DESIGN OF FIBRE REINFORCED CONCRETE STRUCTURES BASED ON NONLINEAR ANALYSIS

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Abstract

The nonlinear finite element analysis can be utilized not only in research but also in the practical design of fibre reinforced concrete (FRC) structures. Behaviour of the structure under service or ultimate loading conditions can be realistically simulated using advanced computer methods. Special constitutive material models were developed for description of fracture of FRC-material in the nonlinear finite element analysis. Crack development, load carrying capacity and post-critical behaviour of engineering structures can be traced and analyzed. The nonlinear fracture analysis accounting tensile capacity of material enables to exploit reserves, which are usually neglected or diminished in codes or in linear analysis, and helps in cases which are not sufficiently supported by the codes. Recently proposed advanced design methods based on the global safety concept, utilizing a newly developed ECOV-Method, stochastic LHS nonlinear analysis and structural reliability assessment of FRC structures are discussed. Practical examples of nonlinear analysis of engineering structures made from the FRC are presented.

Keywords: nonlinear analysis, structural design, fibre reinforced concrete, cracks, global safety concept

The nonlinear finite element simulation is recently a well-established approach for analysis of reinforced concrete structures. Behaviour and properties of fibre reinforced concrete (FRC) differ to a large extent from normal concrete. The tensile strength and especially the fracture energy are substantially larger and the form of the tensile constitutive law is different. Therefore, special material models at macroscopic level are needed for modelling of FRC-material in the numerical simulation of FRC-based structures.

Global format for structural safety should be used in combination with the nonlinear analysis in structural design. Structural resistance can be evaluated e.g. using ECOV method, which estimates coefficient of variation for structural resistance from several deterministic nonlinear calculations. The resulting design resistance can be used for checking of structural safety analogically with existing code procedures. The most general tool for evaluation of structural reliability and safety is application of fully probabilistic analysis based on stratified LHS random sampling. All the described methods, procedures and tools are of significant importance in design of fibre reinforced structures.

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Practical examples of nonlinear analysis of engineering structures made from the FRC – railroad plates and pre-cast tunnel segments – are presented.

Fig. 1: Crack patterns in railroad plates at peak load, left: RC plate, max. crack width 0.12 mm, right: FRC plate, right: max. crack width 0.06 mm

Conclusions

In the fibre reinforced concrete the tensile behaviour is dominating. For that reason the potential profit from the nonlinear analysis of FRC-based structures is much higher than in standard reinforced concrete structures. Therefore, advanced material models for numerical simulation of fibre reinforced concrete were developed. Sophisticated techniques for accounting uncertainties and randomness are available. The described methodology is implemented into integrated software tools for nonlinear analysis of FRC-based structures, which can be utilized in practice. Recently proposed advanced design methods based on the global safety concept, utilization a newly developed ECOV-Method, stochastic LHS nonlinear analysis and structural reliability assessment supports using the nonlinear analysis in design of fibre reinforced structures.

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References


