Chapter 18
Structural Non-Linear Models and Simulation Techniques: An Efficient Combination for Safety Evaluation of RC Structures

Jorge M. Delgado
Polythecnic Institute of Viana do Castelo, Portugal

Antonio Abel R. Henriques
Faculty of Engineering, University of Porto, Portugal

Raimundo M. Delgado
Faculty of Engineering, University of Porto, Portugal

ABSTRACT

Advances in computer technology allow nowadays the use of powerful computational models to describe the non-linear structural behavior of reinforced concrete (RC) structures. However their utilization for structural analysis and design is not so easy to be combined with the partial safety factors criteria presented in civil engineering international codes. Trying to minimize this type of difficulties, it is proposed a method for safety verification of RC structures based on a probabilistic approach. This method consists in the application of non-linear structural numerical models and simulation methods. In order to reduce computational time consuming the Latin Hypercube sampling method was adopted, providing a constrained sampling scheme instead of general random sampling like Monte Carlo method. The proposed methodology permits to calculate the probability of failure of RC structures, to evaluate the accuracy of any design criteria and, in particular, the accuracy of simplified structural design rules, like those proposed in civil engineering codes.

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INTRODUCTION

The behavior of reinforced concrete (RC) structures is characterized by a non-linear response, but the international codes allow simplified procedures based on linear structural analyses for the design of this type of structures. However, advances in computer technology enable the use of powerful computational models in order to describe the non-linear behavior of RC structures. These models can greatly contribute to a more accurate design. Despite that fact, the combination between the procedure based on the application of partial safety factors and the use of material and geometrical non-linear structural models is not so easily achieved.

International codes (EC2 - Eurocode 2, Model Code 2010, *fib* (2010)) introduced some simplified rules that allow the application of non-linear numerical models in the design of RC structures. Nevertheless, it is commonly accepted that more precise and coherent methodologies must be developed in order to achieve more reliable and accurate results through these complex computational structural models.

Several methodologies have already been proposed in an attempt to address this type of problems, including different levels of simplifications and different fields of application. To better understand these different approaches, this chapter begins with a general overview of the fundamentals on structural safety of RC structures.

One of the most common strategies for structural safety evaluation is the application of first-order and second-order reliability methods (FORM/SORM). However, these methods are only easily applied when an analytical definition of the limit state function is available. A common alternative to achieve good results in complex non-explicit formulations, like the non-linear numerical models, is the use of simulation methods. This strategy was adopted to develop a methodology that was used to estimate the probabilities of failure in RC structures, presented in this Chapter. Once the main variable distribution functions are defined, this method allows simulating the real structural behavior and evaluating a global probability of failure.

Generally, the application of simulation methods combined with non-linear analysis procedures requires a large computational capacity in order to avoid an excessive consumption of time. In order to enhance efficiency and minimize the computational time consumption, an efficient simulation technique based on the Latin Hypercube Sampling procedure was combined with a non-linear numerical model. The Latin Hypercube Sampling is a simulation technique that provides a constrained sampling scheme instead of a general random sampling, like the Monte Carlo Method, and its main advantage is that it requires a low number of simulations, when compared to other general simulation methods. A sensitivity analysis is also performed through the application of a multi-linear regression approach and the correlation coefficients obtained from the regression analysis are measures of the structural response sensitivity for each basic random variable. The “Curve-Fitting” technique is used to establish a theoretical probability distribution function of failure and to estimate the structural safety level.

Using non-linear complex models and a simulation method, the proposed methodology enables the calculation of the probability of failure of reinforced concrete structures and can be used as an instrument to evaluate the accuracy and efficiency of simplified structural design rules, like those proposed in civil engineering codes. Finalizing this chapter, a set of ideas for new developments in this field will be presented, in order to identify some precise and applicable strategies for structural non-linear design and reliability analysis.