Fire-Safety Analysis Timber

This documentation refers to the fire safety verifications used in the D10, HO1, HO4 and HO11 software applications for roof and timber structures.

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Fundamentals of the fire-safety analysis as per DIN 4102-22, EN 1995-1-2

(For DIN 1052:2004, EN 1995:2008)

The following constant charring rates are recommended for:

- Softwood (rho >= 290 kg/m³) v = 0.8 [mm/min]
- Laminated timber (Rho >= 290 kg/m³) v = 0.7 [mm/min]
- Hardwood (rho >= 450 kg/m³) v = 0.7 [mm/min]
- Hardwood (rho >= 450 kg/m³) v = 0.5 [mm/min] (EN5 v = 0.55 [mm/min])

It should be noted in this context that the charring rates depend on the moisture content, the density, the shape of the cross section and the nature of the wood.
The charring rates for timber-derived materials should be determined according to the specifications in the approval or in the standard (EN5 4.4.2).

The charring rates provide for the assessment of the fire load applying to one side:

Examples for the representation of the fire load: (b = width and h = height of the cross section)

On one side:	== e.g. $0 \cdot b, 1 \cdot h$ under fire
On two sides:	== e.g. $1 \cdot b, 1 \cdot h$ under fire
On three sides:	== e.g. $2 \cdot b, 1 \cdot h$ under fire
On four sides:	== e.g. $2 \cdot b, 2 \cdot h$ under four fire

The following relations apply to solidity/rigidity:

$$f_{(c,t,m)d} = k_{mod,fi} \cdot k_{fi} \frac{f_{(c,t,m)k}}{\gamma_{M,fi}}$$

$$E_{mod,d,fi} = k_{mod,fi} \cdot k_{fi} \frac{E_{0,05}}{\gamma_{M,fi}}$$

$$G_{mod,d,fi} = k_{mod,fi} \cdot k_{fi} \frac{fak \cdot G_{05}}{\gamma_{M,fi}}$$ fak = 2/3 for solid timber; fak = 1 for gluelam

$$k_{mod,fi}(m) = 1 - \frac{1 \cdot U_r}{225 \cdot A_r} \quad \left(\text{EN5 } k_{mod,fi}(m) = 1 - \frac{1 \cdot U_r}{220 \cdot A_r}\right) \text{ for bending}$$

$$k_{mod,fi}(c) = 1 - \frac{1 \cdot U_r}{125 \cdot A_r} \quad \text{for pressure}$$

$$k_{mod,fi}(t,Emod) = 1 - \frac{1 \cdot U_r}{333 \cdot A_r} \quad \left(\text{EN5: } k_{mod,fi}(t,Emod) = 1 - \frac{1 \cdot U_r}{300 \cdot A_r}\right) \text{ for tension, rigidity}$$

k_{fi}	= 1.25 for solid timber, softwood, hardwood
k_{fi}	= 1.15 for laminated timber, derived timber boards
k_{fi}	= 1.10 laminated veneer timber (Kerto)
A_r	= surface area [m²] and U_r = circumference [m] of the residual cross section
$\gamma_{M,fi}$	= 1.00 partial safety coefficient for material

The calculation method described above is not permitted by ÖNORM B 1995-1-2:2008. The Austrian standard requires the less favourable calculation method with a reduced cross section.

Verification for normal force and moment load

The verifications for bending, bending tension and compression with bending as well as the stability verifications are performed in accordance with the specifications of DIN 1052:2004/2008 and/or EN 1995. The residual cross section and the reduction of the strength and stiffness properties are taken into account in these verifications. The structural system the analyses are based on must not change during the action of the flames.

If axial force is decisive for the fire safety, the following results are displayed:

t_F	Charring time in [min] or alternatively
F30 B, R30	fire safety class when t_F = 30 min, 60 min or 90 min.
Charring	documents briefly the charring behaviour of the surfaces
σ	burning stress; comparison of the existing axial stress and the permissible stress; compressive stress has a negative sign.
min b/h	minimum cross section required for the charring time

Verification of shear force action (DIN 4102-4/-22 5.5.2.4)

DIN 4102-4 requires the examination of the fire resistance under shear action. Until recently, this was based on the simplified equation of condition (11l) or (11). Currently, the verification is based on the limit state of the structural comparison value in accordance with the fire-protection manual “Brandschutz Handbuch” /1/. This approach is prescribed by DIN 1052:2004/2008 and EN 1995.

Shear strength under fire $$f_{v,fi} = f_{v,d} \cdot \frac{k_{fi} \cdot \gamma_M}{k_{mod}}$$

Shear stress under fire $$\tau_{fi} = \tau_{,d} \cdot \frac{b_y \cdot d_z}{b_{y,fi} \cdot d_{z,fi}} \cdot 0{,}5 \cdot \gamma_M$$

Shear utilization under fire $$\eta_{fi} = \frac{\tau_{,d}}{f_{v,d}} \cdot \frac{b_y \cdot d_z}{b_{y,fi} \cdot d_{z,fi}} \cdot \frac{0{,}5 \cdot k_{mod}}{k_{fi}}$$

The charring depth is determined in accordance with the specifications of the ideal residual cross section method.

b_y, d_z	thicknesses of the initial cross sections
by_{fi}, dz_{fi}	Cross-sectional width and height reduced through charring
$f_{v,d}$	permissible shear strength in the structural design load case
$\tau_{,d}$	existing shear stress in the structural verification
$f_{v,fi}$	permissible shear strength under fire
$\tau_{,fi}$	existing shear stress under fire
Condition:	$\eta_{,fi}$ <= 1.0

If axial force is decisive for the fire safety, the following results are displayed:

t_F	charring time in [min] or alternatively
F30 B, R30	fire safety class when t_F = 30 min, 60 min or 90 min.
Charring	documents briefly the charring behaviour of the surfaces
$\tau_{,fi}$ / $f_{v,fi}$	comparison of the existing shear stress and the permissible shear strength
min b/h	minimum cross section required for the charring time