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Numerical Investigation on Design Method of Timber Structures Exposed to Parametric Fire

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Abstract : Timber is favourable structural material due to high strength to weight ratio, recycling possibilities, and green credentials. Despite being flammable material, it has relatively high fire resistance. Everyday engineering practice around the word is based on an outdated design of timber structures considering standard fire exposure, while modern principles of performance-based design enable use of advanced non-standard fire curves. In Europe, standard for fire design of timber structures EN 1995-1-2 (Eurocode 5) gives two methods, reduced material properties method and reduced cross-section method. In the latter, fire resistance of structural elements depends on the effective cross-section that is a residual cross-section of uncharred timber reduced additionally by so called zero strength layer. In case of standard fire exposure, Eurocode 5 gives a fixed value of zero strength layer, i.e. 7 mm, while for non-standard parametric fires no additional comments or recommendations for zero strength layer are given. Thus designers often implement adopted 7 mm rule also for parametric fire exposure. Since the latest scientific evidence suggests that proposed value of zero strength layer can be on unsafe side for standard fire exposure, its use in the case of a parametric fire is also highly questionable and more numerical and experimental research in this field is needed. Therefore, the purpose of the presented study is to use advanced calculation methods to investigate the thickness of zero strength layer and parametric charring rates used in effective cross-section method in case of parametric fire. Parametric studies are carried out on a simple solid timber beam that is exposed to a larger number of parametric fire curves Zero strength layer and charring rates are determined based on the numerical simulations which are performed by the recently developed advanced two step computational model. The first step comprises of hygro-thermal model which predicts the temperature, moisture and char depth development and takes into account different initial moisture states of timber. In the second step, the response of timber beam simultaneously exposed to mechanical and fire load is determined. The mechanical model is based on the Reissner’s kinematically exact beam model and accounts for the membrane, shear and flexural deformations of the beam. Further on, material non-linear and temperature dependent behaviour is considered. In the two step model, the char front temperature is, according to Eurocode 5, assumed to have a fixed temperature of around 300°C. Based on performed study and observations, improved levels of charring rates and new thickness of zero strength layer in case of parametric fires are determined. Thus, the reduced cross section method is substantially improved to offer practical recommendations for designing fire resistance of timber structures. Furthermore, correlations between zero strength layer thickness and key input parameters of the parametric fire curve (for instance, opening factor, fire load, etc.) are given, representing a guideline for a more detailed numerical and also experimental research in the future.

Keywords : advanced numerical modelling, parametric fire exposure, timber structures, zero strength layer
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