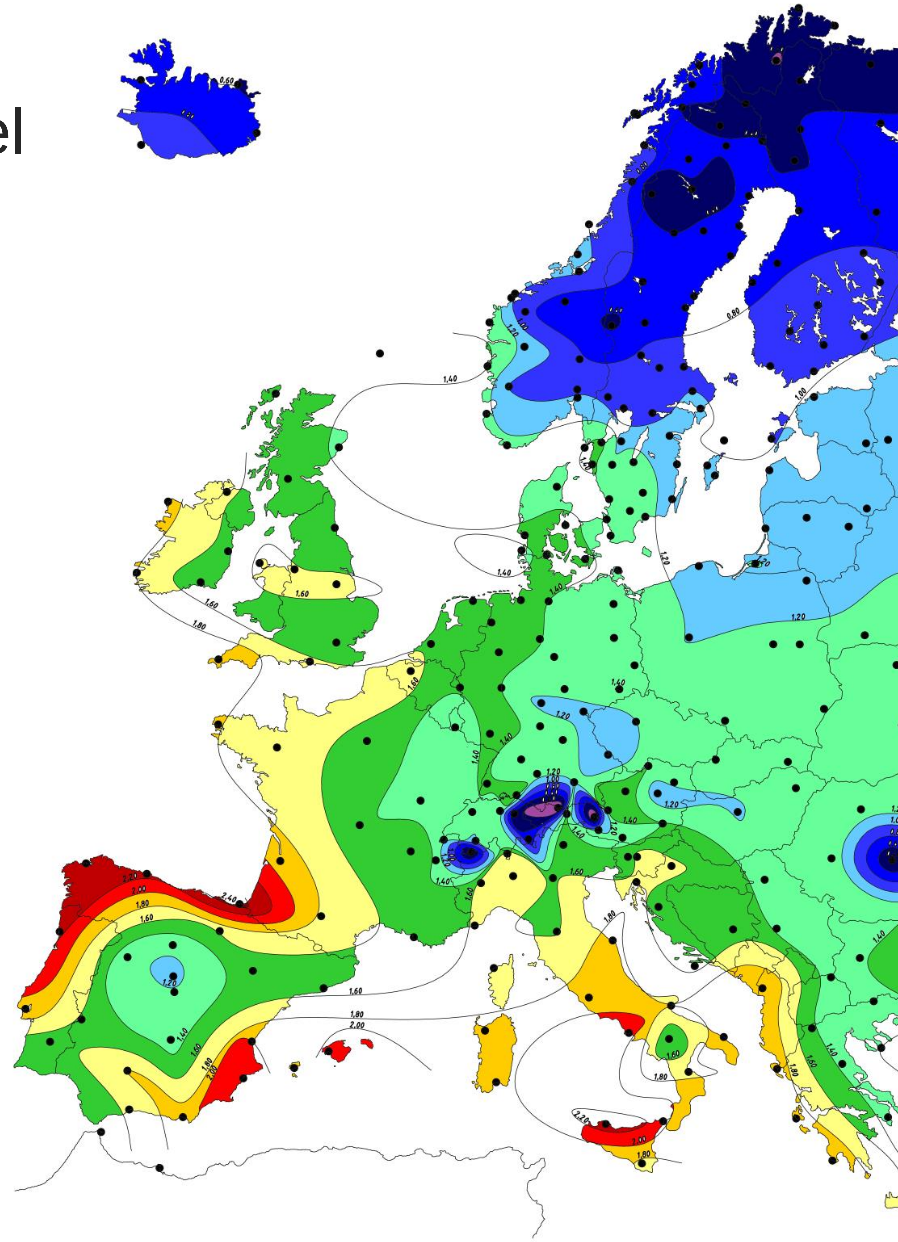
- Exposure model & decay model

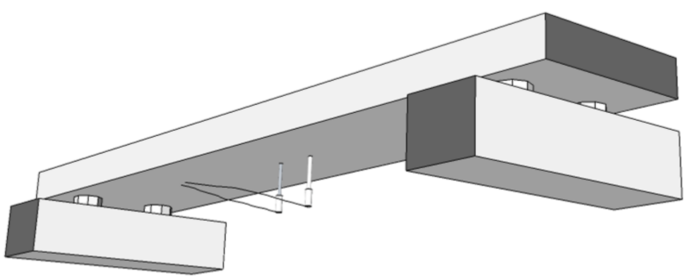
– Meteonorm database

– Annual dose for each location

– Reference site:
  Uppsala, Sweden (dose = **1.0**)

– Describes the climatic effects
  for the reference object





Performance-Modelling

→ 3 step approach

Exposure-Model → **Decay-Model** → **Exposure ≤ Resistance** ← **Resistance-Model**

Exposure-Model
- Climate
- Design
- Surface treatment
- …

Decay-Model
- Fungi
- Termites
- Insects
- Marine organisms
- …

Resistance-Model
- Inherent protective properties
- Wetting ability
- Susceptibility to cracks
- …

Resistance model

→ Design principle

Acceptance for a chosen design, if…

Exposure (D_{Ed}) ≤ Resistance (D_{Rd})*

D_{Ed} = Exposure dose

(based on temperature and wood MC)

D_{Rd} = Resistance dose

(material property)

Resistance model

→ Design principle

D_{Rd} = Resistance dose

(material property)

Resistance model

→ Design principle

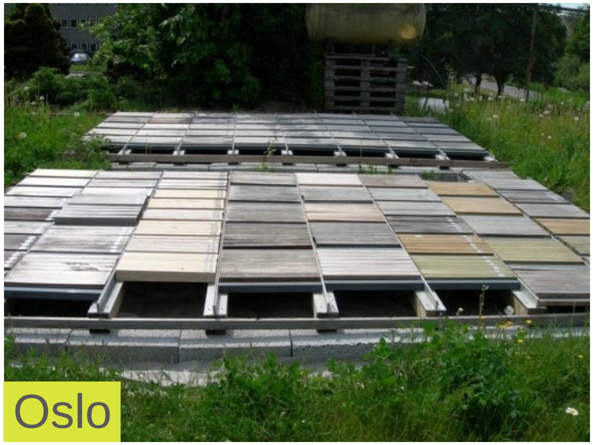
D_{Rd} = Resistance dose

(material property)

Resistance model

Basis 1:

- Field tests above ground at 3 locations in Norway
- 25 materials exposed for 10 – 12 years



Resistance model

Basis 2:

- Corresponding lab test data for k_{inh} & k_{wa} :

'Wetting ability' (k_{wa})

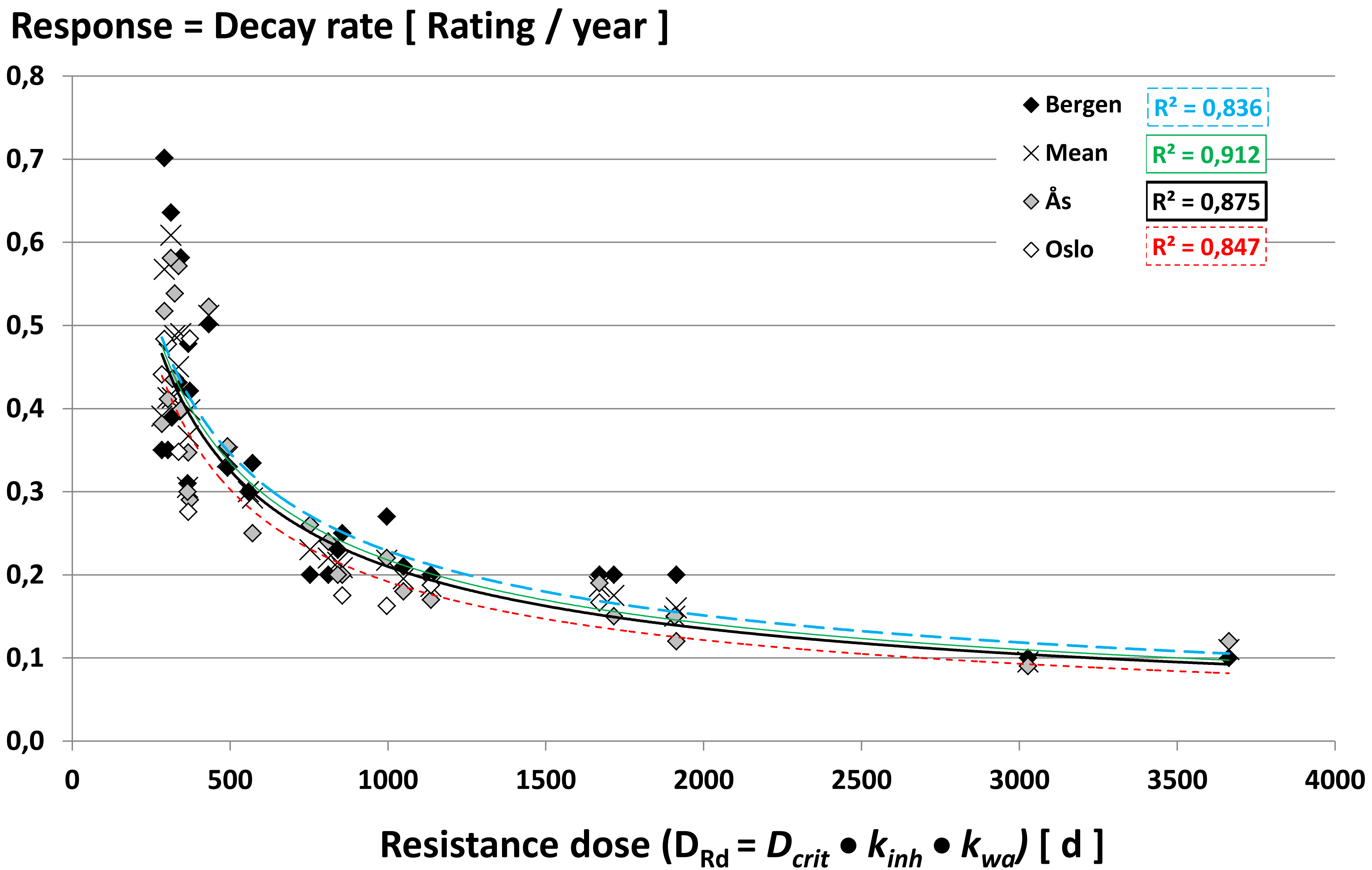
Capillary water uptake (tensiometer)	Liquid water uptake (submersion)	Vapour water uptake (100 % RH)	Water release (desorption at 0 % RH)

'Inherent resistance' (k_{inh}):

Soft rot (Soil contact tests)	White rot (Basidiomycete tests)	Brown rot (Basidiomycete tests)

→ Model is open to consider further tests

Resistance model



Conclusion

Exposure-Model → **Decay-Model** → **Exposure ≤ Resistance** ← **Resistance-Model**

Exposure-Model:
- Climate
- Design
- Surface treatment
- …

Decay-Model:
- Fungi
- Termites
- Insects
- Marine organisms
- …

Resistance-Model:
- Inherent protective properties
- Wetting ability
- Susceptibility to cracks
- …

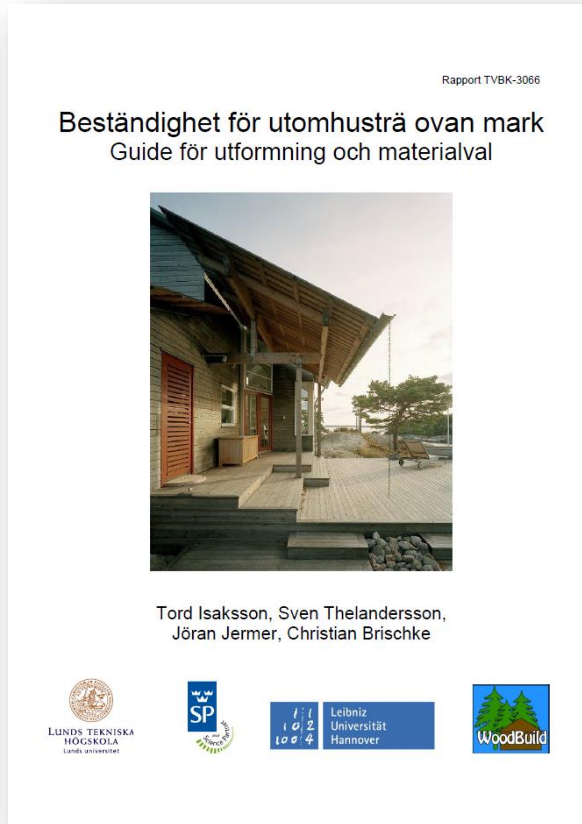
- 3-step modelling approach:

  → Design guidance & Performance prediction ✓

Conclusion

Service life of wood in outdoor above ground applications

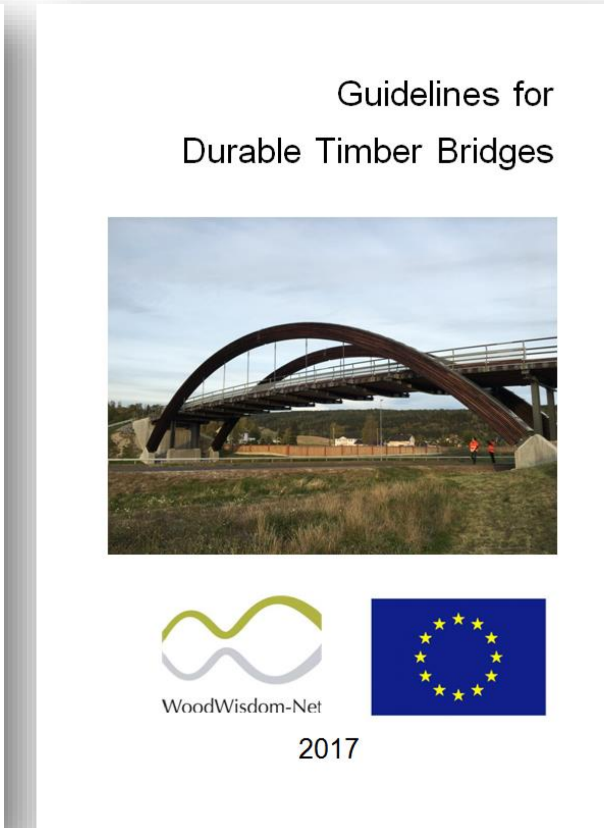
Engineering design guideline



Rapport TVBK-3066

Beständighet för utomhusträ ovan mark
Guide för utformning och materialval

Tord Isaksson, Sven Thelandersson, Jöran Jermer, Christian Brischke



Guidelines for Durable Timber Bridges

2017

Durability-based design of timber structures – Quantifying design, exposure, and resistance on the basis of dose-response relationships

Linda Meyer-Veltrup, Christian Brischke

Leibniz University Hannover
Faculty of Architecture and Landscape Sciences
Institute of Vocational Sciences in the Building Trade (IBW)

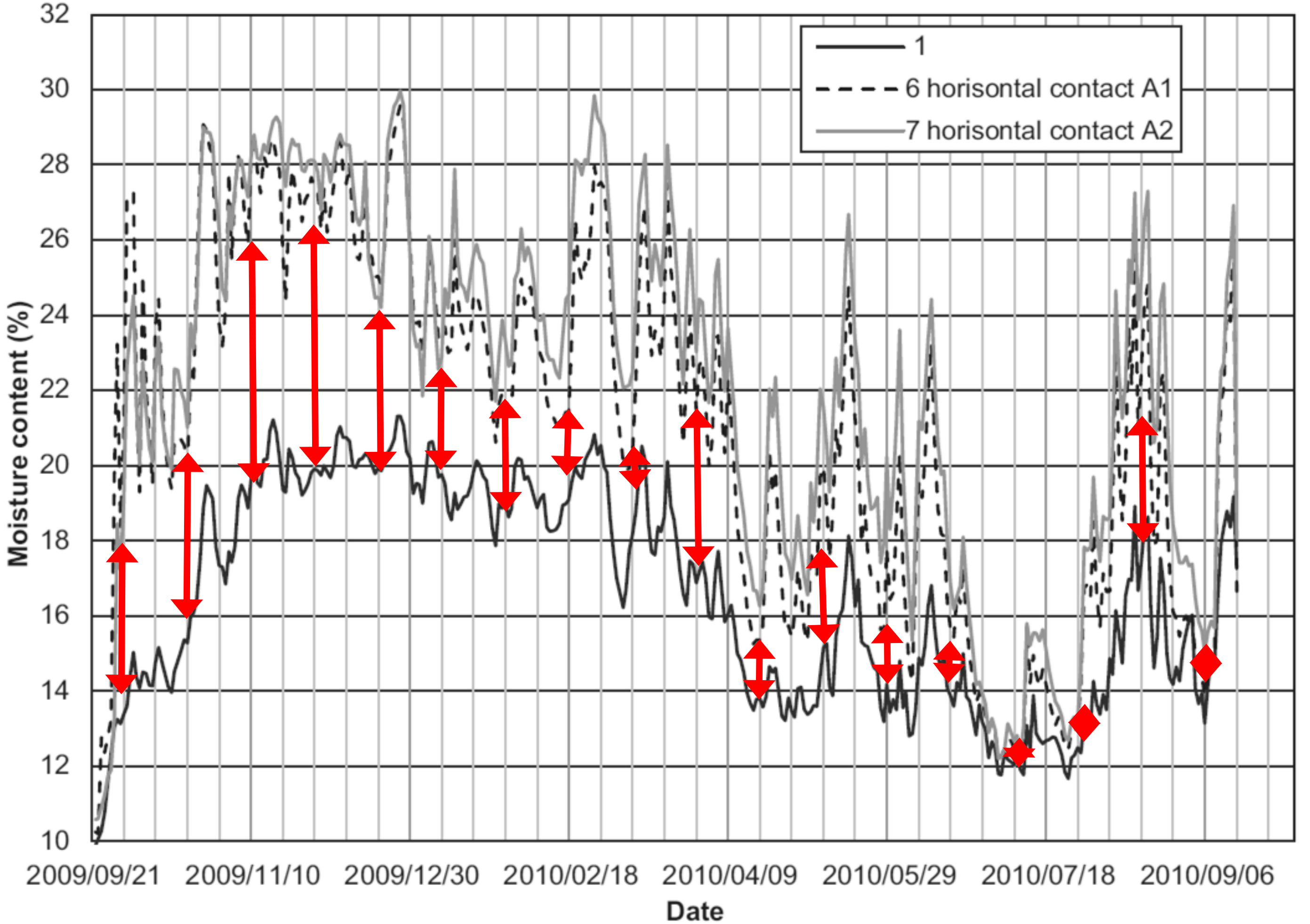
Leibniz Universität Hannover

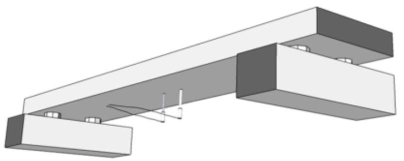
COST FP1303
Performance of bio-based building materials

COST FP1303 Meeting
28 Feb – 01 Mar 2017
Sofia, Bulgaria

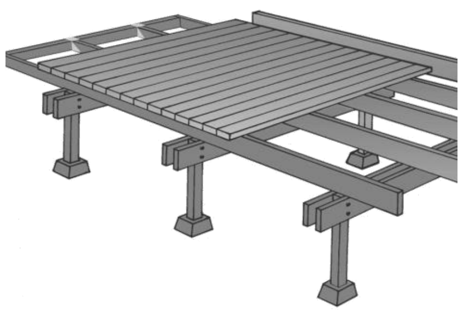
Leibniz Universität Hannover

Principle of relative performance





1 = reference detail



6 = horizontal contact

Ratio: Detail 6 (horizontal contact face) : Detail 1 (reference detail) = 1.25
→ Detail 6 performs 1.25 times worse than reference