Abstract

Every engineering calculation is an approximation of reality, with inevitable uncertainties involved. This fact implies that a reliability verification accounting for the uncertainties is a necessary step in the design and assessment of structures. Nowadays, probability-based partial safety factor format is widely adopted in the structural reliability verification in design codes. The safety format calibration is a continuing updating process with the advancements of knowledge in structural engineering.

For reinforced concrete structures, open questions for the safety format calibration emerge with the increasing application of advanced nonlinear structural resistance analysis approaches (e.g. strain-based approaches and numerical methods like the NonLinear Finite Element Analysis) as well as the application of new materials. Aiming at meeting these new challenges, several topics within the partial safety factor format framework are investigated.

In the first part of this work, the simplifications and assumptions in the classical partial safety factor format for the resistance of reinforced concrete structures are examined. Their suitability for the implicit nonlinear analysis models is investigated focusing on the influence of multiple failure modes. Reliability analysis case studies at different scales (cross-sectional resistance or load-bearing capacity of structural elements and of simple structural systems) show that the partial safety factors applied to material strength variables leads to a satisfactory level of reliability, independent of the development of different failure modes induced by material uncertainties.

In the second part of this work, the characteristic of the model uncertainties of strain-based approaches is investigated using the punching shear resistance model based on the Critical Shear Crack Theory (CSCT) as an example. It is shown that the model uncertainty of global resistance solution of strain-based approach can be viewed as the resultant of the model uncertainties of the sub-models. In addition, the model uncertainty of the global resistance solution can be lower than those of the sub-models, depending on their sensitivity relationship. Based on these observations, different types of partial safety formats for strain-based approaches are compared. The relationship between the safety factors of the punching shear provisions in the second generation of Eurocode 2 for the design of new structures and the assessment of existing critical ones is established.

The last part of this work deals with the partial safety factor format calibration problem for structures with brittle response. As an example, the partial safety format for the flexural resistance of Textile Reinforced Concrete (TRC) is calibrated focusing on the model uncertainties of action effect for brittle systems.

Based on these works, it is concluded that a suitable probabilistic modelling of the basic uncertainties is fundamental for the effective calibration of the partial safety format and it should be based on a good understanding of the relevant load bearing mechanisms. On its basis, a

detailed safety format composed of calibrated partial safety factors for the dominating uncertainties is an effective reliability verification approach for both classical analytical design equations and advanced nonlinear analysis methods.

Keywords: reinforced concrete structures, reliability analysis, partial safety factor format, exponent sensitivity analysis, nonlinear analysis, multiple failure modes, strain-based approach, model uncertainty quantification, Bayesian inference, brittle systems, Textile Reinforced Concrete.