Moisture Resistance Design (MRD) model

The MRD model can be used to evaluate the risk for mould growth on materials exposed to moisture. Background and verification of the model against test results are given in [1].

The model is related to a limit state for *initiation of mould growth,* defined as *sparse, but clearly established growth* observed in microscope (40x magnification), see [2]. For a given material surface the potential for mould growth depends on relative humidity ϕ, temperature T and duration of exposure. In general both ϕ and T depend on time t. The MRD-model transforms an arbitrary climate exposure $[\phi(t), T(t)]$ to a dose $D(t)$. This dose has the unit time duration and varies continuously with time. The dose increases when the climate conditions are favourable for mould growth (e.g. humid and warm conditions) and decreases when conditions are unfavourable for growth (dry and/or cold conditions). In order that the limit state (initiation of mould growth) shall not be violated the following condition shall hold for all t .

$$D(t) < D_{crit} \qquad (1)$$

where D_{crit} is critical dose for inititiation of mould growth, depending on the material considered.

The model can be applied over arbitrary long time and is based on 12 hour average values for relative humidity and temperature. The averaging is done so that one daytime average from 08.00 to 20.00 and one night time average from 20.00 to 08.00 are defined. The choice of 12 hour averages is made to capture daily climate variations in e.g. attics.

The MRD-model is based on reference values for relative humidity, $\phi_{ref} = 90$ %, and temperature $T_{ref} = 20$ °C. It is tuned so that exposure during a certain time Δt to constant values ϕ_{ref} and T_{ref} gives a dose $D(\Delta t) = \Delta t$, i.e. exposure to constant climate corresponding to the reference values gives a dose corresponding to the actual time spent. Thus, the critical dose kan be interpreted as the time required to reach the limit state "initiation of mould growth" under time constant exposure (ϕ_{ref} , T_{ref}) = (90%, 20°C). This means that the critical dose D_{crit} can be directly measured in experiments where a certain material is constantly exposed to the reference climate and where mould development is observed in microscope continously. D_{crit} is then determined as the time it takes to reach the limit state described above.

The condition in Eq. (1) can be written as

$$I_{MRD}(t) = \frac{D(t)}{D_{crit}} < 1 \qquad (2)$$

The quantity I_{MRD} is called MRD-index and can be calculated as a function of time t, for an arbitrary dynamic exposure history. If the MRD index exceeds 1,0 for a given exposure and material, the limit state is violated, else not.

When the MRD-index is calculated in the current WUFI software it is assumed that the critical dose D_{crit} = 17 days, which is valid for planed spruce (Picea Abies) as a reference material. This means that the limit for mould growth corresponds to I_{MRD}=1 for planed spruce. Limit values for other wooden materials can be estimated. Some examples are shown in the table below.

Material	**Limit value for I_{MRD}**
Planed spruce	1,0
Planed pine	0,7
Kiln dried spruce - original surface[1]	0,6
Kiln dried pine - original surface[1]	0,5
Pressure treated pine, NTR AB	>3

[1]Surface has not been mechanically treated after kiln drying

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Critical dose for mould growth, D_{crit}

Materials exhibit different resistance against surface mould growth, depending on for instance available nutrition, surface treatment and presence of biocides. In the MRD model, the critical dose D_{crit} is used as a measure of the potential for growth on a given material surface. D_{crit} is defined as the time until the limit state for initiation of mould growth is reached under steady exposure at relative humidity 90 % and temperature 20 °C, see Moisture Resistance Design (MRD) model. Larger values of D_{crit}, implies higher resistance against growth. Recommended values for D_{crit} are given in Table 1. The principles behind these values are summarised below.

1) The values are based on data from experimental investigations found in the literature
2) Planed Norway spruce of commercial quality was used as a reference, since many published tests include this material
3) Performance of other materials were estimated by comparisons with this reference
4) A certain safety margin of the order 20 % is included in the values

Some important studies of experimental investigations of mould growth as influenced by climatic factors are reported in references [1-11].

It should be noted that data for mould resistance reported in different investigations have a large variability. A primary difficulty is a to verify whether the tested materials are representative for commercially available materials. Data from different sources are often contradictory and tested materials are inadequately defined in many studies. A risk assessment should therefore be made in design applications.

Table 1. Design value of critical dose $D_{crit,d}$ for selected material surfaces

Material (surface)	**$D_{crit,d}$ (days)**
Norway spruce, planed, commercial quality	17
Scots pine, planed	12
Norway spruce, sawn surface[1]	10
Scots pine, sawn surface[1]	8
Scots pine, treated, class NTR AB[2]	>50
Norway spruce, surface treated with Vital Protect (boron compound)	>70
Modified wood: furfurylerated pine WPG[3] (≈ 45 %)	35
Modified wood: thermotreated wood, 212 °C (Thermowood D)	12
Modified wood: acetylated radiata pine[4] ≈ 20 %	>50
Wood polymer composite (50 % pine fibres/50 % polypropylene)	>50

[1] Valid for kiln dried wood and where the surface has not been machuíned after drying
[2] Treatment with copper organic wood preservation agents
[3]For furfurylated wood the concentration of furfuryl alcohol is given as WPG = Weight Percent Gain
[4]For acetylated wood the concentration of acetyl is specified in %.

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