Evaluation of natural and parametric temperature-time curves for the fire design of cross-laminated wood slabs

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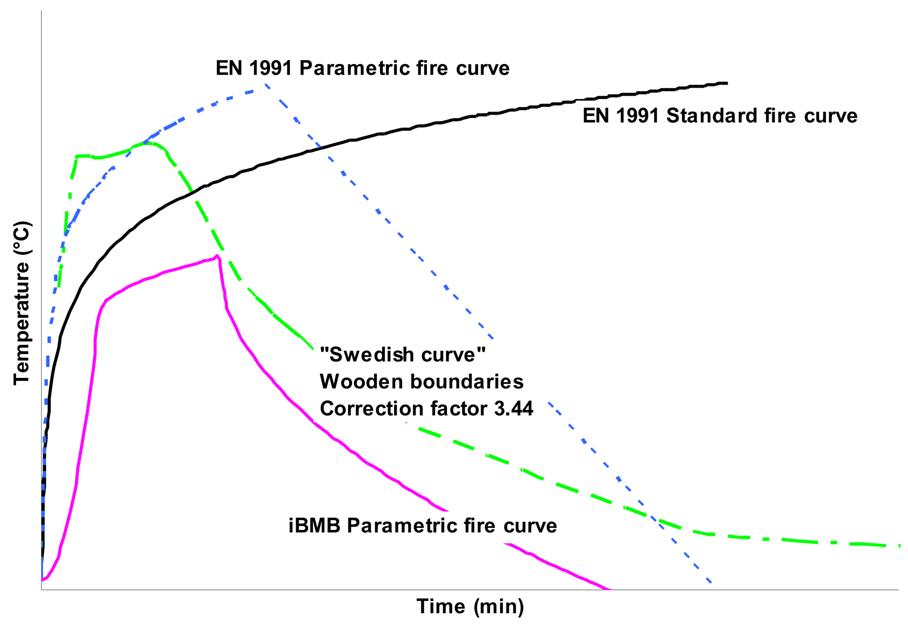
INTRODUCTION

Temperature-time curves found in the literature for complete fires, including growth stage, flashover, fully developed fire and decay stage, have been evaluated based on their ability to describe the temperature development in compartments with boundaries of cross-laminated slabs, their applicability and suitability to these types of structures. Four models for determining temperature-time curves that might be applicable to wooden structures were found and evaluated. These are the "Swedish curves", EN 1991-1-2 Standard temperature-time curve and Parametric temperature-time curve, and the iBMB curve. The figure to the right shows typical trends of the temperature-time curves. Please be aware that the curves are not in scale with each other.



THE MODELS

The chosen models have different approaches to the temperature-time curve, and they incorporate various factors.

1. The "Swedish curves" are developed based on the fire load density (MJ/m² of bounding surface area), the area and height of the ventilation openings, the thermal properties of the bounding surfaces, and the heat balance in the compartment, i.e. heat transfer through the structures bounding the enclosed space, radiation through the openings, and the replacement of combustion gases by cold air. Curves for a standard compartment A have been developed and can be multiplied with a correction factor to find the fire curves for compartments with boundaries with other thermal properties.

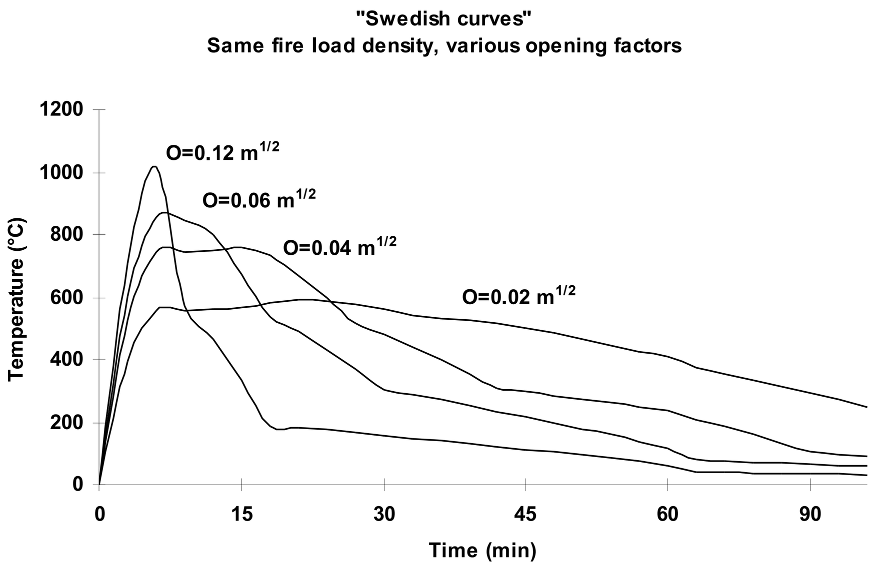
The top left figure shows how the opening factor affects the temperature development for one fixed fire load density.

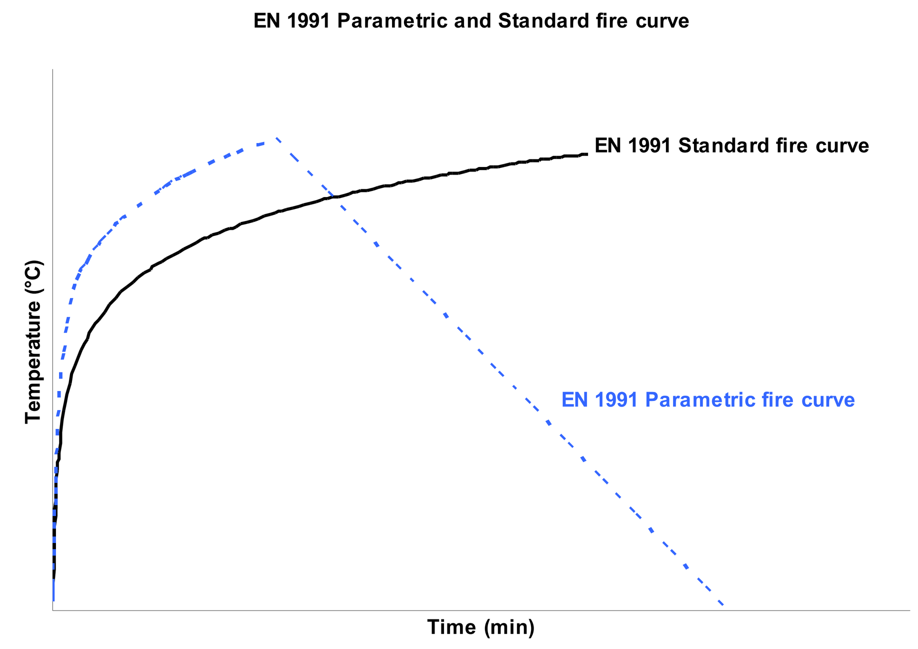
2. EN 1991-1-2 Standard temperature-time curve is constant for all materials, compartments and fire load densities, and does not have a cooling stage. However, a cooling rate of 10°C/min has been used.

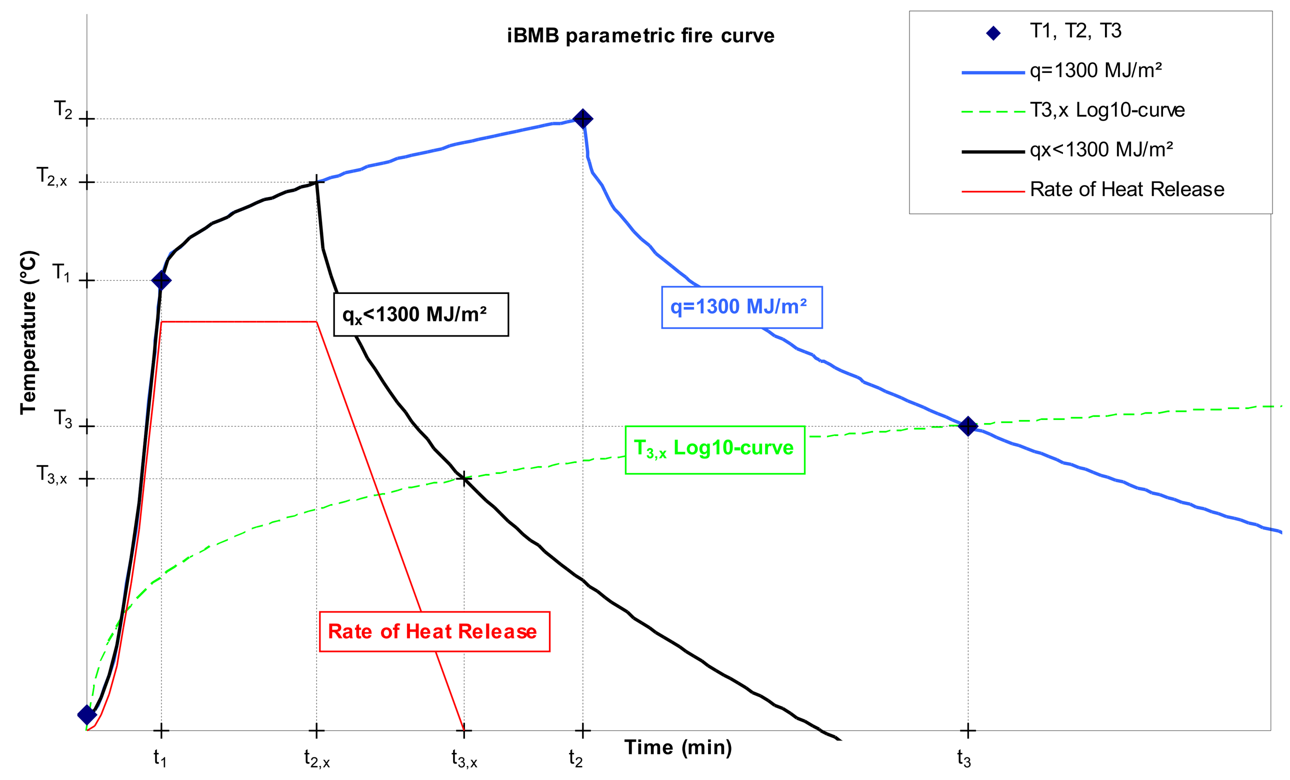
3. EN 1991-1-2 Parametric temperature-time curve. The growth stage of the curve is similar to the standard fire described above, but varies with the opening factor and thermal properties of the boundaries. The max temperature is determined by the fire load density, opening factor and the type of occupancy the compartment has, and whether the fire is fuel or ventilation controlled. The cooling stage is described by the fire load and opening factor.

4. The iBMB curve

The model considers the actual boundary conditions of the fire compartment concerning fire load, ventilation, geometry and thermal properties of the enclosure. The parametric equations were developed for a reference fire load density of q"=1300 MJ/m², as shown in the bottom figure. The shape of the curve is determined by the Rate of Heat Release.







SUMMARY

Based on the evaluation of the temperature-time curves, the following conclusions can be drawn:

1. The geometry of the compartment, and the position and size of the ventilation openings will have a great effect on the temperature, flashover and decay stage of the fire.
2. Many of the curves have growth rates much higher than real fires.
3. Linear cooling stages are not realistic. Fire curves with linear cooling stage give too fast cooling for compartments with large surfaces of exposed wooden structure.
4. None of the curves include the fire load from the structure directly. Iterations have to be made to incorporate this contribution to the fire.
5. Assumptions can be made to determine a relevant part of the structure to be part of the fire load.
6. The "Swedish curves" and the iBMB curves resemble a real fire in a compartment with exposed wooden structures most. But are the curves applicable to compartments with exposed wooden structures?
7. The EN 1991-1-2 Parametric fire curve has too many restrictions for use.

Viken Skog AS administration building
Photo: Moelven MassivTre AS

Egenes Park terrasse houses
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