# Design steps for simplified design of VoidPro slabs in fire

For a 30 minute fire resistance rating no additional reinforcement is required (based on EN 1994-1-2 guidelines). For 60 minute and higher resistances the capacity of floor slabs in sagging is calculated according to the 500°C Isotherm Method of EN 2-1-2 (BSI 2005), or Buchanan (2001). The basis for this simplified method is that all concrete with a temperature greater than 500°C is to be ignored, while all concrete with a temperature less than 500°C is to be assumed to have its full strength. Reinforcement is designed with a reduced strength based on its temperature. Slabs are designed as simply-supported T-beams, even for continuous slabs.

**The process to be followed is:**

1. Ensure that the minimum slab thickness specified in Table 1 is satisfied.
2. Calculate the fire limit bending moments, based on the load combinations provided in Equation 1 and Table 2. The load combination to be checked is at the fire limit state (FLS) and is based upon the accidental load combination (ACC) of SANS 10160-1:

| | |
|---|---|
| $Fire\ limit\ state\ load = 1.0 \times Permanent\ Load + \psi \times Imposed\ Load$ | *Eq. 1* |

   The combination factor, $\psi$, is taken according to SANS 10160 as specified in Table 2.
3. Determine the depth of the 500°C temperature isotherm for the standard fire. See Table 3 and Figure 1 for more details.
4. Determine the temperature of reinforcing steel at the centre of bars and calculate the reduced strength of reinforcing steelwork ($f_{yT} = k_{yT} f_y$). This is provided in Table 4.
5. Calculate the resistance of the section according to normal concrete design methods (SANS 10100-1, SANS 51992-1-1 / EN 1992-1-1, or to Buchanan (2001)) but using the reduced rebar strength, $f_{yT}$. Ignore the contribution of the permanent formwork. The following equations are suggested as a simple approach:

   Depth of concrete compression block:

| | |
|---|---|
| $a_f = \frac{A_s f_{y,T}}{0.67 f_{cu} b}$ | *Eq. 2* |

   Sagging moment capacity in fire:

| | |
|---|---|
| $M_f = A_s f_{y,T}(d - a_f/2)$ | *Eq. 3* |

   Where:

| | |
|---|---|
| $a_f$ | Depth of compression block |
| $A_s$ | Area of reinforcing steel in tension (per rib) |
| $b$ | Width of the rib |
| $d$ | Effective depth to centre of reinforcement |
| $f_{cu}$ | Characteristic strength of the concrete |
| $f_{y,T}$ | Yield strength of reinforcing steel at temperature T, where $f_{y,T} = k_{y,T} f_y$ |

6. Ensure that the neutral axis (referred to as $x$ in SANS 10100-1) of the section falls within the upper section of the beam which is cooler than 500°C. This is calculated as $\frac{a_f}{0.9}$, and is measured from the top of the slab.

| Profile | Min. slab thickness for 60min fire rating | Min. thickness above flute (mm) |
|---|---|---|
| VoidPro 50 | 120 | 70 |
| VoidPro 115 | 190 | 75 |
| VoidPro 200 | 275 | 75 |

*Table 1: Minimum thickness of VoidPro systems to satisfy a 60 minute insulation fire resistance rating*

| Category | Specific use | $\psi$ – Combination factor |
|---|---|---|
| A | Domestic and residential areas | 0.3 |
| B | Public areas not susceptible to crowding | 0.3 |
| C | Public areas where people may congregate | 0.3 |
| D | Shopping areas | 0.3 |
| E1 | Light industrial use | 0.5 |
| E2 | Industrial use | 0.6 |
| E3 | Storage areas | 0.8 |
| H | Inaccessible roofs | 0.0 |
| J | Accessible flat roofs, excluding occupancy categories A to D | 0.3 |
| K | Accessible flat roofs with occupancies A to D | In accordance with Categories A to D |

*Table 2: Combination factor for the fire limit state (FLS)*

| Fire time (min) | $a_{500}$ - 500°C Isotherm Depth (mm) |
|---|---|
| 60 min | 23 |
| 90 min | 32 |
| 120 min | 40 |

*Table 3: Depth of 500°C isotherm for the design of slabs in sagging according to EN 1994-1-2 Table D.5*

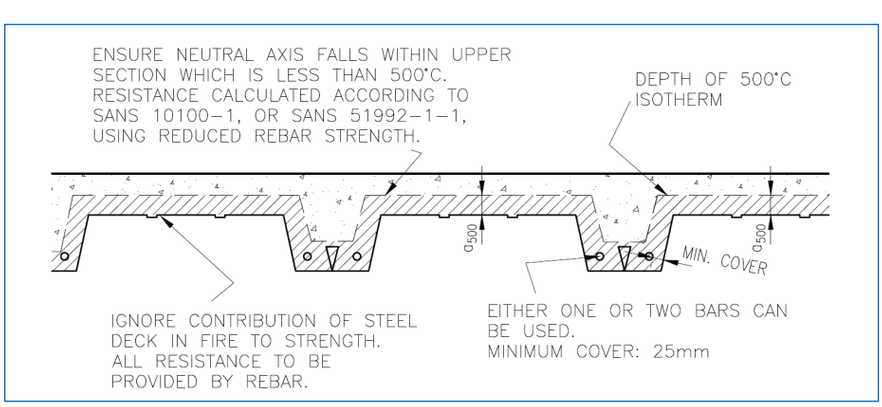


*Figure 1: Fire limit state (FLS) design considerations and layout*

| Fire resistance time (min) | T - Steel temp (°C): | $k_{yT}$ - Reduction factor |
|---|---|---|
| 60 min | 460 | 0.78 |
| 90 min | 610 | 0.37 |
| 120 min | 720 | 0.19 |

*Table 4: Temperature and reduction factors for reinforcing steel at different standard fire times assuming 20mm*

# Design Assumptions

**The following assumptions have been made to calculate fire resistance ratings of the VoidPro panels:**

| | |
|---|---|
| Concrete strength: | C25/30 (i.e. 30MPa cube strength) |
| Rebar properties: | Yield strength – 450 MPa. Young's modulus – 200 GPa. |
| Cover: | 25mm |
| Top steel / mesh: | If required minimum top reinforcement as per EN 1994-1-1 should be added to reduce cracking for continuous beams. |

The entire steel formwork profile is neglected for calculations as it rapidly loses strength in fire. Rebar detailing specifications must apply with applicable SANS requirements.

# Notes

For composite steel-concrete floors in fire specialist literature should be consulted such as that of the MACS+ design software or Slab Panel Method (SPM) for designing slabs in fire. This can lead to reductions in required reinforcement and reduced passive protection requirements for steel beams. Detailing requirements associated with the aforementioned methods must be adhered to, to ensure that cracking in slabs does not occur.

The Eurocode EN documents permit using a lower partial material factor for the ACC limit state. Hence, partial material factors for concrete and steelwork may be been taken as 1.0. For continuous slabs a savings in sagging reinforcement can be made using continuity, but the literature listed above should be consulted for the calculation of hogging moment capacity.