World Academy of Science, Engineering and Technology
International Journal of Structural and Construction Engineering
Vol:12, No:10, 2018

Statistical Correlation between Ply Mechanical Properties of Composite and Its Effect on Structure Reliability

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Abstract : Due to the large uncertainty on the mechanical properties of FRP (fibre reinforced plastic), the reliability evaluation of FRP structures are currently receiving much attention in industry. However, possible statistical correlation between ply mechanical properties has been so far overlooked, and they are mostly assumed to be independent random variables. In this study, the statistical correlation between ply mechanical properties of uni-directional and plain weave composite is firstly analyzed by a combination of Monte-Carlo simulation and finite element modeling of the FRP unit cell. Large linear correlation coefficients between the in-plane mechanical properties are observed, and the correlation coefficients are heavily dependent on the uncertainty of the fibre volume ratio. It is also observed that the correlation coefficients related to Poisson's ratio are negative while others are positive. To experimentally achieve the statistical correlation coefficients between in-plane mechanical properties of FRP, all concerned in-plane mechanical properties of the same specimen needs to be known. In-plane shear modulus of FRP is experimentally derived by the approach suggested in the ASTM standard D5379M. Tensile tests are conducted using the same specimens used for the shear test, and due to non-uniform tensile deformation a modification factor is derived by a finite element modeling. Digital image correlation is adopted to characterize the specimen non-uniform deformation. The preliminary experimental results show a good agreement with the numerical analysis on the statistical correlation. Then, failure probability of laminate plates is calculated in cases considering and not considering the statistical correlation, using the Monte-Carlo and Markov Chain Monte-Carlo methods, respectively. The results highlight the importance of accounting for the statistical correlation between ply mechanical properties to achieve accurate failure probability of laminate plates. Furthermore, it is found that for the multi-layer laminate plate, the statistical correlation between the ply elastic properties significantly affects the laminate reliability while the effect of statistical correlation between the ply strength is minimal.

Keywords : failure probability, FRP, reliability, statistical correlation
Conference Title : ICSECM 2018 : International Conference on Structural Engineering and Composite Materials
Conference Location : Sydney, Australia
Conference Dates : October 04-05, 2018