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Why Eurocode Parametric Fire Design Framework Cannot Maintain Target Reliability Through Cooling- A First Principles Analysis

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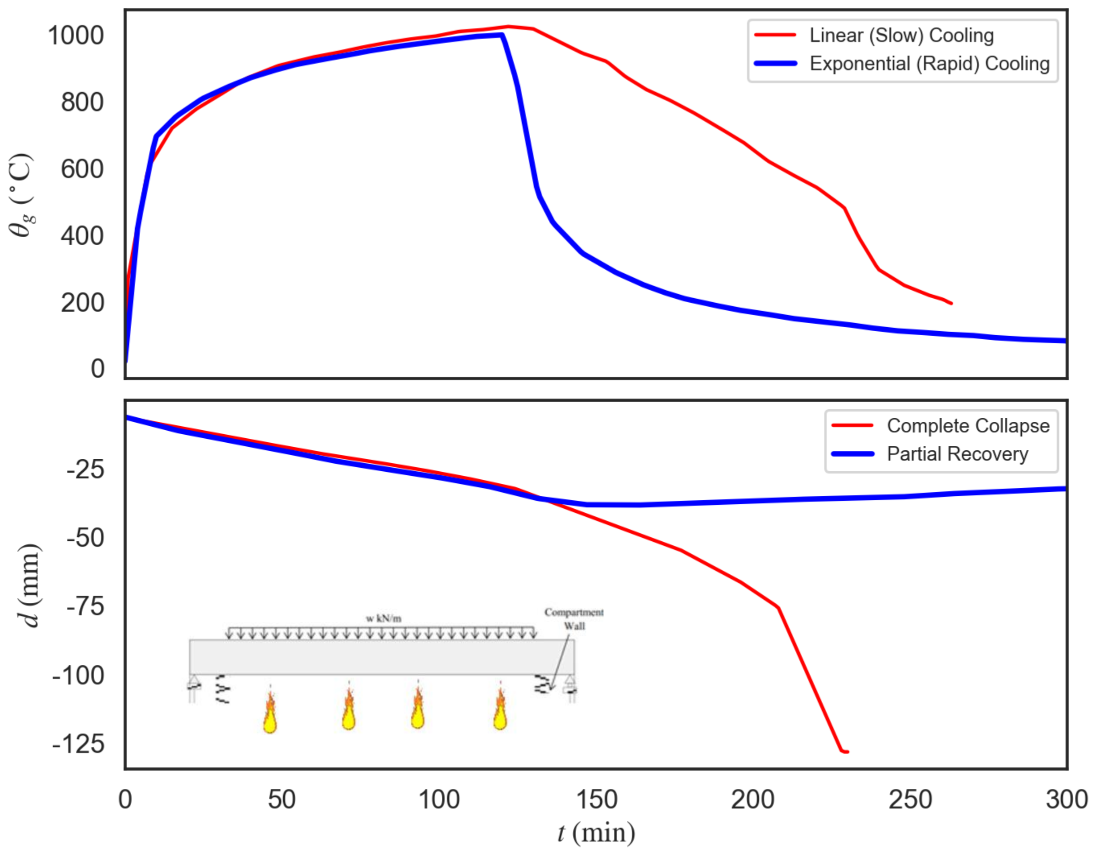
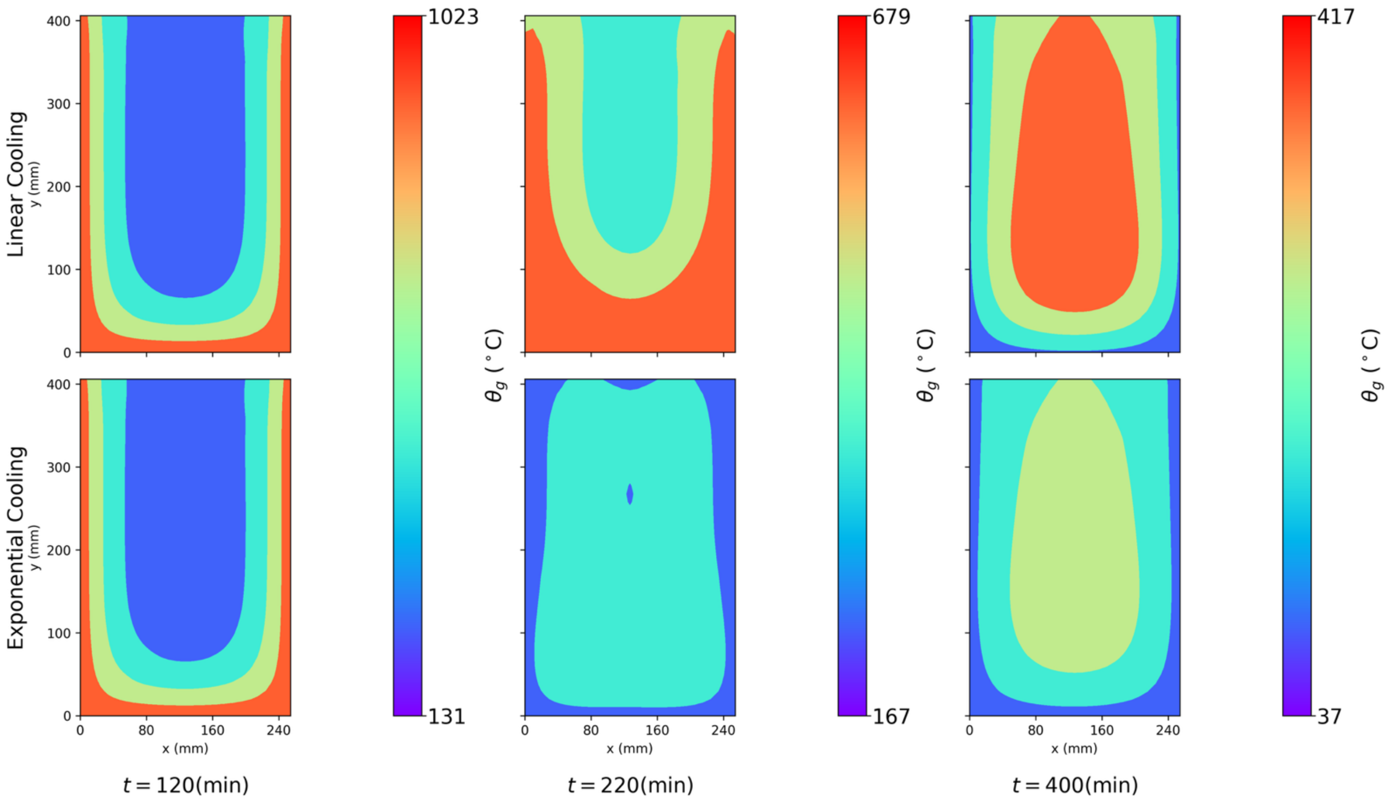
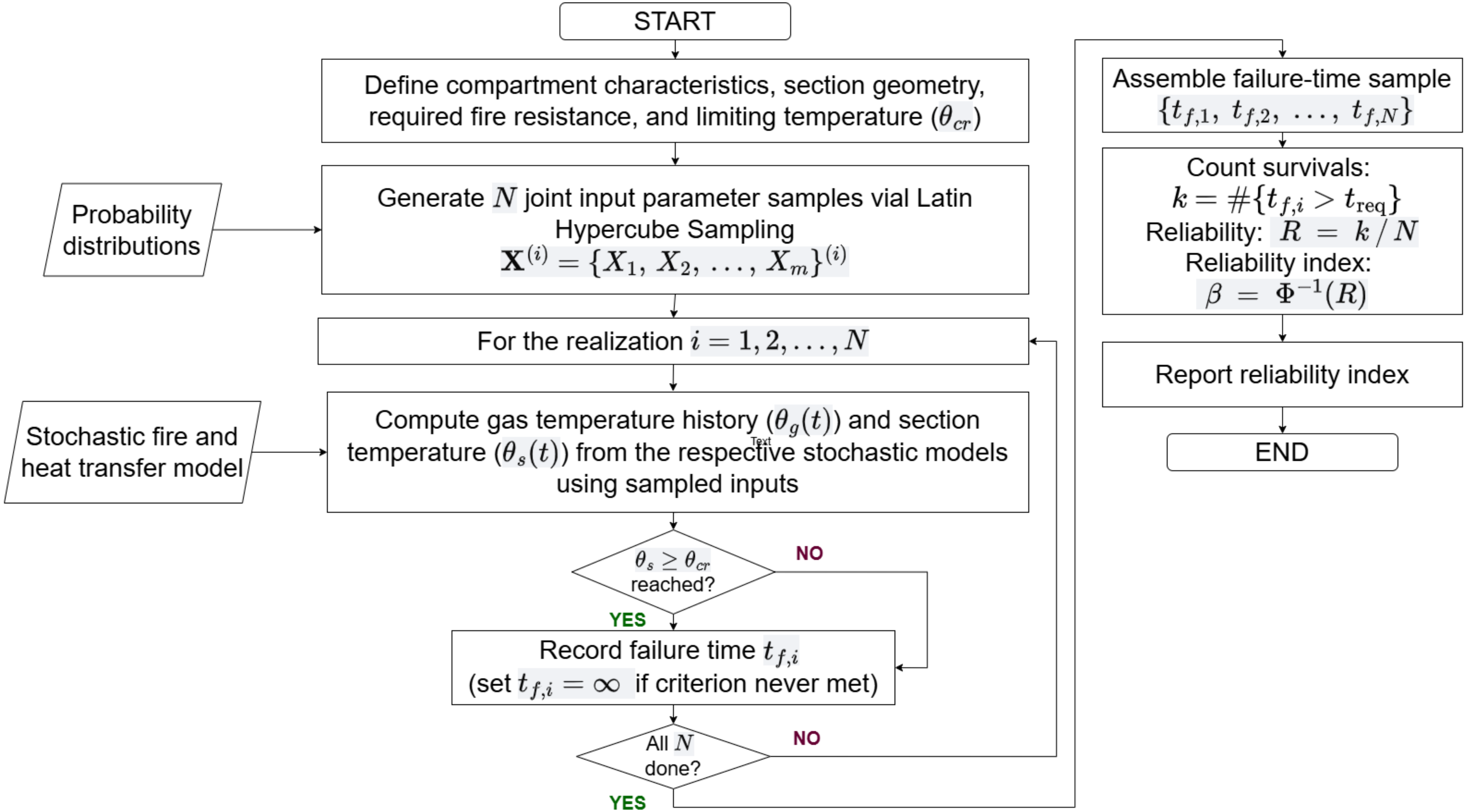
Cooling Phase Matters!



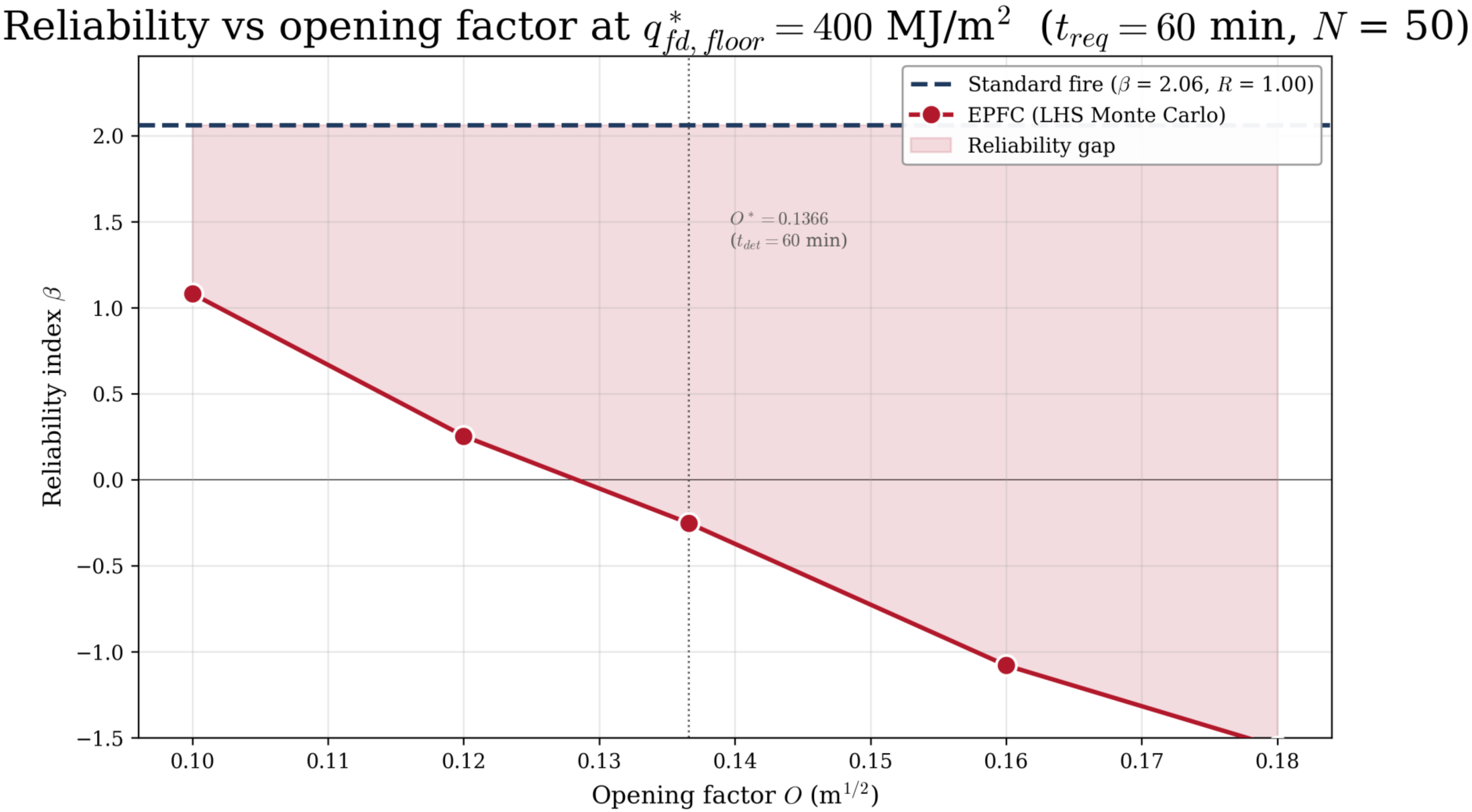


Agrawal, A., Kodur, V.K.R. A Novel Experimental Approach for Evaluating Residual Capacity of Fire Damaged Concrete Members. *Fire Technology* 56, 715–735 (2020).

Incorporating Cooling- Reliability Calculation Framework



Implications on Reliability- Standard vs EPFC Design Framework



Understanding Implications on Reliability- Mathematical Preliminaries

For a smooth function $f(X_1,\dots,X_n)$ of independent random variables,

$$\mathrm{Var}[f(X)] \approx \sum_{i=1}^{n} \left(\left. \frac{\partial f}{\partial X_i} \right|_{\mu} \right)^2 \mathrm{Var}[X_i], \tag{1}$$

The Eurocode heating curve is

$$T_g(t) = T_0 + 1325\left[1 - 0.324e^{-0.2\Gamma t} - 0.204e^{-1.7\Gamma t} - 0.472e^{-19\Gamma t}\right], \tag{2}$$

with a single lumped random variable $\Gamma = [(F_v/F_{\mathrm{ref}})/(b/b_{\mathrm{ref}})]^2$.

The derivative with respect to Γ is

$$\frac{\partial T_g}{\partial \Gamma} = 1325\left[0.324(0.2t)e^{-0.2\Gamma t} + 0.204(1.7t)e^{-1.7\Gamma t} + 0.472(19t)e^{-19\Gamma t}\right]. \tag{3}$$

Applying Eq. (1) with $n = 1$ gives

$$\mathrm{Var}[T_g(t)] \approx (1325)^2\,\mathrm{Var}[\Gamma]\left[0.324(0.2t)e^{-0.2\Gamma t} + 0.204(1.7t)e^{-1.7\Gamma t} + 0.472(19t)e^{-19\Gamma t}\right]^2. \tag{4}$$

Because each term contains $e^{-c_i\Gamma t}$, the variance decays as t grows, keeping β near its target during heating.

Understanding Implications on Reliability- Mathematical Preliminaries

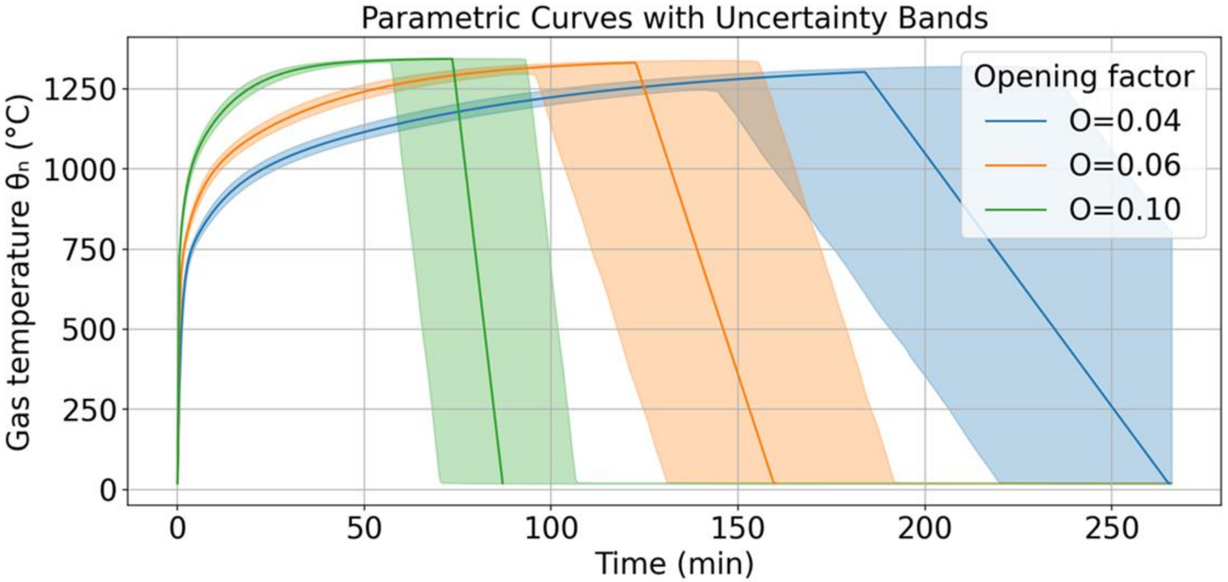
Consider

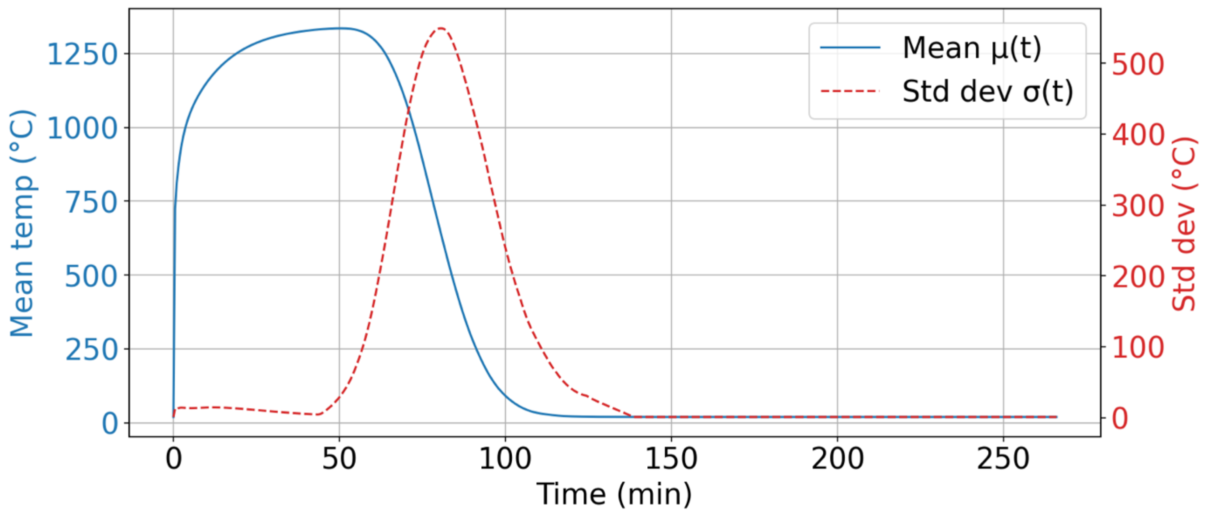
$$T(t) = T_{\text{peak}} - kt, \tag{5}$$

with independent random inputs T_{peak} and k. Partial derivatives are $\partial T/\partial T_{\text{peak}} = 1$ and $\partial T/\partial k = -t$, hence

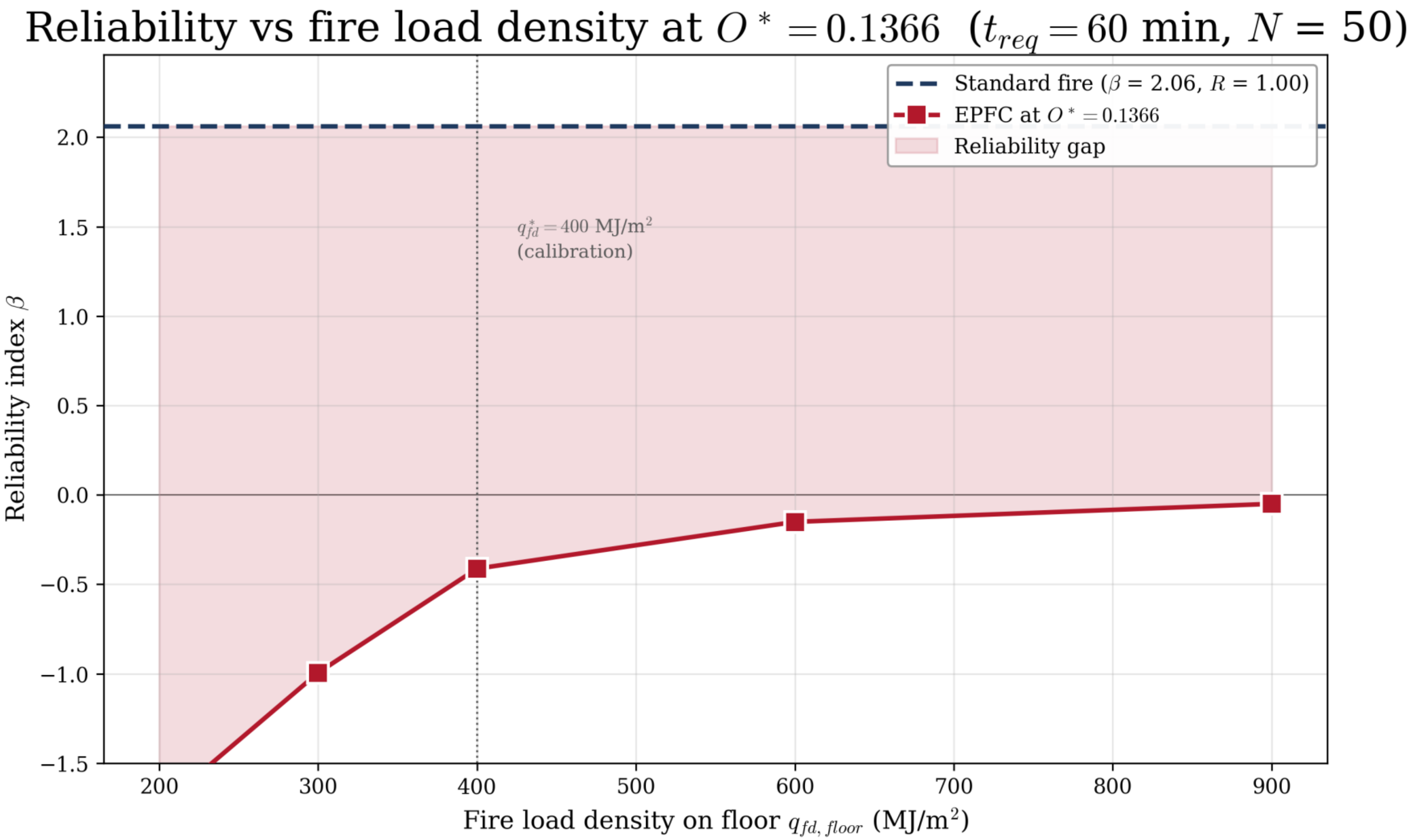
$$\text{Var}[T(t)] = \text{Var}[T_{\text{peak}}] + t^2\text{Var}[k]. \tag{6}$$

Variance grows quadratically ($\propto t^2$).

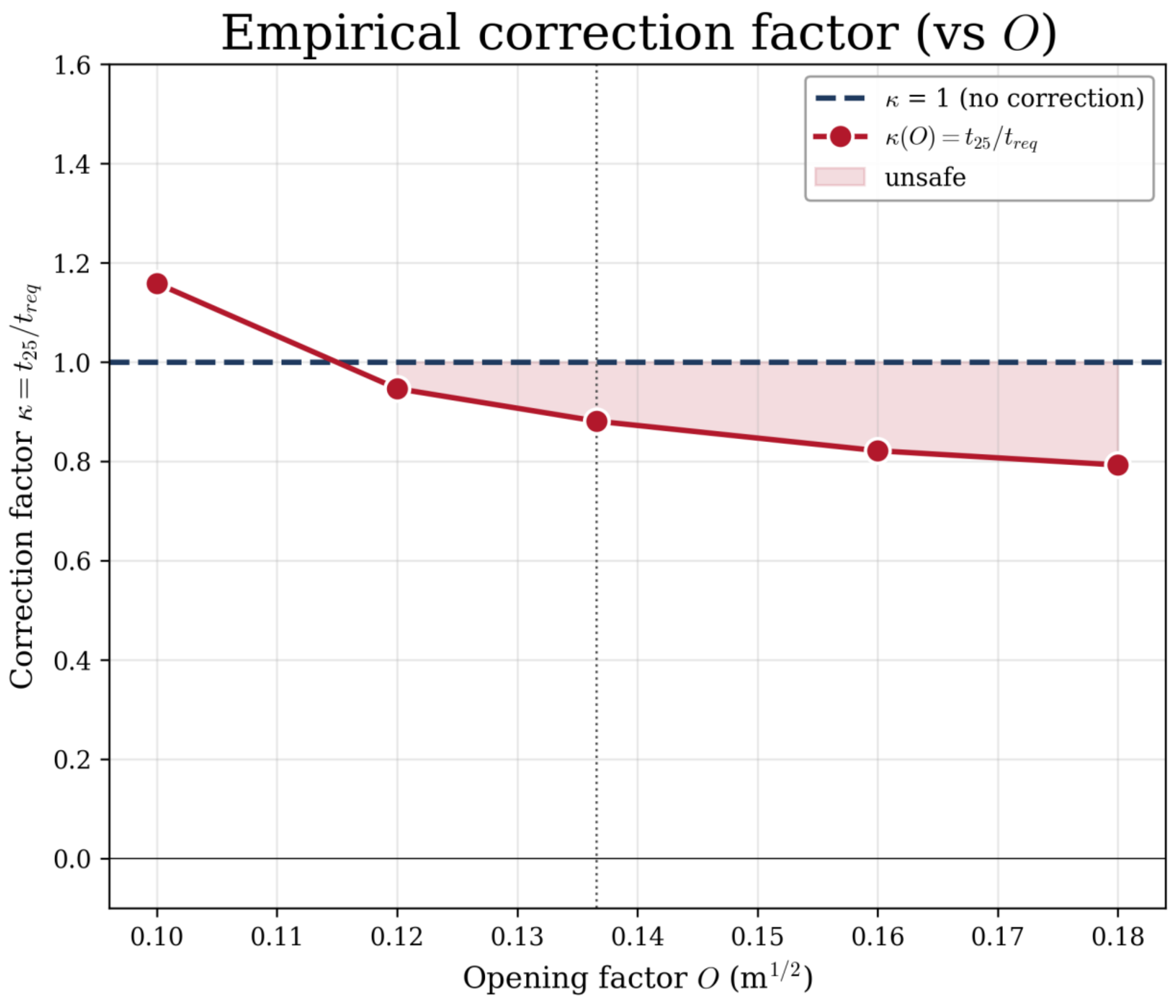


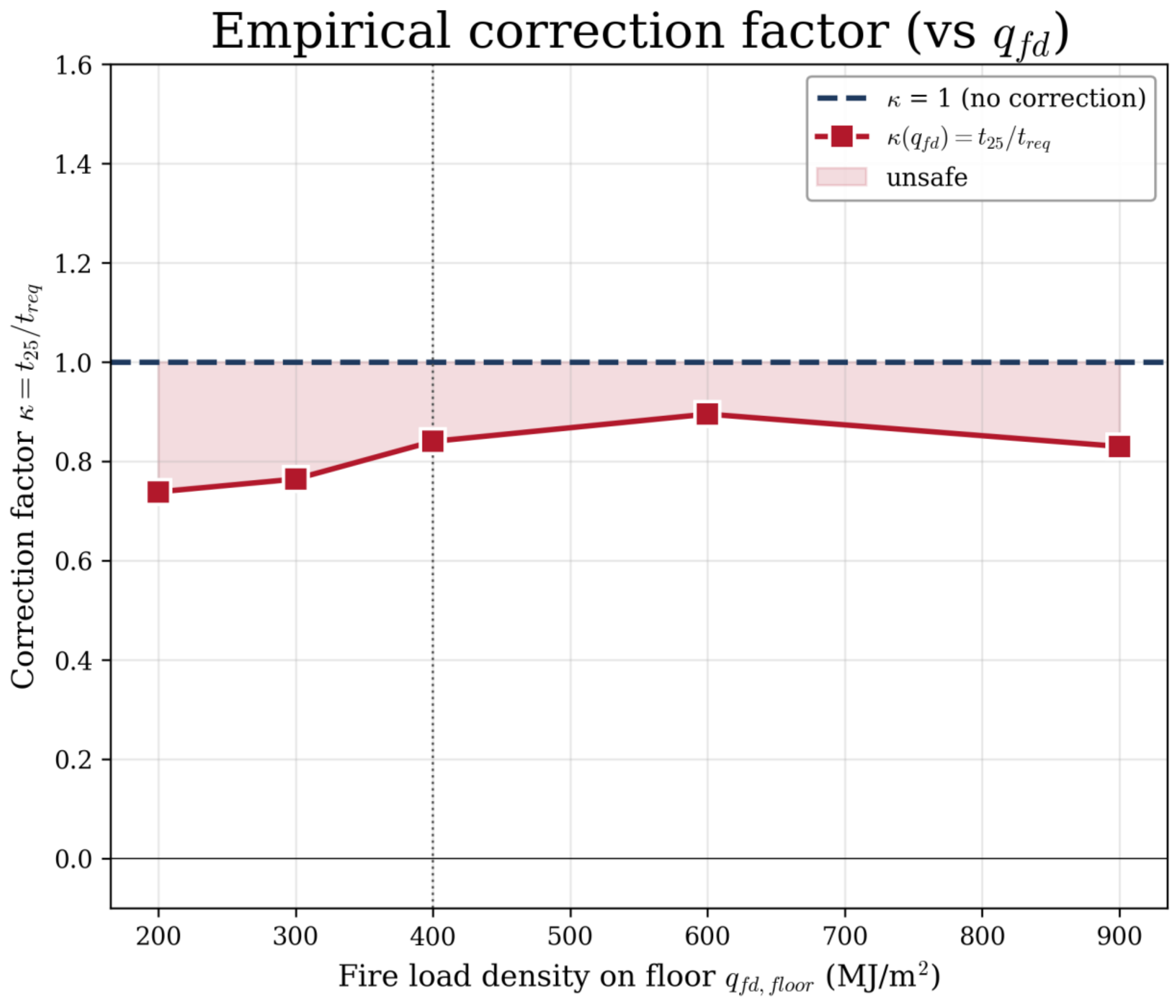


Incorporating Cooling Phase can have Adverse Impact on Reliability!



Possible Mitigation for Adverse Impact on Reliability

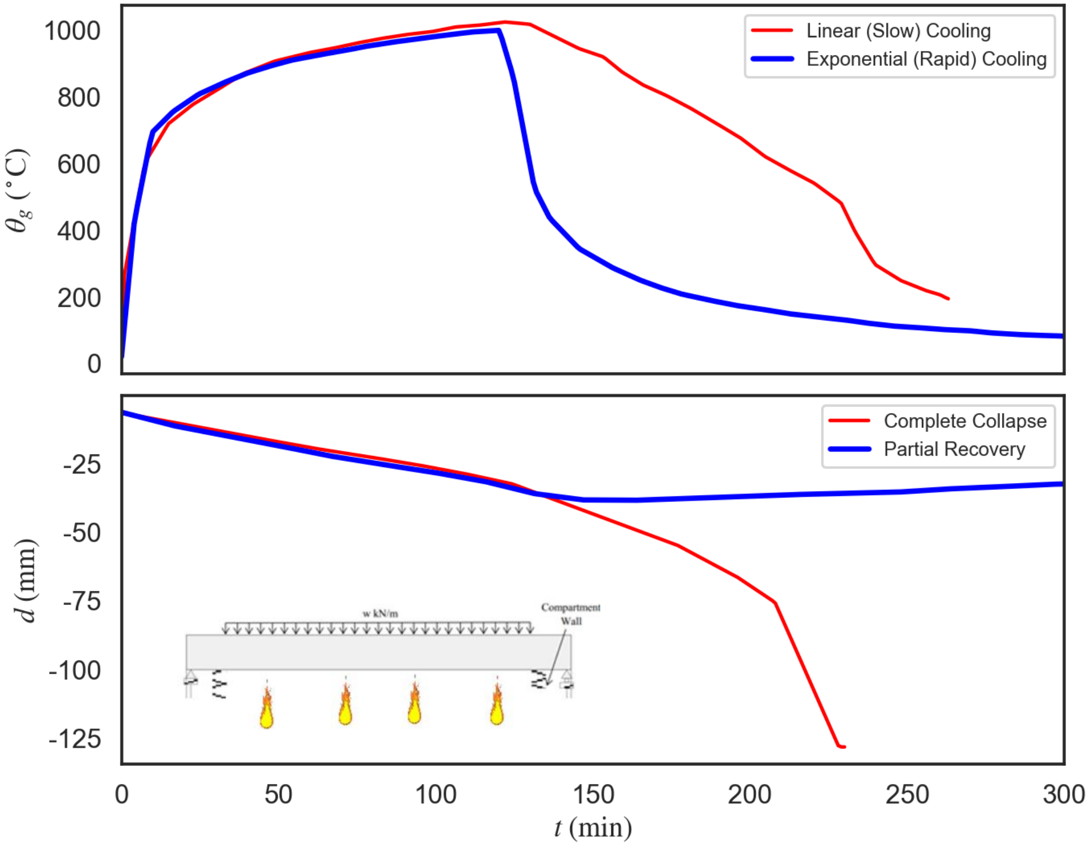


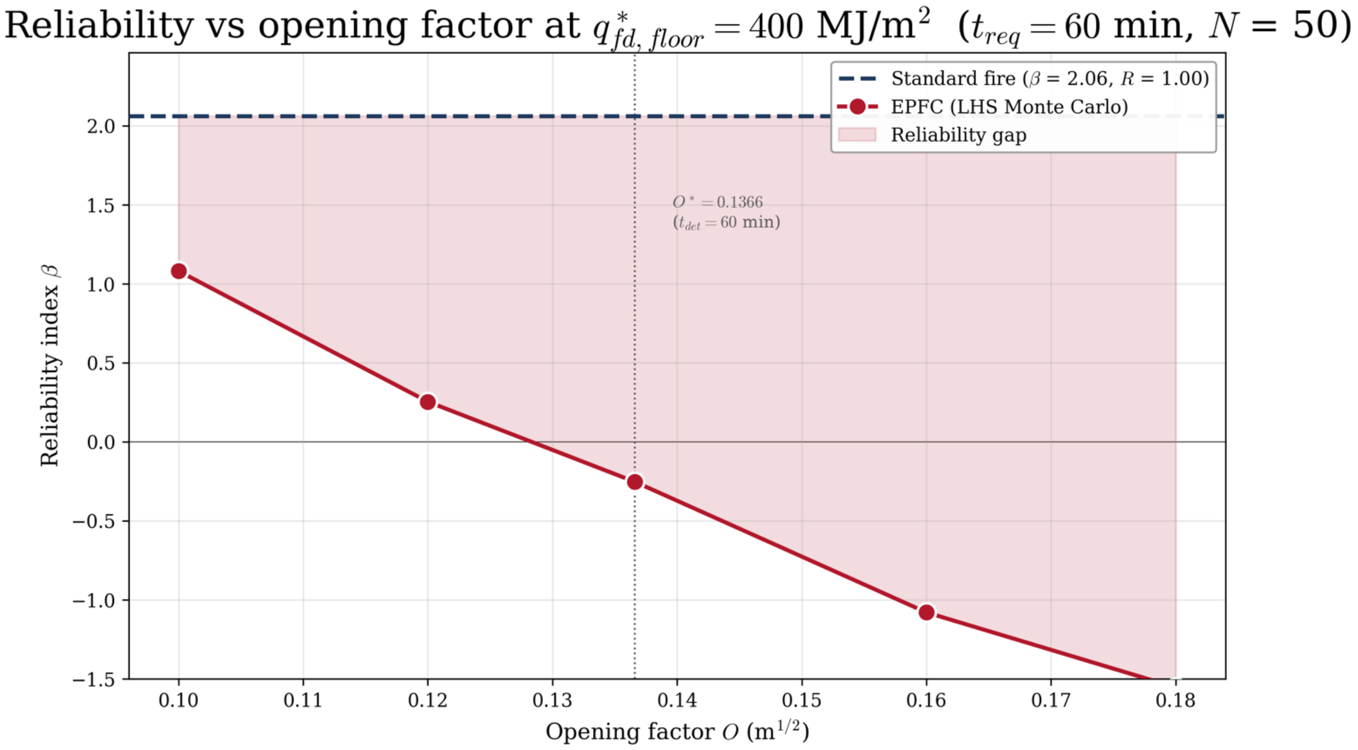


Closing Remark

Under a **common thermal limit state**, the **Eurocode parametric fire framework** yields systematically **lower reliability** than the **standard-fire framework** because it propagates **uncertainty in the fire exposure itself** rather than only in section response. The β–opening factor and β–fire load density results show that this **hidden reliability penalty grows** as the **fire becomes more severe or longer-lasting.**

Thank You for Your Time and Attention!





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