Eurocode 1: Actions on structures –

Part 1–2: General actions – Actions on structures exposed to fire

Annex A (informative)

→ Parametric temp-time curves

Part of the One Stop Shop program

Introduction

- Method of determining a more realistic temperature-time curve
- Valid for compartments
  - Up to 500m^2 of floor area
  - Without openings in roof
  - Up to 4m in height

Basic fundamental equation

- Temperature-time curves in heating phase are given by:

$$\Theta_g = 20 + 1325 \cdot \left(1 - 0.324e^{-0.2t^*} - 0.204e^{-1.7t^*} - 0.472e^{-19t^*}\right)$$

where Θ_g is the gas temperature in the fire compartment

- The "time" t^* is not strictly the time, but an adjusted time based on other factors

Breaking down the equation

$$t^* = t \cdot \Gamma$$

$$\Gamma = \frac{(O/b)^2}{(0.04/1160)^2}$$

$$b = \sqrt{(\rho c \lambda)}$$

$$O = \frac{A_v \sqrt{h_{eq}}}{A_t}$$ ("Opening factor")

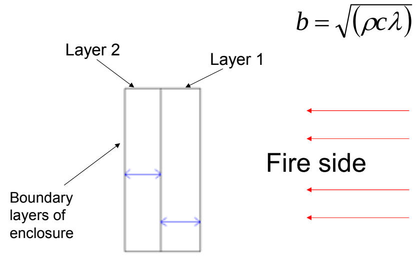
ρ – Density of enclosure boundary
c – Specific heat of enclosure boundary
λ – Thermal conductivity of enclosure boundary
A_v – Total area of vertical openings on walls
h_{eq} – Weighted average of window heights on all walls
A_t – Total area of enclosure (incl. openings)

This outlines the basis of the equation used

Further details of limitations and further provisos are also necessary…..

Different materials in surface layer

$$b = \sqrt{(\rho c \lambda)}$$



For layer 1, the subscript $_1$ is used and similarly for layer 2……

Different materials in surface layer

$$b = \sqrt{(\rho c \lambda)}$$

- If $b_1 < b_2$, then $b = b_1$
- If, however, $b_1 > b_2$ then a limit thickness is calculated for the exposed material:

$$s_{\lim} = \sqrt{\frac{3600 \cdot t_{\max} \cdot \lambda_1}{c_1 \rho_1}}$$

(We will find an expression for $t_{\max}$ in a few slides time….)

If $s_1 > s_{\lim}$, then $b = b_1$

If $s_1 < s_{\lim}$, then $b = \frac{s_1}{s_{\lim}} b_1 + \left(1 - \frac{s_1}{s_{\lim}}\right) b_2$

Different materials in surface layer

$$b = \sqrt{(\rho c \lambda)}$$

- To account for the different b factors in the walls, the above equation should be introduced as

$$b = \frac{\sum (b_j A_j)}{A_t - A_v}$$

Where A_j is the area of the surface enclosure and b_j is the b factor derived from the previous slide

Maximum temperature limit

- The maximum temperature in the heating phase occurs when $t^* = t^*_{\max}$

at which point $t^*_{\max} = t_{\max} \cdot \Gamma$

with $t_{\max} = \max\left[\left(\frac{2\times10^{-4}\cdot q_{t,d}}{O}\right); t_{\lim}\right]$

Where………

Maximum temperature limit

- $q_{t,d}$ is the *design value* of the fire load density related to the area of the enclosure

$$q_{t,d} = q_{f,d} \cdot \frac{A_f}{A_t}$$

Surface area of the floor (A_f)

Total surface area of compartment (A_t)

Design value of fire load density related to surface area of the floor – from Annex E ($q_{f,d}$)

- $t_{\lim}$ is described later…..

Maximum temperature limit

- When $t_{\max} = t_{\lim}$ the t^* in the main equation is replaced by $t^* = t \cdot \Gamma_{\lim}$

with $\Gamma_{\lim} = \frac{(O_{\lim}/b)^2}{(0.04/1160)^2}$

where $O_{\lim} = \frac{1\times10^{-4}\cdot q_{t,d}}{t_{\lim}}$

$t_{\lim}$ is 25min for slow fire growth, 20min for medium fire growth and 15min for fast fire growth.

This is expanded upon in Annex E

Further numerical limit

- A further limit is imposed on the operation under the following criteria:

If $O > 0.04$

and $q_{t,d} < 75$

and $b < 1160$

Then $\Gamma_{\lim}$ must be multiplied by a factor given below….

$$k = 1 + \left(\frac{O - 0.04}{0.04}\right)\left(\frac{q_{t,d} - 75}{75}\right)\left(\frac{1160 - b}{1160}\right)$$

Curves in the cooling phase

- For $t^*_{\max} \le 0.5$

$$\Theta_g = \Theta_{\max} - 625(t^* - t^*_{\max} \cdot x)$$

Where

$t^* = t \cdot \Gamma$

$t^*_{\max} = \left(\frac{2\times10^{-4}\cdot q_{t,d}}{O}\right)\cdot \Gamma$

For $t_{\max} > t_{\lim}$ → $x = 1$

For $t_{\max} = t_{\lim}$ → $x = \frac{t_{\lim}\cdot\Gamma}{t^*_{\max}}$

Curves in the cooling phase

- For $0.5 < t^*_{max} < 2$

$$\Theta_g = \Theta_{max} - 250\left(3 - t^*_{max}\right) \cdot \left(t^* - t^*_{max} \cdot x\right)$$

Where

$$t^*_{max} = \left(\frac{2 \times 10^{-4} \cdot q_{t,d}}{O}\right) \cdot \Gamma$$

$$t^* = t \cdot \Gamma$$

For $t_{max} > t_{lim}$ $\longrightarrow$ $x = 1$

For $t_{max} = t_{lim}$ $\longrightarrow$ $x = \frac{t_{lim} \cdot \Gamma}{t^*_{max}}$

Curves in the cooling phase

- For $t^*_{max} \geq 2$

$$\Theta_g = \Theta_{max} - 250(t^* - t^*_{max} \cdot x)$$

Where

$$t^* = t \cdot \Gamma$$

$$t^*_{max} = \left(\frac{2 \times 10^{-4} \cdot q_{t,d}}{O}\right) \cdot \Gamma$$

For $t_{max} > t_{lim}$ $\longrightarrow$ $x = 1$

For $t_{max} = t_{lim}$ $\longrightarrow$ $x = \frac{t_{lim} \cdot \Gamma}{t^*_{max}}$