8th. World Congress on Computational Mechanics (WCCM8)
5th. European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 – July 5, 2008
Venice, Italy

PROBABILISTIC LIFE-CYCLE OPTIMIZATION OF CONCRETE STRUCTURES

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Key Words: *Concrete Structures, Damage, Diffusion, Life-Cycle Performance, Probabilistic Optimization.*

ABSTRACT

Life-cycle performance of concrete structures under attack of aggressive environmental agents is generally investigated through the study of the local deterioration of materials, and design for durability with respect to chemical-physical damage phenomena is based on simple criteria associated with prescribed environmental conditions. However, due to the interaction between damage process and structural behavior, a durable design cannot be based only on such indirect evaluations of the effects of structural damage, but needs to take into account the global effects of the local damage on the overall performance of the structure. In fact, the global effects of the local damage may significantly depend on structural aspects associated with design variables related for example to the geometry of the cross-sections and the reinforcement layout. In addition, a design for durability should consider the role played by the unavoidable uncertainty affecting the main parameters of both diffusive and damage processes.

Based on these premises, a probabilistic approach to life-cycle optimal design of concrete structures in aggressive environments is presented. First, a systematic approach to optimal limit state design of concrete cross-sections is described [1]. Design variables include either the shape and dimensions of the concrete cross-sections, or the amount and location of the reinforcement. Design constraints are directly applied on such variables accounting for both serviceability and ultimate limit conditions. In particular, the design constraints are evaluated over time by using a general procedure for life-cycle analysis of concrete structures in aggressive environments [2], [3]. In this procedure the diffusion process of the aggressive agents is modeled by using cellular automata and the mechanical damage coupled to diffusion is evaluated by introducing proper material degradation laws. The design constraints are then associated with a prescribed target of structural reliability and, based on a probabilistic model, evaluated by means of a Monte Carlo simulation. The high computational cost associated with the multiple simulation processes is reduced by a proper selection of the design constraints that are found to be of crucial importance in finding the optimal solution.

The objective of the design process is to minimize the lifetime cost of the system under side, behavioral, and other constraints. Since concrete dimensions and location of the reinforcement are usually required as discrete quantities, and the reinforcing bars are manufactured in standard sizes, the optimization problem should be formulated by assuming the design variables as discrete values. Having stated the problem in such a way, a genetic algorithm approach is selected as an efficient and robust search method. The effectiveness of the proposed approach is proven through applications.

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