Bridging Mechanisms, Monitoring, and Modelling for Strainburst Support Design in Deep Cave Mining

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As mining operations extend deeper to meet rising demand and replace depleted near-surface resources, they face mounting challenges from high-stress conditions and brittle failure mechanisms such as spalling and strainbursting. In cave mining, large excavation footprints amplify exposure to these hazards, posing significant risks to safety, infrastructure and production continuity. These conditions have revealed fundamental limitations in conventional empirical and numerical design tools, which are primarily based on shear failure in lower-stress, weaker rock environments and assume volumetric yielding. Brittle failure, in contrast, is governed by extensional fracturing that is highly sensitive to confinement and produces directional bulking. This underscores the need for new design approaches tailored to brittle failure mechanisms.

To address this, a comprehensive, data-driven framework has been developed to advance strainburst hazard management and support design in deep cave mining, drawing on research from the Deep Mill Level Zone (DMLZ) panel cave mine. A new methodology for analyzing rockburst damage features two custom indices—the Rockburst Damage Index and Rockburst Cluster Index—established for the spatial and operational context of cave mines. Strainburst susceptibility is quantified using multivariate logistic regression, incorporating factors such as mining geometry, sequencing, and veining heterogeneity. Advanced geotechnical monitoring—integrating borehole camera surveys and LiDAR scanning—is employed to track stress-induced fracturing and bulking, enabling early warning of elevated deformation demand. These insights support timely reinforcement strategies, improving the effectiveness of Deformation-Based Support Design (DBSD) and Preventive Support Maintenance (PSM).

Complementing the monitoring program, new numerical tools—particularly bonded block modelling techniques—were developed to explicitly simulate stress fracturing, bulking, and support interaction. Calibrated against field observations, these models successfully reproduce spalling depths, bulking behaviour, and strainburst mechanisms, and were used to evaluate support strategies under realistic stress paths, including dynamic loading scenarios. Their strong alignment with observed ground behaviour confirms their utility as a robust tool for DBSD in high-stress environments.

Together, these innovations offer an integrated approach to strainburst hazard management—bridging field data, predictive modelling, and support design to enhance safety and resilience in deep cave mining.