Probabilistic demand models and reliability based code calibration for reinforced concrete column and beam subjected to blast loading

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A B S T R A C T

Performance-based probabilistic demand models for reinforced concrete (RC) columns and beams have been estimated due to ongoing blast loading attacks on structures and inadequate design codes. The unknown model parameters are evaluated using the Bayesian approach. The required reliable data is generated using LS-DYNA numerical experimental design with the Arbitrary Lagrangian-Eulerian (ALE) method. This numerical method is based on finite element (FE) analysis, and all realistic material and geometrical variables are exposed to different combinations of detonation mass and stand-off distance. These developed probabilistic models are based on the deflection-based mechanical equation from the UFC 3-340-02 code and dimensionless correction terms. A comparison study with experimentation and fragility analysis demonstrates the efficiency of the models. Due to the inadequacy of existing Load and Resistance Factors for Design (LRFD) which are usually ‘1.0’ in available codes, the current study developed new LRFD factors for chosen performance levels based on probabilistic capacity and demand models. Furthermore, hazard curves for mass and standoff distance are evaluated to determine the dataset’s distribution. Grounded on these curves the total probability of failure for an RC column constructed at the Supreme Court of India (an important building) has analysed and obtained results are promising.

1. Introduction

Structures are generally designed for specific loading conditions based on their function and geographical location. Extreme load cases, such as shocks, impact, blast, and impact-induced blast, are unaffected by utility or geography. It has been observed in recent decades in the acceleration of intentional attacks by terrorist groups/nations and unintentional attacks on structures in several countries [1]. Blast loading happenings on constructions have increased abruptly in recent years across the sphere. South Asia nations accounted for nearly one-third of all terrorist activities in 2017 [2]. The occurrence of blasts has a significant impact on all aspects of life [3]. Similarly, these misfortunes caused by blast loadings may result in irreversible mutilation of structures and loss of manhood/habitations [4,5]. Columns, decks, and other structural members of the Yichang bridge (China) collapsed in 2013 as a result of a fire work truck explosion [6]. In India, 1993 Mumbai blasts damaged several structures due to blast loading. Based on these previous disasters, reinforced concrete (RC) columns and beams of pyrotechnics facilities, laboratories, bridge columns/decks, parking lot columns, aircraft shelters, storage tanks, and other structures may prone to blast events. Such tragic measures can occur as a result of nuclear/conventional missiles, truck detonations, or the backfire of explosive materials in storage shelters, etc.

Numerous methods have been used to model RC members that have been subjected to blast loadings. Analytical studies of Timoshenko RC beams show the importance of strain rate effects [7]. Blast loading produces higher strain rates than earthquake and impact loadings, ranging from 10−2 to 104 per second [8,9] created a performance-based design for bridges subjected to detonation, demonstrating that one-order single degree of freedom (SDF) assessment could not offer reliable security due to not consideration of higher-order failure modes. Introducing too many degrees of freedom can improve the accuracy of the model. Ref. [10] introduced a single-degree-of-freedom Blast Effects Design Spreadsheet (SBEDS) as an SDOF analysis tool for component behaviour due to blast. Because of the complex dynamic mechanism of blast load, analytical studies are not very accurate in producing notable responses. Damage pattern, spallation, scabbing, deflection, energy absorption, and resistance are the predominant quantity of interests of the