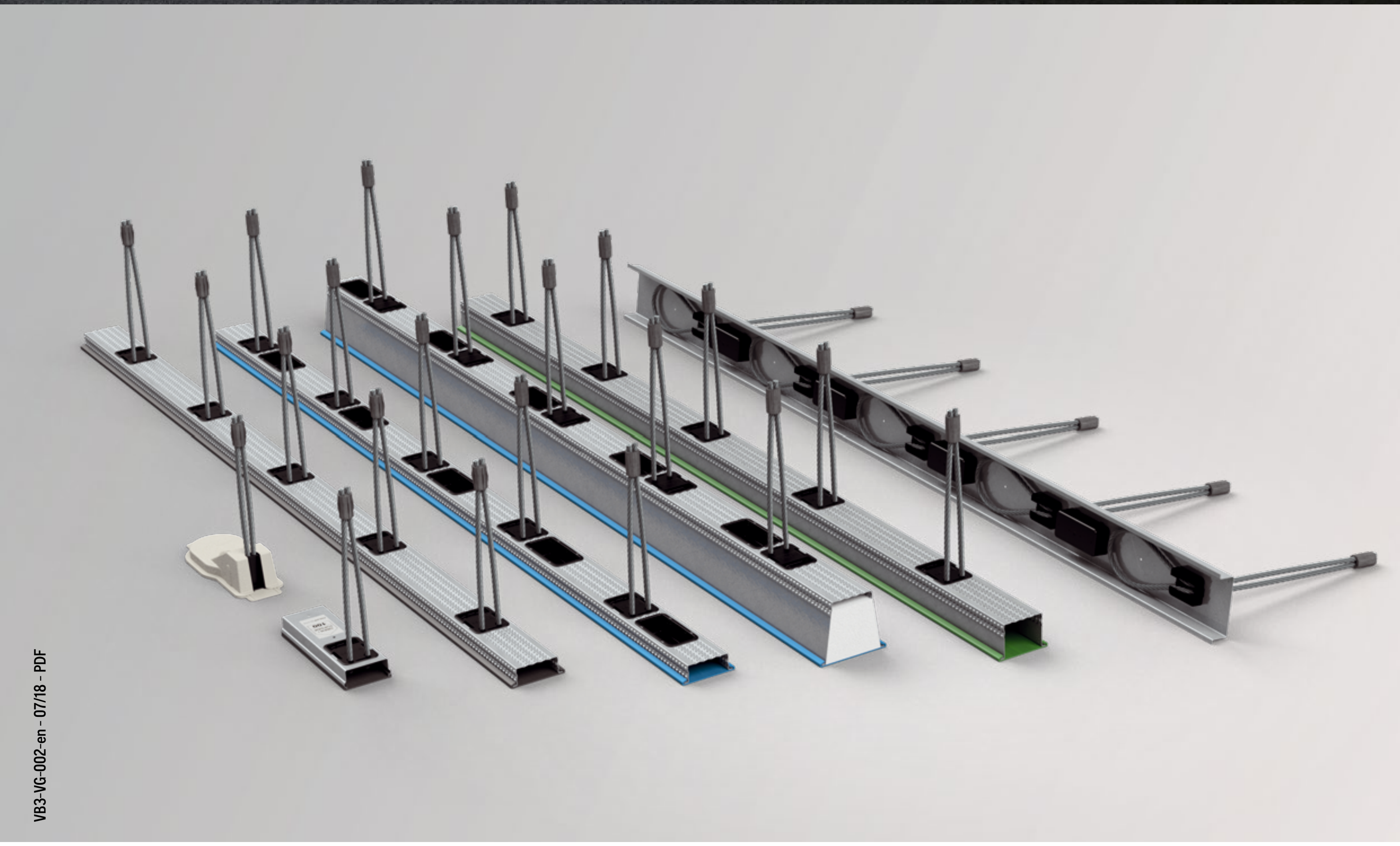
PHILIPPGROUP

Connection technology
Fire protection



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Expert opinion

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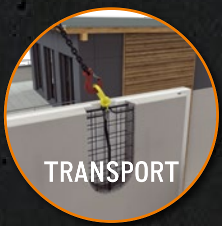

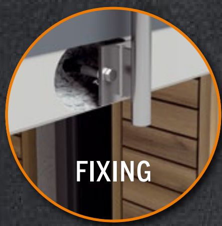

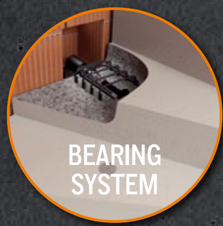

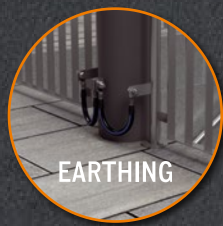

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This translation of the expert opinion fully corresponds to the original issued document in German language

Expert opinion

GS 3/12-14

Subject	Thermal 2D FEM simulation of the PHILIPP wire rope loop connection Power Duo in combination with the PHILIPP P&T mortar system, PHILIPP BETEC grouting as well as thixotropic mortar and concrete
Client:	PHILIPP GmbH Lilient-halstrasse 7-9, 63741 Aschaffenburg, Germany
Order date:	12.01.2016
Processor:	M.Sc. Mayur Patil

This expert opinion consists of 15 pages

1. Motivation

This report contains the results of the 2D FEM simulation of the PHILIPP wire rope loop connection Power Duo in combination with PHILIPP P&T as well as BETEC mortar system and with concrete. To reduce the simulation time, a single loop was modelled and calculated with mortar and concrete. This expert opinion applies both to the products for the approved application, such as PHILIPP Power Duo and PHILIPP Power Box, as well as to the products for the constructive application, such as PHILIPP Connecting loops and Connecting rails.
The simulation results are calculated for the wall thicknesses (d) 140 mm with 50 mm overlap and 150 mm with 70 mm overlap of the parts for the approved application and 110 mm with 45 mm overlap, 120 mm with 50 mm overlap and 150 mm with 70 mm overlap of the parts for the constructive application for the fire resistance classes F90, F120 and F180.
The thermal action follows the standard temperature-time curve acc. to EN 1991-1-2. As boundary conditions for the simulation calculation the characteristic values acc. to EN 1992-1-2 and EN 1993-1-2 are used. All material properties of the mortar system were taken from the documents of the PHILIPP company. The simulation was made using the software ANSYS Mechanical (Workbench) 15.0.

2. Geometry

The geometry of the “wall-to-wall T-connection” for a 140 mm wall thickness with 50 mm overlap of the loops is shown in the following figure. Here, the wire rope loops connect two precast concrete walls. The construction-conditioned joint is filled with either mortar or concrete so that it surrounds all parts. The wall thickness is 140 mm and 150 mm for the approved application and 110 mm, 120 mm and 150 mm for the constructive application. The overlap of the loops is 45 mm for wall thickness ≥ 110 mm, 50 mm for wall thickness ≥ 120 mm and 70 mm for wall thickness ≥ 150 mm.

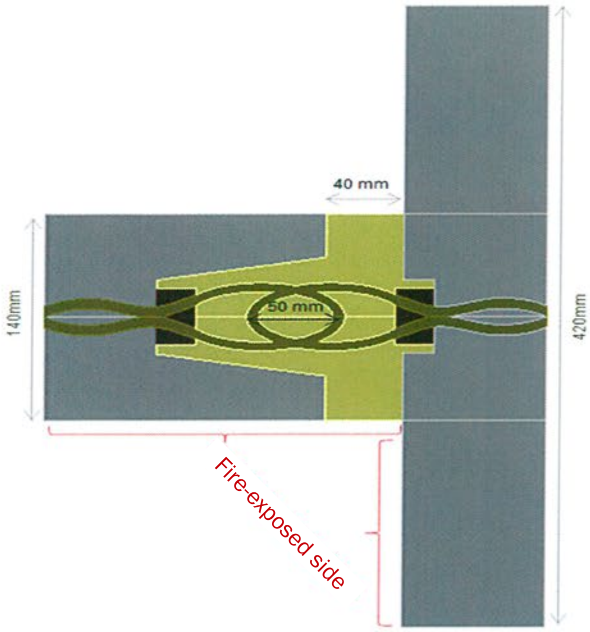


Fig. 1: Geometry of the Power Duo connecting rail

3. Mesh

With the help of 2D-plane elements, a very fine mesh size of 1 mm is created. PLANE 77 is a two-dimensional thermal element of a higher order. Here, the degree of freedom temperature can be taken at each node. SURF151 is used for various load and surface effects. In figure 2 the centre section of the mesh is shown. The precast concrete elements (grey), the mortar or concrete (yellow), the Power Duo connecting loops (dark yellow) and the profile (brown) can be seen.

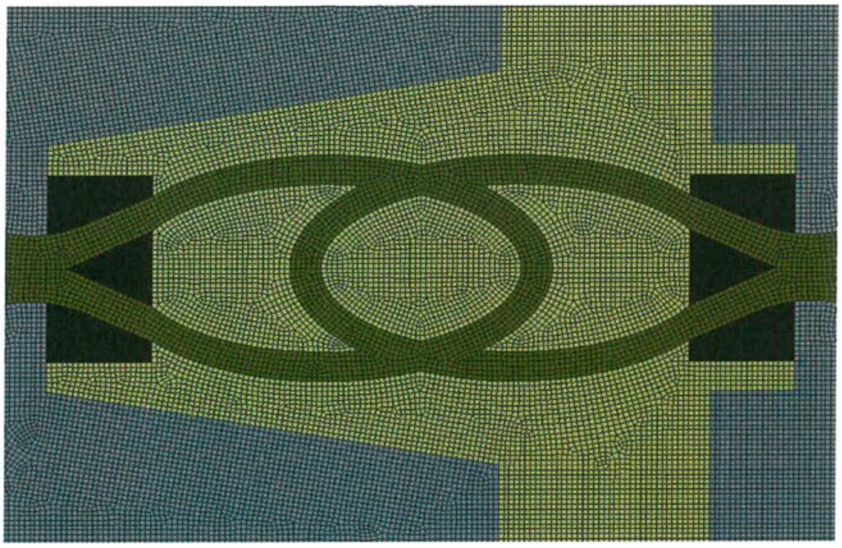


Fig. 2: FEM mesh

4. Material characteristics

Material characteristics such as thermal conductivity, specific thermal capacity and the density of concrete and steel are temperature-dependent and are determined in accordance with EN 1992-1-2 and EN 1993-1-2. In the following diagrams 1 - 5 the variations of the characteristics with regard to temperature are shown.
The thermal conductivity and specific thermal capacity of the mortar are 1.4 W/mK and 900 J/kgK respectively. As the maximum density the density of concrete is taken, which is 2.300 kg/m³.

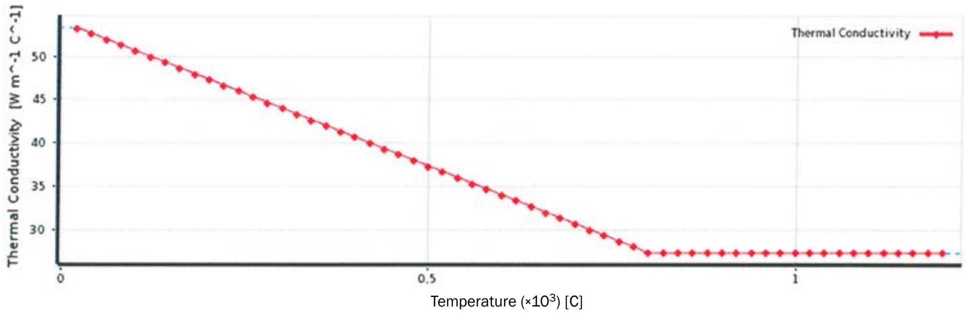


Diagram 1: Steel thermal conductivity

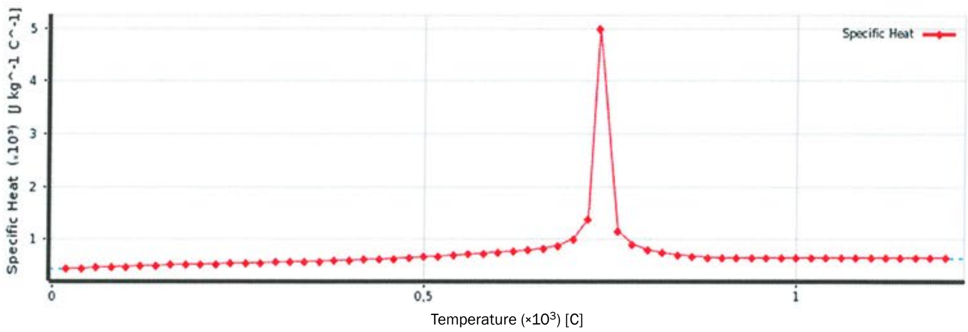


Diagram 2: Steel specific thermal capacity

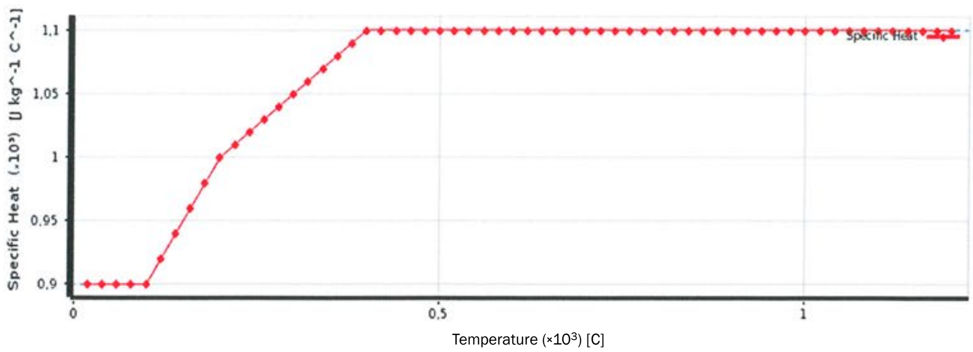


Diagram 3: Concrete specific thermal capacity

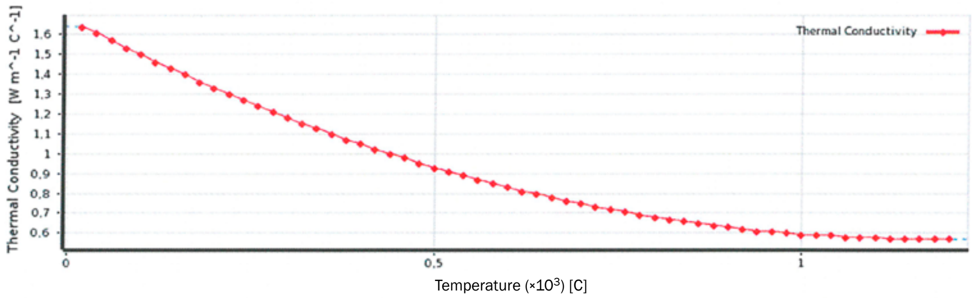


Diagram 4: Concrete thermal conductivity

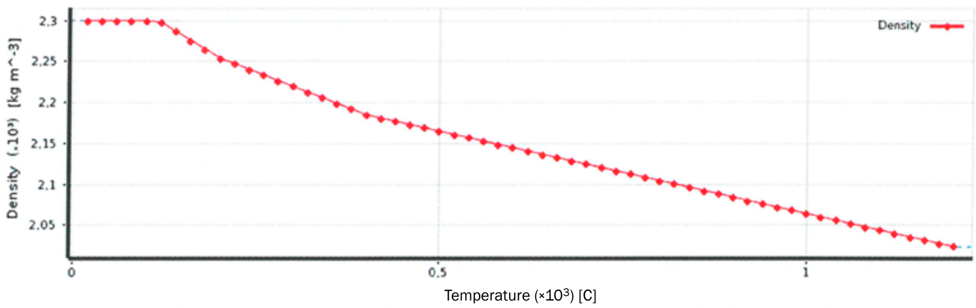


Diagram 5: Concrete density

5. Boundary conditions

Convection and radiation are defined for this simulation for both the side directly exposed to the fire and the side not directly exposed. The definition of convection, radiation, emissivity of the material and the heat transfer coefficients are defined in accordance with EN 1992-1-2 and EN 1993-1-2. For the heat transfer coefficients, the values of 25 W/m²K for the side exposed to the fire and 4 W/m²K for the far side from the fire. Emissivity values for steel and concrete are set to 0.7.

6. Critical temperature

According to EN 1991-1-2, the critical temperature for steel is assumed to be 350 °C. This critical temperature of the reinforcement is the temperature in the concrete element at which the fracture stress of the steel decreases to the steel stress. The existing steel stress changes during exposure to fire.

7. Results of the temperature development in wire rope loops with mortar for approved applications

The comparison of the standard temperature-time curve, loop temperature for the wall thicknesses 140 with 50 mm overlap and 150 mm with 70 mm overlap as well as critical temperature is shown in diagram 6.

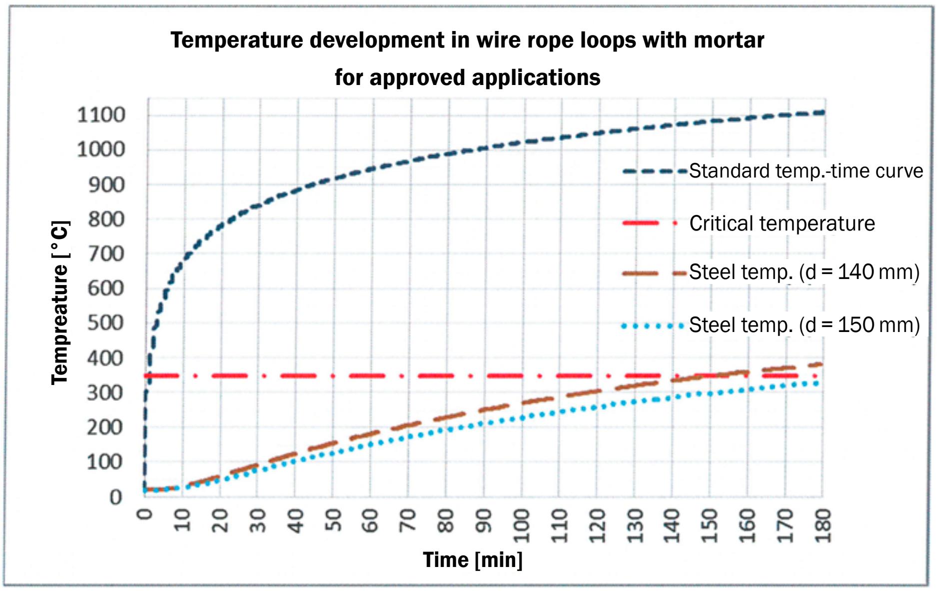
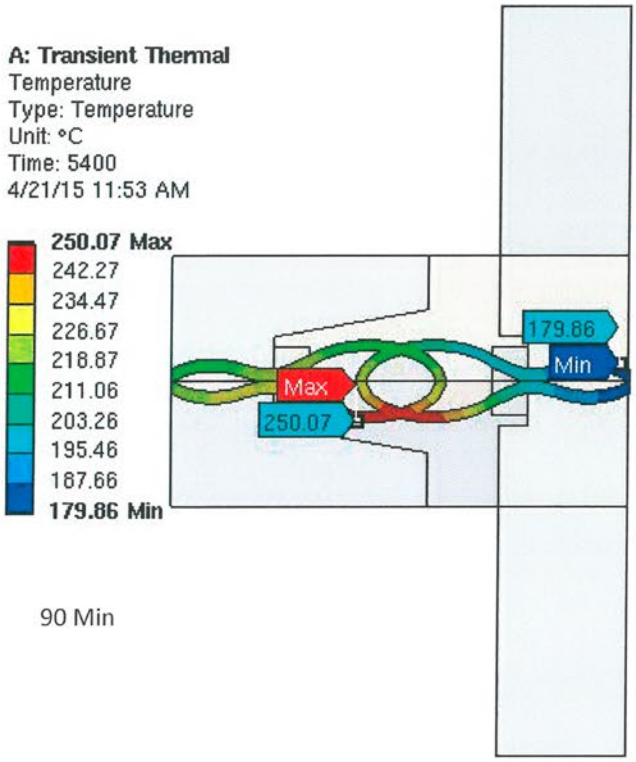


Diagram 6: Development of steel temperature for approved applications

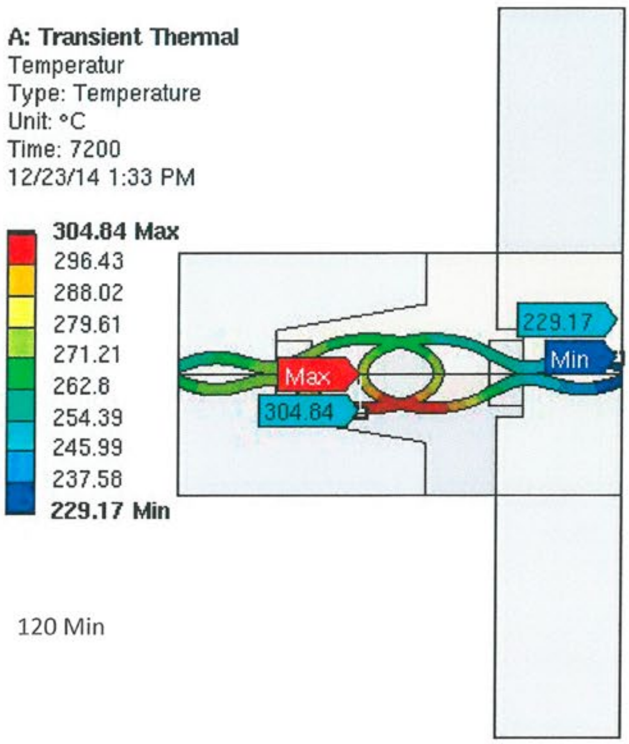
7.1. Verification for wall thickness (d) 140 mm

The maximum temperatures for a fire duration of 90 min or 120 min or 180 min on the steel profile for a wall thickness of d = 140 mm are 250 °C or 305 °C or 383 °C.

The critical temperature of 350 °C is reached in the steel itself after 150 minutes. From this it can be concluded that a wall thickness d ≥ 140 mm is suitable for achieving the fire resistance classes F90 and F120.
A wall thickness d = 140 mm is not sufficient to achieve the fire resistance class F180.



90 Min



120 Min

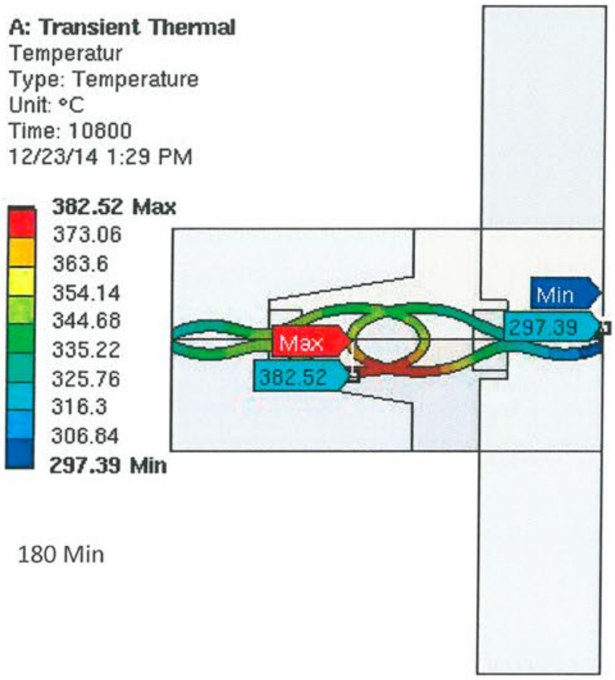


Fig. 3: Temperature distribution in the loop at 90 min, 120 min and 180 min for d = 140 mm

7.2. Verification for wall thickness (d) 150 mm

The maximum temperatures at 120 min and 180 min on the steel profile for the wall thickness d = 150 mm are 260 °C and 331 °C.

The critical temperature of 350 °C is not reached in the steel during the 180 minutes. From this it can be concluded that a wall thickness d = 150 mm is suitable for achieving the fire resistance class F120 and F180.

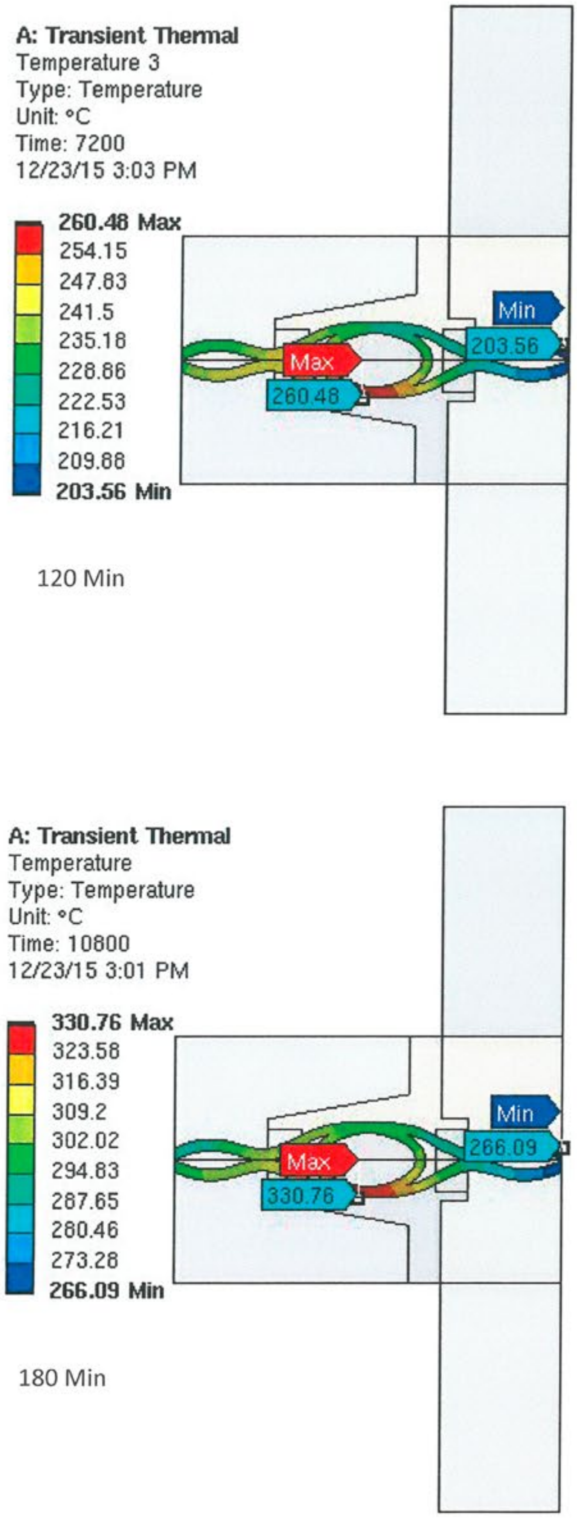


Fig. 4: Temperature distribution in the loop at 120 min and 180 min for d = 150 mm

8. Results of the temperature development in wire rope loops with concrete for constructive applications

The comparison of the standard temperature-time curve, loop temperature for the wall thicknesses 110 with 45 mm overlap and 120 mm with 50 mm overlap and 150 mm with 70 mm overlap as well as critical temperature is shown in diagram 7.

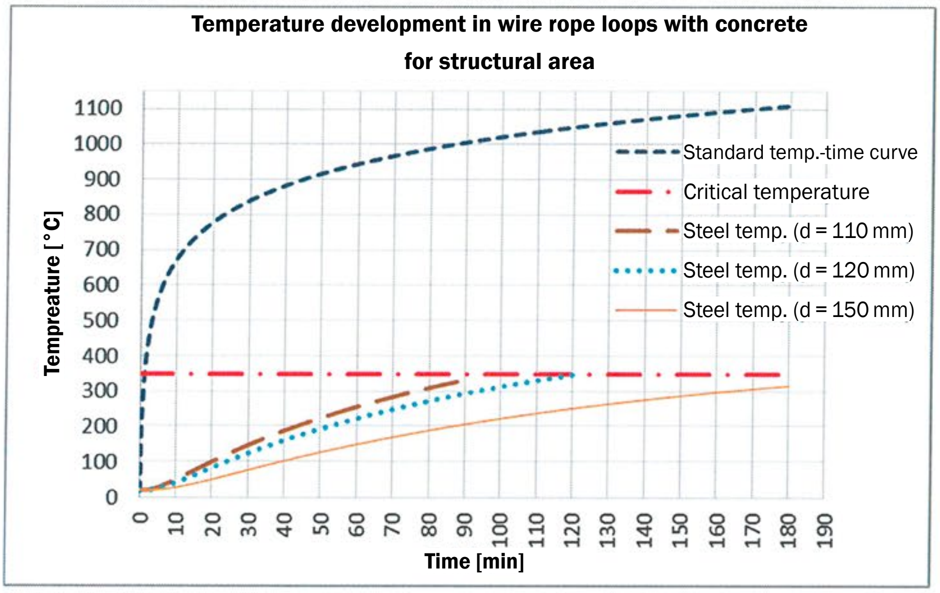


Diagram 7: Development of steel temperature for constructive applications

8.1. Verification for wall thickness (d) 110 mm

The maximum temperature for a fire duration of 90 min at the steel profile for a wall thickness of d = 110 mm and an overlap of 45 mm is 333 °C.

The critical temperature of 350 °C is not reached in the steel during the 90 minutes. From this it can be concluded that a wall thickness of d = 110 mm is suitable for achieving the fire resistance class F90.

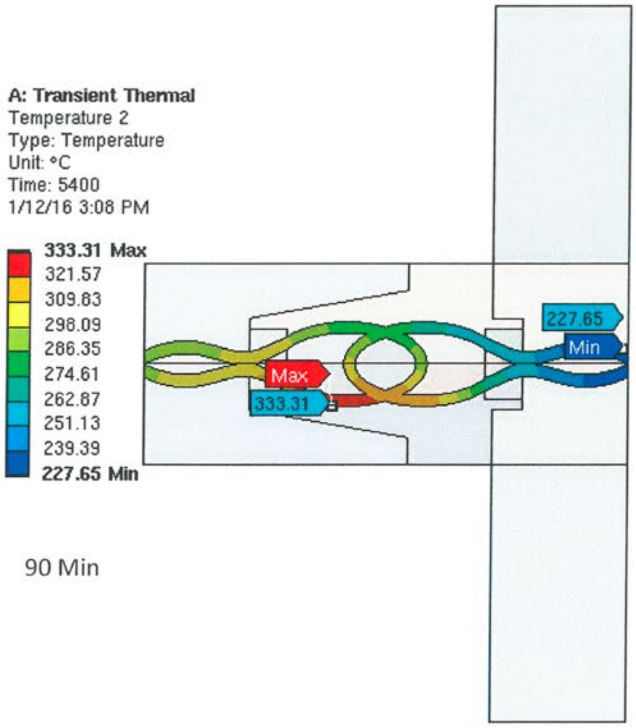


Fig. 5: Temperature distribution in the loop at 90 min for d = 110 mm

8.2. Verification for wall thickness (d) 120 mm

The maximum temperature for a fire duration of 120 min at the steel profile for a wall thickness of d = 120 mm and an overlap of 50 mm is 348 °C.

The critical temperature of 350 °C is not reached in the steel during the 120 minutes. From this it can be concluded that a wall thickness of d = 120 mm is suitable for achieving the fire resistance class F120

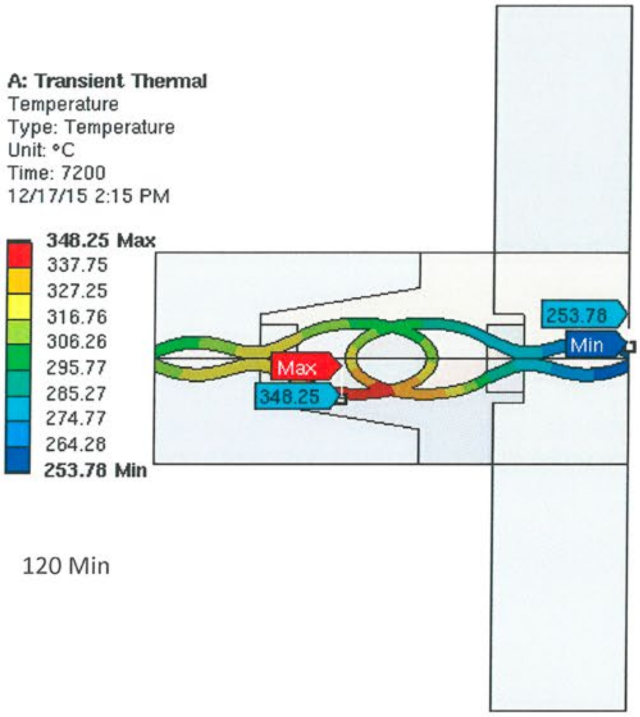


Fig. 6: Temperature distribution in the loop at 120 min for d = 120 mm

8.3. Verification for wall thickness (d) 150 mm

The maximum temperature for a fire duration of 180 min at the steel profile for a wall thickness of d = 150 mm and an overlap of 70 mm is 318 °C.

The critical temperature of 350 °C is not reached in the steel during the 180 minutes. From this it can be concluded that a wall thickness of d = 150 mm is suitable for achieving the fire resistance class F180.

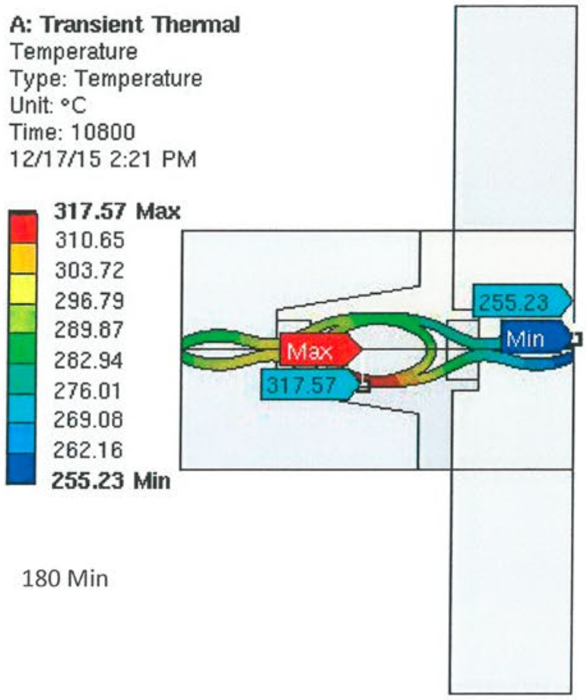


Fig. 7: Temperature distribution in the loop at 180 min for d = 150 mm

9. Summary

The results of the fire simulation calculations listed here show that under full load

for the approved application the

verification for F90

- is fulfilled for wall thickness ≥ 140 mm;

verification for F120

- is fulfilled for wall thickness ≥ 140 mm;

verification for F180

- is fulfilled for wall thickness ≥ 150 mm;

and

for the constructive application the

verification for F90

- is fulfilled for wall thickness ≥ 110 mm;

verification for F120

- is fulfilled for wall thickness ≥ 120 mm;

verification for F180

- is fulfilled for wall thickness ≥ 150 mm;

Kaiserslautern, 12.01.2016

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