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Multi-scale reliability analysis of composite structures – Application to the Laroin footbridge

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ABSTRACT

This work aims at developing a new methodology for the reliability assessment of composite structures and their design optimization. It relies on the coupling of well established methods: homogenization scheme for the mechanical modelling of composite materials and reliability methods to account for their inherent variability. Moreover, such approach is based on an accurate treatment of inherent uncertainties of these mechanical systems at various scales, including microscopic and macroscopic levels, that provides new perspectives for structural design. As an illustration, we propose to apply the multi-scale reliability analysis on the case of the Laroin footbridge (France) with carbon–epoxy stay cables. Since the reliability assessment of such structure is evaluated through the fibre failure, numerical simulations require the coupling of reliability methods, finite element modelling to derive macroscopic loading within cables and micromechanics to estimate the effective elastic properties of composite and local responses within constituents. Results demonstrate the feasibility of the coupled approach at a structure scale and its main interests for the optimization phase of materials and engineering structures.

1. Introduction

Applications of fibre-reinforced composite materials were initially associated for the most part to aerospace and marine industries. Actually, their outstanding mechanical properties made them very attractive to many engineering contexts by providing new design perspectives [1]. Yet, important safety factors are still introduced to cover the important scatter of their mechanical properties, which could lead obviously to a major increase in the structure dimensions.

In this way, the recent development of structural reliability analyses has allowed significant progress: for the composite structures design first, by providing the range of use to achieve a specified reliability level and also, for the risk control by giving the security level of existing structures [2,3]. On the other hand, the specific mechanical response of heterogeneous materials has been widely explained by its microscopic features (properties of the constituents, phase geometry) [4]. In order to explain and analyze the influence of such aspects, micromechanics offer the most appropriate framework for the composite mechanical modelling since representations derive from the description of materials microstructure and from the physical mechanisms involved at their micro scale [5,6].

The present contribution aims at associating reliability methods and micromechanical modelling in view of the design and optimization of composite structures. In order to represent scattering aspects introduced at the different scales of the structure, we integrate as random design variables both microscopic parameters of the composite material (constituents

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