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Uncertainty Quantification of Crack Widths and Crack Spacing in Reinforced Concrete

Authors : Marcel Meinhardt, Manfred Keuser, Thomas Braml

Abstract : Cracking of reinforced concrete is a complex phenomenon induced by direct loads or restraints affecting reinforced concrete structures as soon as the tensile strength of the concrete is exceeded. Hence it is important to predict where cracks will be located and how they will propagate. The bond theory and the crack formulas in the actual design codes, for example, DIN EN 1992-1-1, are all based on the assumption that the reinforcement bars are embedded in homogeneous concrete without taking into account the influence of transverse reinforcement and the real stress situation. However, it can often be observed that real structures such as walls, slabs or beams show a crack spacing that is orientated to the transverse reinforcement bars or to the stirrups. In most Finite Element Analysis studies, the smeared crack approach is used for crack prediction. The disadvantage of this model is that the typical strain localization of a crack on element level can't be seen. The crack propagation in concrete is a discontinuous process characterized by different factors such as the initial random distribution of defects or the scatter of material properties. Such behavior presupposes the elaboration of adequate models and methods of simulation because traditional mechanical approaches deal mainly with average material parameters. This paper concerned with the modelling of the initiation and the propagation of cracks in reinforced concrete structures considering the influence of transverse reinforcement and the real stress distribution in reinforced concrete (R/C) beams/plates in bending action. Therefore, a parameter study was carried out to investigate: (I) the influence of the transversal reinforcement to the stress distribution in concrete in bending mode and (II) the crack initiation in dependence of the diameter and distance of the transversal reinforcement to each other. The numerical investigations on the crack initiation and propagation were carried out with a 2D reinforced concrete structure subjected to quasi static loading and given boundary conditions. To model the uncertainty in the tensile strength of concrete in the Finite Element Analysis correlated normally and lognormally distributed random filed with different correlation lengths were generated. The paper also presents and discuss different methods to generate random fields, e.g. the Covariance Matrix Decomposition Method. For all computations, a plastic constitutive law with softening was used to model the crack initiation and the damage of the concrete in tension. It was found that the distributions of crack spacing and crack widths are highly dependent of the used random field. These distributions are validated to experimental studies on R/C panels which were carried out at the Laboratory for Structural Engineering at the University of the German Armed Forces in Munich. Also, a recommendation for parameters of the random field for realistic modelling the uncertainty of the tensile strength is given. The aim of this research was to show a method in which the localization of strains and cracks as well as the influence of transverse reinforcement on the crack initiation and propagation in Finite Element Analysis can be seen.

Keywords : crack initiation, crack modelling, crack propagation, cracks, numerical simulation, random fields, reinforced concrete, stochastic
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