Comparative evaluation of empirical and regression-based models for predicting blast-induced ground vibrations in Indian coal surface mines

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Blasting is the most economical rock fragmentation method in surface mining, but the resulting ground vibrations pose safety and environmental challenges, requiring reliable predictions of peak particle velocity (PPV). The present study evaluates empirical and regression-based models for predicting blast-induced ground vibration in coal surface mines. Widely used empirical predictors, including the United States Bureau of Mines, Ambraseys–Hendron, Indian Standard Predictor, and Langefors–Kihlström equations, were evaluated using field-monitored vibration data. Regression models for site-specific and multi-mine purposes were developed using key blast parameters, including the maximum cooperating charge per delay (Q_{max}) and the total mass of charge per round (Q_T). The Ambraseys–Hendron model showed superior predictive performance, with higher coefficients of determination (R^2) at the Jarangdih (0.714), Joyrampur (0.728), and Bokaro (0.788) mines, and consistent accuracy for total charge per round across multi-mine conditions. Using this model and industry-prescribed PPV limits (5–15 mm/s), the maximum allowable charge per delay (Q_{max}) was estimated for 25–500 m. Controlling the maximum allowable charge is required at short distances (25–50 m), whereas higher charges can be safely used beyond 200 m; at 100 m, Q_{max} ranged from 41.6 to 240.5 kg depending on allowable PPV. These findings provide a practical framework for optimising blast design, limiting PPV, and enhancing both environmental and operational sustainability in surface coal mining.

breaks rock; the remaining energy manifests as undesirable side effects such as flyrock, backbreak, noise, airblast, and ground vibrations, exceeding prescribed safety thresholds and causing damage to nearby structures or operational disruptions[2–5]. An effective blast design ensures efficient rock fragmentation, produces a properly distributed, loosened muck pile, and facilitates faster, more energy-efficient excavation and loading operations.

Consequently, systematic blast design and vibration control are essential to maintain blast-induced vibrations within permissible regulatory and empirical limits. Careful optimisation of blast parameters further minimises adverse effects while improving overall mining efficiency and operational performance[6–8]. Accordingly, bench blast planning and ground vibration monitoring should focus on quantifiable indicators, such as peak particle velocity (PPV), airblast levels, flyrock throw distance, and scaled distance, to achieve safe and optimised blasting outcomes.

In reality, blast-induced ground vibration (BIGV) is caused by high-pressure stress waves that radiate through the surrounding rock mass when explosive charges detonate in blast-holes[9]. These waves radiate outward as surface waves (Rayleigh and Love waves) and body waves (P-waves and S-waves)[10,11]. Ground movements are frequently caused by surface waves, such as Rayleigh and Love waves, which result in substantial horizontal shearing, whereas P-waves travel through all kinds of materials and S-waves move only through solids[12,13].

The intensity of blast-induced ground vibrations is primarily controlled by the explosive charge weight per delay, explosive energy (strength), and the degree of confinement, while other influences include blast geometry