Probabilistic analysis of concrete beams during fire

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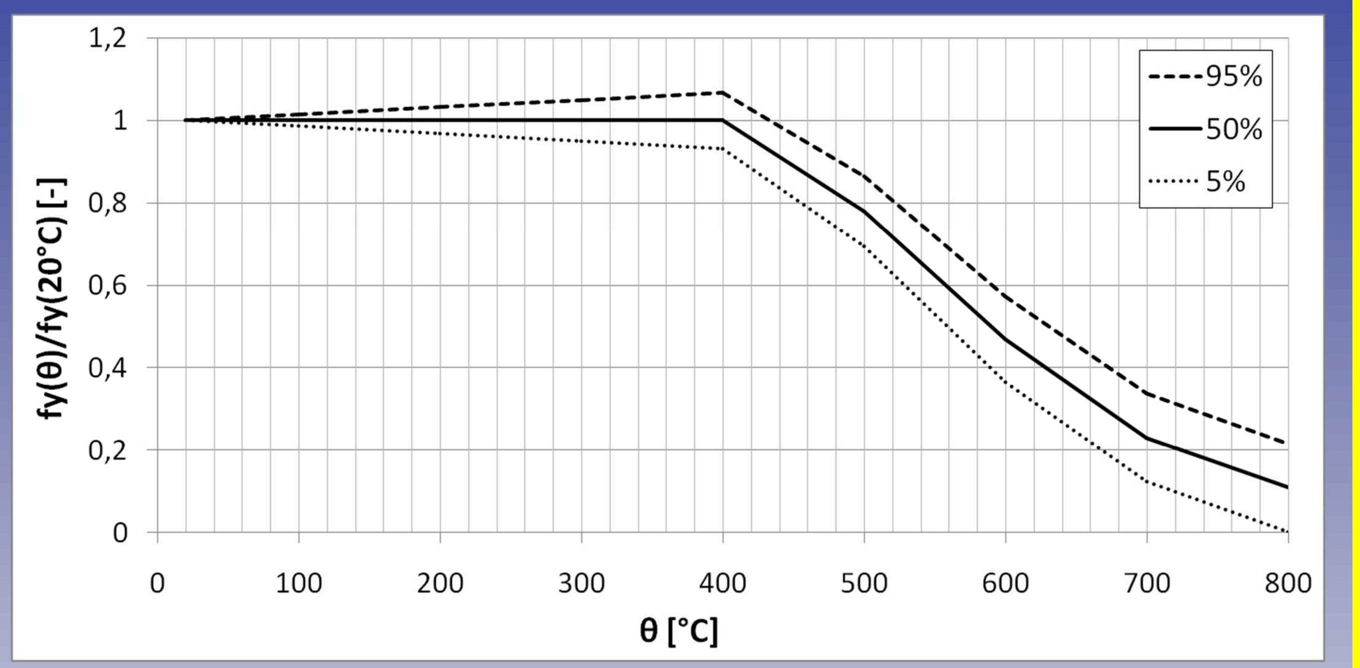
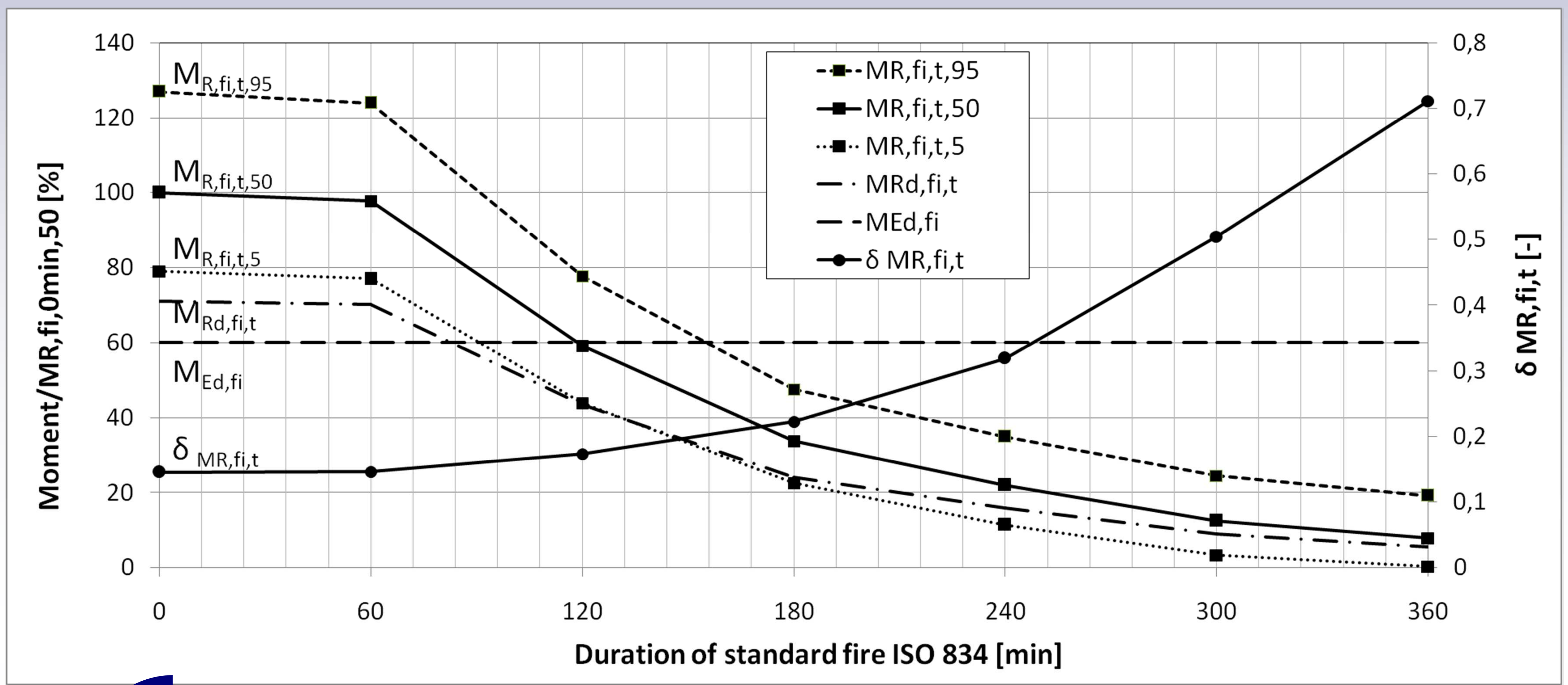
Due to an increasing temperature distribution over the concrete cross-section, the limit state function for bending during fire cannot be formulated analytically. Hence, in order to gain insight in the time and temperature dependent reliability of concrete beams during fire, a full-probabilistic model is developed quantifying the evolution of the structural safety of concrete beams subjected to bending during fire.

Model concepts

- Concrete beam exposed to ISO 834 from three sides.
- Bending moment capacity at t min of fire exposure ($M_{R,fi,t}$) calculated based on assumptions of classical linear-elastic structural analysis of EN 1992-1-1 [1].
- Basic stochastic variables implemented in accordance with (Holický and Sýkora, 2010) [2]
- Effect of fire on mechanical properties implemented through temperature dependent reduction factors of EN 1992-1-2 [3], elaborated with additional uncertainty.
- Calculation mesh 5 mm (square grid).
- 10.000 simulations



Model results for example beam (R90 table method EN 1992-1-2)



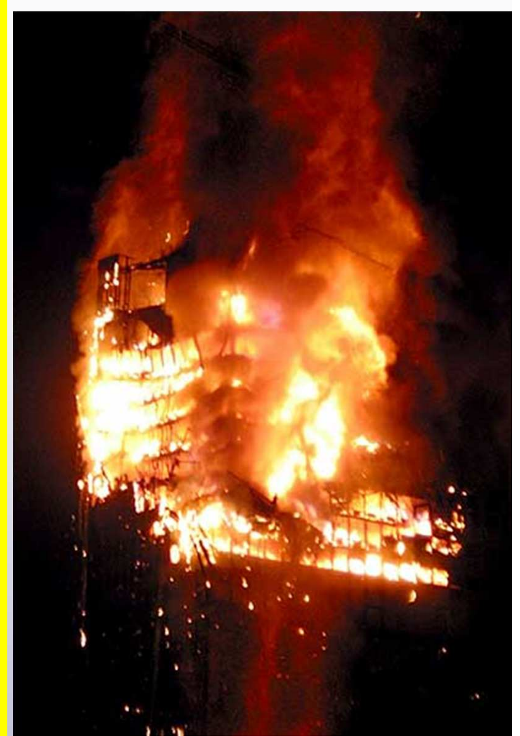
Fire resistance time t_R
(EN 1992-1-2):

$$M_{Rd,fi,t} \geq M_{Ed,fi,t} \quad \text{for } t \leq t_R$$

with:

$M_{Rd,fi,t}$ = design value of the bending moment capacity.

$M_{Ed,fi,t}$ = design value of the bending moment induced by the design loads.



Evaluating the safety level during fire and alternative calculation t_R
(since α_R = 1)

$$P_f = P\left[M_{R,fi,t} < M_{Ed,fi}\right] = \Phi(-\beta_1)$$

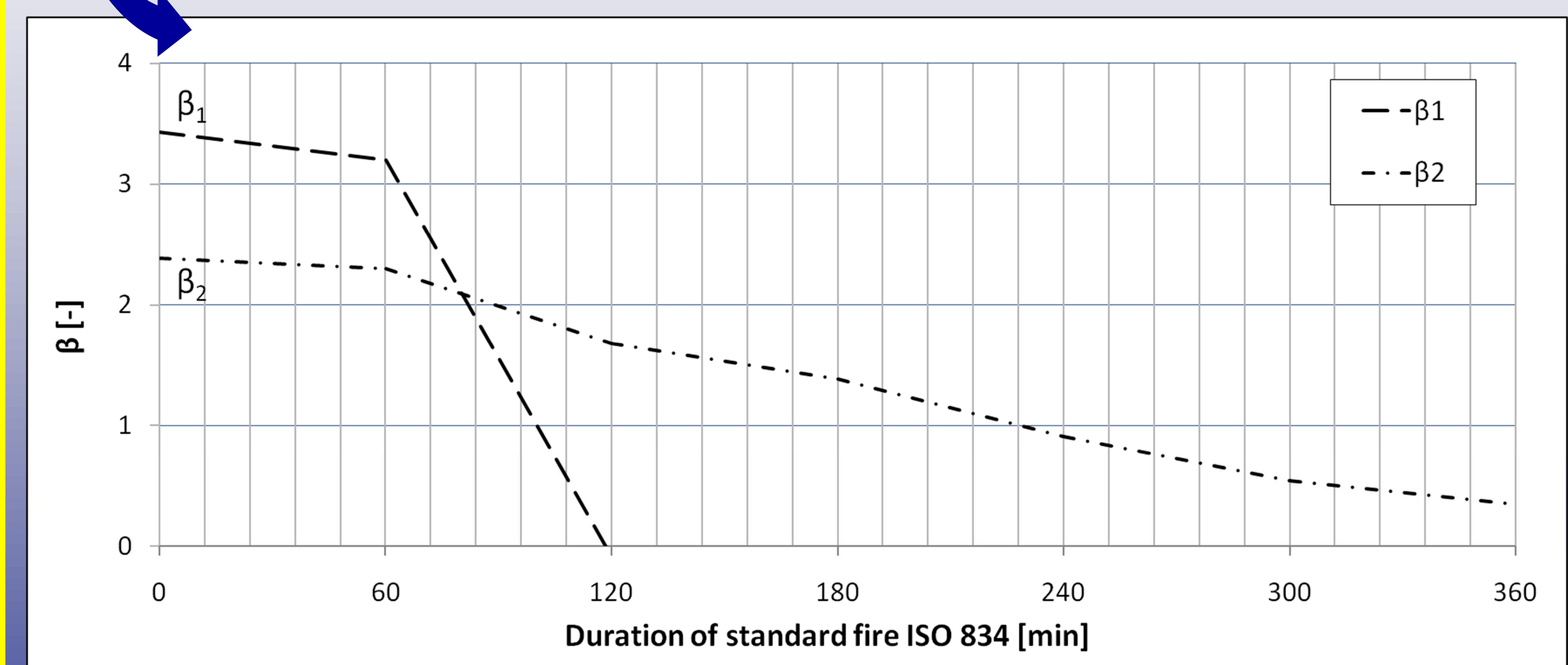
β_1 => structural fire resistance, dependent on the variable load.

$$P_f = P\left[M_{R,fi,t} < M_{Rd,fi,t}\right] = \Phi(-\alpha_R\beta_2) = \Phi(-\beta_2)$$

β_2 => fractile of the bending moment capacity distribution corresponding to the design value of the Eurocodes.

$$\Phi(-\beta_{1,t_R}) = P\left[M_{R,fi,t} < M_{Ed,fi,t_R}\right] = P\left[M_{R,fi,t} < M_{Rd,fi,t_R}\right] = \Phi(-\alpha_R\beta_{2,t_R}) = \Phi(-\beta_{2,t_R})$$

Intersection of β_1 and β_2 defines t_R



Conclusions

- A full-probabilistic model allows for an assessment of the safety level of concrete beams exposed to fire.
- A smaller fire resistance time is found based on the probabilistic analysis than the resistance time tabulated by EN 1992-1-2.
- The fire resistance of a beam can be increased by altering the beam configuration, e.g. Increasing concrete cover.

References

[1] CEN. Eurocode 2: Design of concrete structures: Part 1-1: General rules and rules for buildings, European Standard EN 1992-1-1; 2004.

[2] Holický M, Sýkora M. Stochastic models in analysis of structural reliability, Proceedings of the International Symposium on Stochastic Models in Reliability Engineering, Life Sciences and Operation Management, Beer Sheva; 2010.

[3] CEN. Eurocode 2: Design of concrete structures: Part 1-2: Structural fire design, European standard EN 1992-1-2; 2004.

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