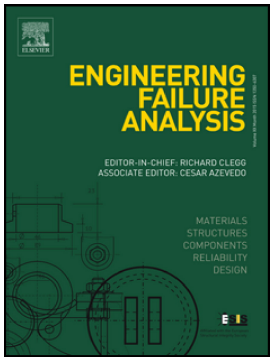

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Structural failure investigations through probabilistic nonlinear finite element analysis: Methodology and application

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Abstract

Structural failure investigations can be strongly influenced by high levels of uncertainty in modelling parameters, particularly in the case of historical constructions. This suggests forensic analysts to perform probabilistic simulations, allowing a risk-informed diagnosis and prognosis of structural failures. In this study, a failure investigation methodology including uncertainty characterisation, modelling and propagation is presented and applied to a historic piperno stone balcony, the collapse of which caused four casualties. High uncertainty in physical and mechanical properties of piperno stone, which has been widely used for a long time in the architectural heritage of Naples and Southern Italy, motivated stochastic finite element (SFE) simulations to account for spatial variability of material properties throughout the balcony. Based on field inspections, laboratory surveys and experimental testing, a three-dimensional finite element (FE) model with four alternative restraint conditions was developed and material properties were statistically characterised. Experimental data were found to be in agreement with those available in the literature for similar piperno stones. Deterministic nonlinear FE simulations with mean material properties showed a major influence of restraint conditions, providing an initial identification of the most realistic model that was able to reproduce the observed damage. Then, SFE simulations were performed on structural models having random fields of material properties. It is shown that the selected SFE model of the balcony had a mean load capacity very close to the total load expected at the time of collapse, allowing the lowest uncertainty level in the output of forensic analysis.

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