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Modelling of service life and durability of wooden structures

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The present paper presents

- In this paper, attempts to model the service life of wood structures is developed by utilising earlier durability experiments and relating the decay models to a hygrothermal analysis of building physics.
- The model is also used in connection with the ERA-40 weather observations in Europe to assess the geographical dependence on service life related to durability.
- These studies provide new tools to evaluate the durability and service life of wooden commodities and a preliminary European wood decay map, is presented in this paper.
- A further enhancement of the model, which is currently under development, is the assessment of the effects of the various structural choices (e.g. protection to driving rain, coatings, etc.) and other parameters (e.g. geographical location and orientation) on the durability of wooden structure.

A building is subjected to different water sources, ageing processes and damages during the life time. Exposure conditions -> durability, service life.

Facades
Cladding

Use class 3.1
(EN 335-1)

Balconies
Terraces Fences

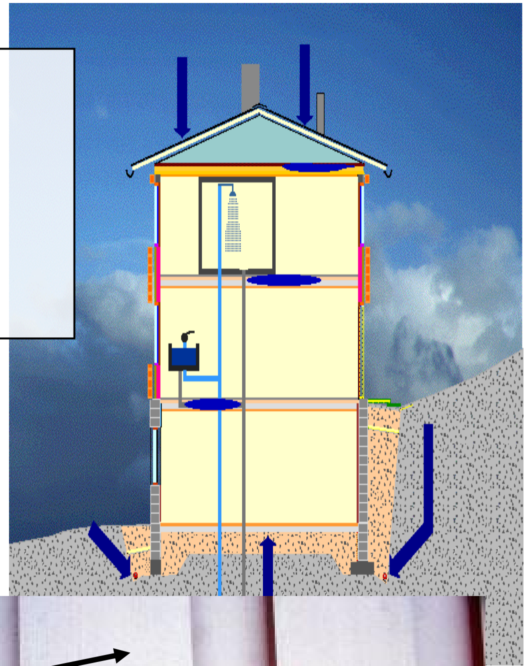
Use class 3.2
(EN 335-1)

Critical parts of the building for exposure modelling

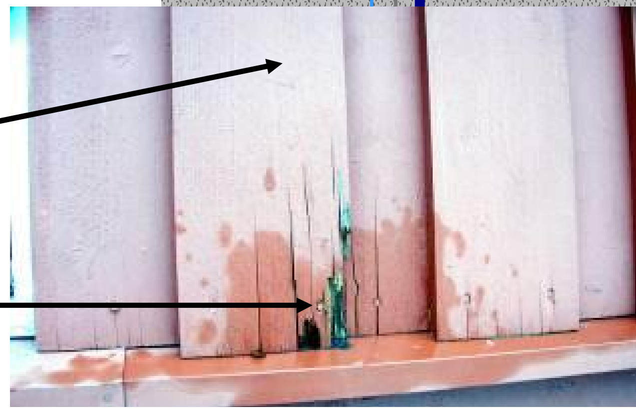
- **Indoor surfaces**
  - Wet rooms, attic, indoor rooms
- **Structural parts / envelopes**

RH, moisture temperature, exposure time

materials



- **Outdoor structures**
  - **facades, windows, fences, balconies, terraces**



- **Intended use conditions**
- **Critical details**

- **Mould / decay / other organisms**

Use of model organisms to simulate and modelling the critical conditions for decay development under controlled conditions

MODELLING THE DECAY DEVELOPMENT IN WOOD, Viitanen et al 2010

Activation process:

- **α parameter**, which is initially 0 and gradually grows depending on the air conditions to a limit value of 1. This process is able to recover (**α can get lower values)** in favourable conditions for wood (dry air) at a given rate (no experimental evidence of recovery is available).
- In this model, these processes only occur when the temperature is 0..30 ˚C and the relative humidity is 95% or above (other temperatures were not tested).

$$\text{Activation process} \quad \alpha = 0..1$$

$$\alpha(t) = \int_0^t d\alpha = \sum_0^t (\Delta\alpha), \text{where}$$

$$\Delta\alpha = \frac{\Delta t}{t_{crit}(RH,T)} \quad \text{or (in favorable conditions of decay)}$$

$$\Delta\alpha = -\frac{\Delta t}{17520} \quad \text{(in unfavorable conditions of decay)}$$

$$t_{crit}(RH,T) = \left[\frac{2.3T + 0.035RH - 0.024T \times RH}{-42.0 + 0.14T + 0.45RH}\right] \times 30 \times 24 \quad \text{[hours]}$$

MODELLING THE DECAY DEVELOPMENT IN WOOD

Mass loss process:

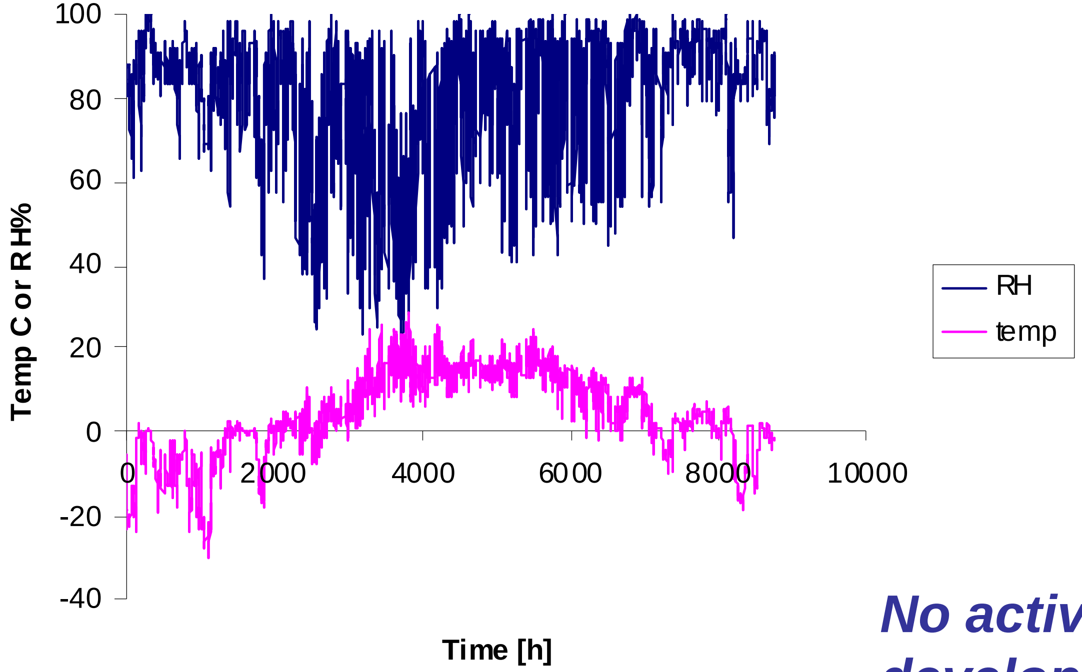
- This occurs when the activation process has fully developed (α=1) otherwise it does not occur. This process is naturally irrecoverable.

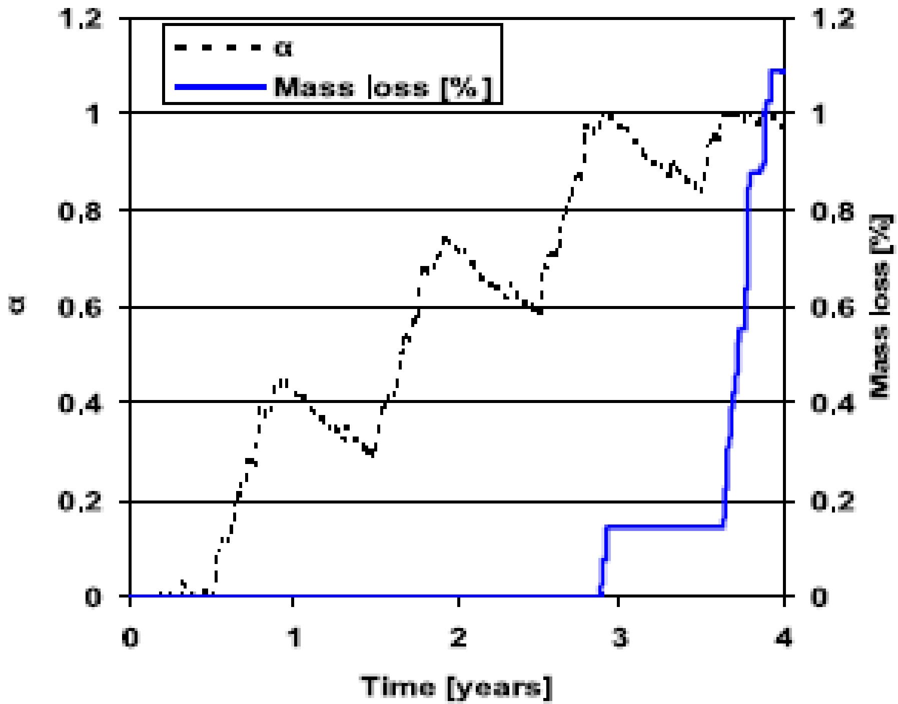
Mass loss process when $\alpha \geq 1$

$$ML(t') = \int_{t\,at\,\alpha=1}^{t'} \frac{ML(RH,T)}{dt}\,dt = \sum_{t\,at\,\alpha=1}^{t'} \left(\frac{ML(RH,T)}{dt} \times \Delta t \right)$$

$$\frac{ML(RH,T)}{dt} = -5.96 \times 10^{-2} + 1.96 \times 10^{-4} T + 6.25 \times 10^{-4} RH \ [\%/hour]$$

Measured climate data (Helsinki) used in the decay activity model for one year (Viitanen et al 2010).

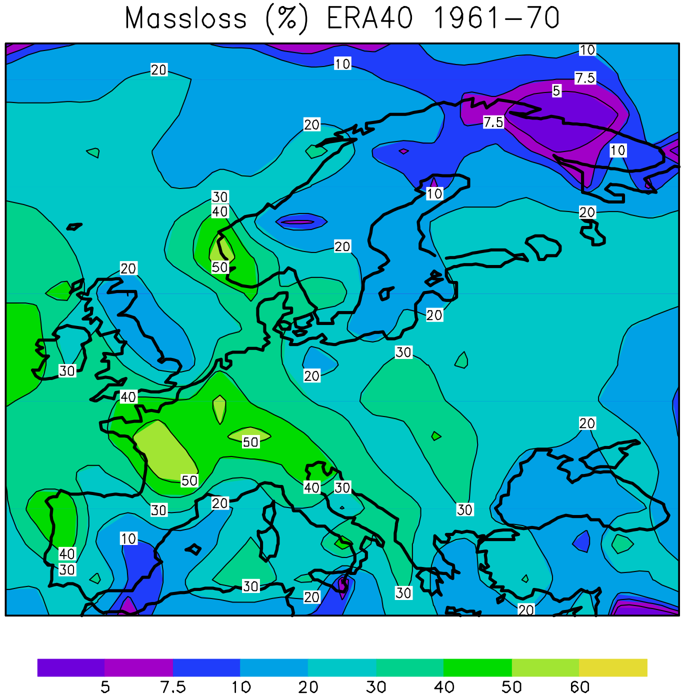




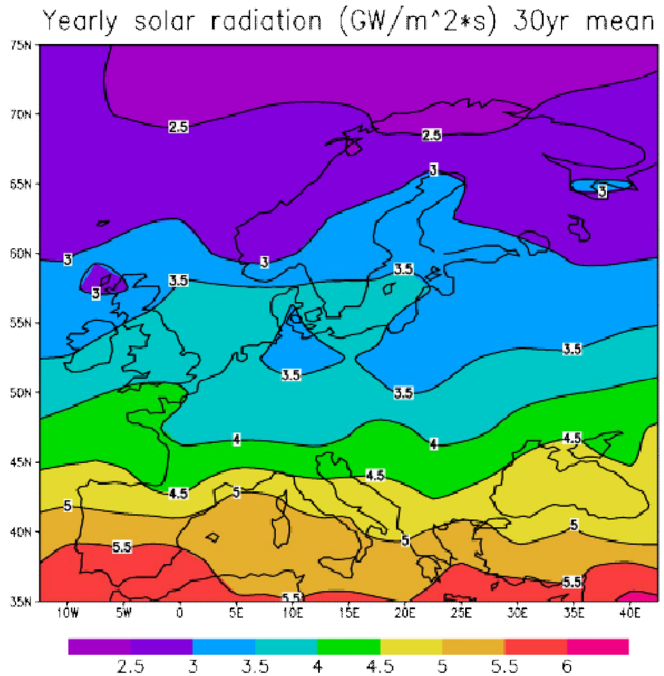
Decay model presented by Viitanen et al 2010.

No activation of growth or decay development during the first and second years, an activation of decay process after 4 years exposure may be expected

Outdoor exposure conditions in different part of Europe based on the decay activity model (uncovered situation)



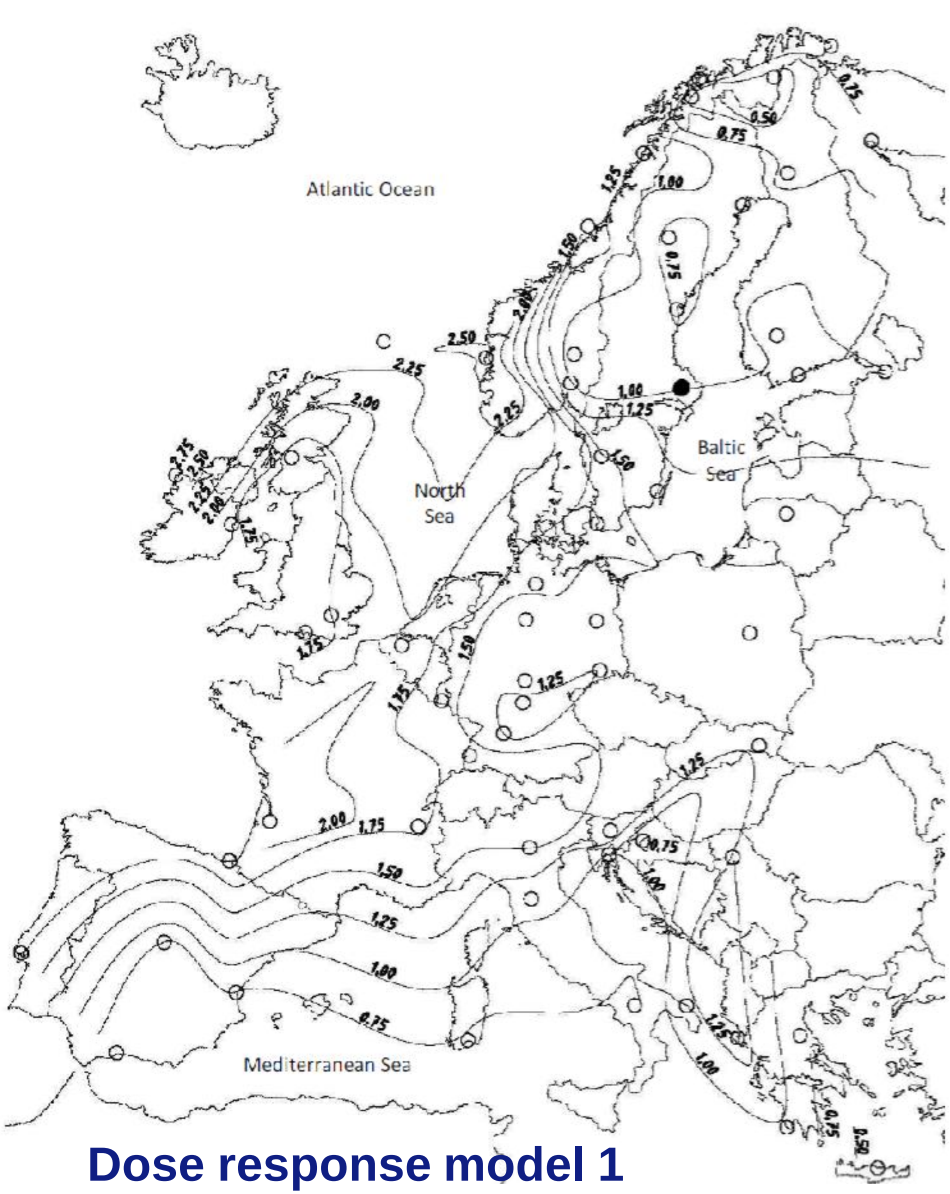
Modelled mass loss (in %) of small pieces of pine wood that are exposed to rain in 10 years in Europe (from [Viitanen et al. 2010]).



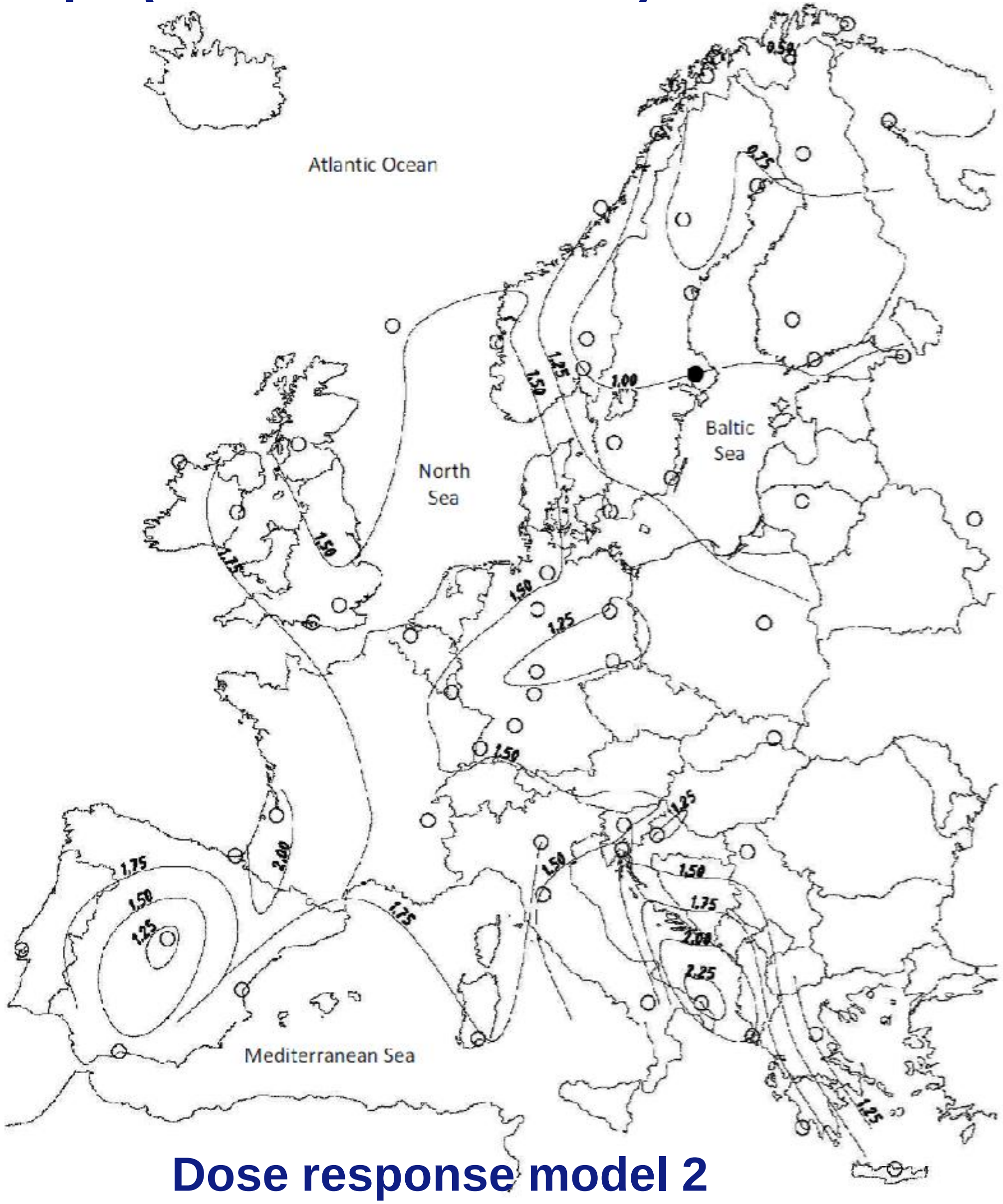
Solar radiation in Europe.

For sheltered structure, the exposure to water and solar radiation is lower.

Relative decay potential for Europe (Brischke et al 2011)



Dose response model 1



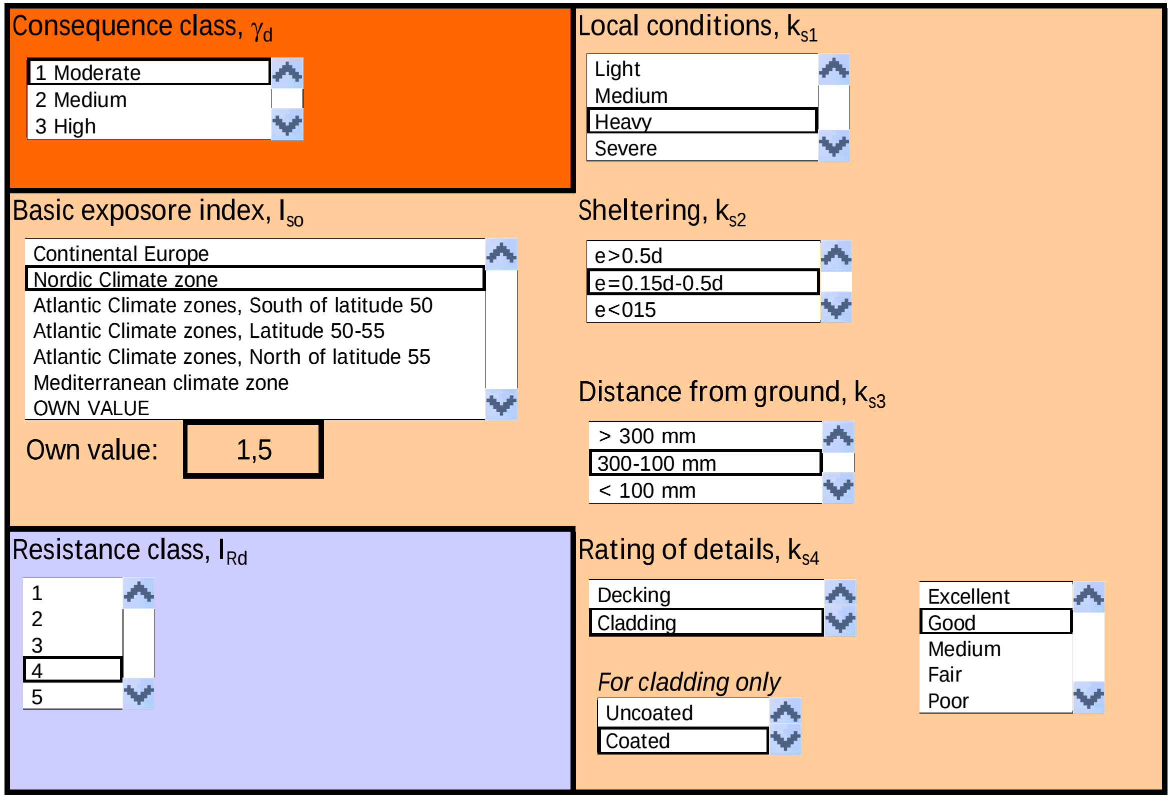
Dose response model 2

An example on a calculation method to evaluate the service life of wooden cladding and decking -> www.kstr.lth.se

Design Guidelines for wood in outdoors above ground applications

Design condition Isd = Iskgd ≤ IRd

Parameters	Value
k_{s1}	1,2
k_{s2}	0,85
k_{s3}	1,5
k_{s4}	0,6
I_{so}	1
c_a	1
I_{sk}	0,92
γ_d	0,8
I_{Sd}	0,73
I_{Rd}	1
OK	



An example 2 on a calculation method to evaluate the exposure conditions and service life of wooden cladding and decking.

Service life estimator for claddings and deckings

Consequence class

1

Is this a decking (horizontal structure) ? Tick here if yes ☐

Otherwise this is a cladding (vertical structure)

CC 1 = cladding
CC 2 = decking close to ground
CC 3 = decking and balcony

	Is the solution acceptable	**Acceptable**
	Service life factor [OK if > 1]	**1,1**
Cons	**Consequence class factor**	**1,00**
A1	**Wood material**	**0,70**
A2	**Surface coating**	**1,85**
B	**Design /structural details**	**0,87**
C	**Construction works**	**1,00**
D	**Climate conditions**	**0,96**
F	**Repair and service procedures**	**1,00**

Service life factor = Consequence class factor x A1 x A2 x B x C x D x F

VTT

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date
16.9.2009

Factors for service life of wooden facades (modified based on Vesikari et al 2001).

Code	Factor	Parameters / factors for estimated service life
A_1	Wood material	Wood species, decay and weather resistance, water permeability, board quality, dimension, wood modification, preservation
A_2	Coating	Coating type and properties (thickness, opacity, color), needs for repainting (maintenance)
B_1 B_2	Structure, design, especially details	Structure of the houses: eaves, height of the wall and foundations (B_1). Structure of the façade; board type, bonds and joints, ventilation, protection of joints and end grains, fixing (B_2)
C	Work execution	Achievements and treatments details, fixing, wood moisture content, storage condition
D	Indoor environment	Temperature, RH, condensation (not so important for exterior structure)
E_1 E_2	Exposure conditions	Point of compass, type of environment (protective – exposed) macroclimate (E_1) and local conditions, exposure to driving rains (E_2) → microclimate conditions
F	Use conditions	Indoor environment, moisture stress, mechanical injuries
G	Maintenance	Care of accidental damage, serviceable, repainting (opaque – stains) time of repaint

Definition of local conditions (Factor E2, see the table 2)

Rating	Description
Light	Local conditions have little impact on performance as the three features all offer sheltering (i) land topography (ii) local buildings (iii) >5km from the sea (so no maritime effect).*
Medium	Local conditions have some impact on performance as one of the three features does not offer sheltering (i) land topography (ii) local buildings (iii) >5km from the sea (so no maritime effect).
Heavy	Local conditions have an impact on performance as two of the three features do not offer sheltering (i) land topography (ii) local buildings (iii) >5km from the sea (so no maritime effect).
Severe	Local conditions have a significant impact on performance as the three features do not offer sheltering (i) land topography (ii) local buildings (iii) >5km from the sea (so no maritime effect).**

* e.g. Building is sheltered by hills and neighbouring buildings and is inland.

** e.g. Building is on a flat plain, with no nearby buildings and is 1km from the sea.

Rating of design details (Factor B2)

Rating	Description
1. Excellent	Excellent design with features to maximize water shedding and ability to dry when wet. The end grains are well protected.
2. Good	Good design with features to provide water shedding and ability to dry when wet (corresponds to the reference of a horizontal board without possibility of moisture trapping)
3. Medium	Design with a limited probability of water trapping. and with some ability to dry when wet
4. Fair	Design with medium probability of water trapping and limited ability to dry when wet
5. Poor	Design with high risk of water trapping and very limited ability to dry when wet. The end grains are not protected.

(1 The index is for well coated cladding

Conclusions

- The presented numerical decay development model is based on experimental results from laboratory studies under controlled conditions using model organisms, e.g. *Coniophora puteana*.
- New attempts have been made to develop calculation methods for service life estimations for different exposure conditions.
- It still remains to be verified with field experience.
- So far the comparison of the method result to practice has been encouraging.
- The variation of the material sensitivities is high, estimation of a product sensitivity class is difficult without testing under controlled conditions
- The evaluation of the actual conditions in the critical material layers may include uncertainties.

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