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Steel components under compression and bending – Con-sistent verification for fire conditions AiF No.: 20189N/1

Summary of the research project AiF No.: 20189N/1

Fire resistance design is an important aspect for the safe and cost-efficient design of steel structures and has received increasing global attention in recent years. In addition to suitable design for fire situations, a good knowledge of the basic load-bearing behavior of steel structures in the event of fire is required, as well as verification methods which are safe, cost-efficient and at the same time easy-to-apply, especially for stability problems of bars with I/H cross-sections and hollow sections at elevated temperatures. The design of steel components at risk of fire is currently covered by EN 1993 1 2 and was largely adopted for the next generation of standardization in prEN 1993 1 2. This design format is based on normal temperature rules of the ENV version of Eurocode 3 from 1992 and uses modified member slendernesses and adapted flexural and lateral-torsional buckling curves. While for normal temperatures the stability proofs were already provided with the introduction of EN 1993 1 1 and again for the next generation of EC3 with prEN1993-1-1, no adaptation has been made for fire cases so far. Furthermore, the scope of application is defined in prEN 1993 1 1 to structural steels up to a yield strength of 700 N/mm^2. The development of regulations for the fire resistance design of components made of high-strength steels is still pending. A harmonization of the verification methods for normal temperatures and for fire situations is therefore desirable. To achieve this goal, the stability behavior at elevated temperatures was systematically analyzed, taking into account the latest research results on material behavior in fire. The evaluation of the material behavior showed that high and ultra-high strength structural steels can essentially be mapped by the formulations of prEN 1993 1 2. However, the temperature-dependent reduction of the effective yield point is underestimated and the reduction of the gradient in the elastic range is over-estimated. In addition, the end of the elastic range (proportionality limit) for higher steel grades occurs at larger strains. Numerical investigations into the influence of mechanical material properties have shown that the increased proportionality limit has a positive effect on the stability behavior of steel bars. A more differentiated material definition can therefore contribute to increased load-bearing capacities. Further experimental investigations to clearly define the material are currently the subject of research at the RUB.

Numerical simulation models were developed to investigate the stability behavior. The models were validated using both experimental results for normal temperature and numerical data from the literature for elevated temperatures. Using the simulation models, the fire behavior of steel components subjected to compression and bending stress was then systematically analyzed and comprehensive data sets on load-bearing capacity were generated.

For the stability cases of flexural buckling and lateral-torsional buckling, the influence of temperature, cross-sectional dimensions and type, steel grade and system slenderness was investigated. Existing detection methods were critically analyzed and evaluated. The developed method is based on the corresponding models at normal temperature and takes into account new reduction and interaction factors (Figure 1). A statistical evaluation proves the quality of the procedure. The application of the design proposal was presented using practical case studies. The design proposal presents a verification procedure for components at risk of stability in the event of fire. The method is consistent with the verification at normal temperatures and represents the load-bearing behavior more accurately than the methods introduced according to prEN 1993-1-2. This provides engineering practice with a uniform verification procedure for design at normal temperature and in the event of fire. This facilitates the fire resistance design of steel components, especially for SMEs.

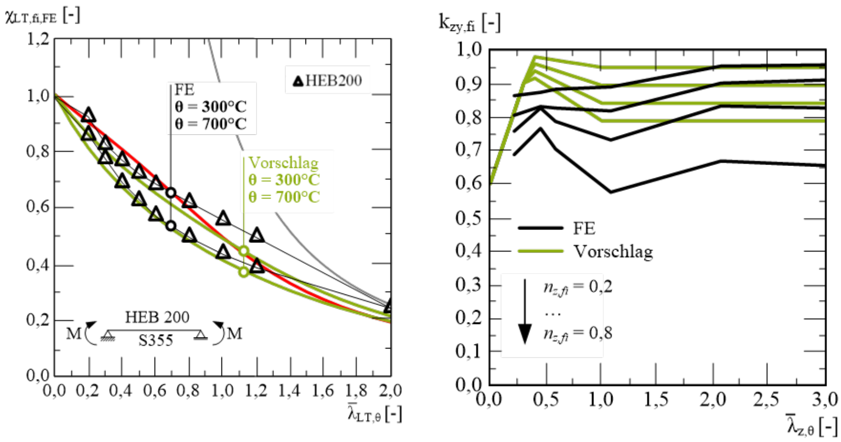

Image 1: Design proposal for reduction factors for lateral-torsional buckling xLT,fi (left) and for the interaction factor kzy,fi (right) at elevated temperatures.

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