Abstract

Blast-induced ground vibrations (BIGV) in open-cast mining regions pose significant risks to the safety and stability of nearby structures. Most existing studies and regulatory guidelines rely on empirical approaches that lack the precision and adaptability of advanced numerical methods and tend to ignore important building parameters such as aspect ratio and loading direction. To address these gaps, this study proposes a performance-based framework that explicitly incorporates structural geometry and loading direction to evaluate the vulnerability of unreinforced masonry (URM) walls and reinforced concrete (RC) frame structures under realistic BIGV scenarios. Nonlinear finite element modelling was performed in ABAQUS CAE, comprising 1120 nonlinear dynamic simulations under both in-plane and out-of-plane blast excitations. Incremental dynamic analysis (IDA) was used to establish displacement-based damage thresholds, and direction specific fragility curves were developed. ANCOVA (analysis of covariance) was performed to assess the significance of influencing variables and their interaction effects across different wall geometries and loading directions. Results indicate strong statistical correlations between construction type, aspect ratio, excitation frequency, and resulting displacement and damage behaviour. At peak particle velocities (PPV) within the national statutory body's operational limit (≤50 mm/s), squat URM walls remained undamaged across all tested frequencies. Robustly detailed RC walls also showed no damage across the range of conditions, while slender or under reinforced walls approached or exceeded damage thresholds, particularly under out-of-plane loading even at lower PPVs. The findings underscore the need to account for geometry and directionality in BIGV safety assessments and support the revision of existing guidelines issued by the statutory body. Design recommendations to improve structural resilience in mining zones are presented. Recommendations for design modifications to improve structural performance in mining zones are proposed.