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Title: Integrated Roof Strata Reaction Curves (RSRCs) for Roof Bolt Design with Standing Support Ground Reaction Curve (GRC) Design for Longwall Gateroad Support Optimization
Organization: West Virginia University
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Focus Area: Health and Safety Interventions – Ground Control

Burden: In 2019, approximately 38% of the total coal production in the United States was by underground mining (MSHA, 2020) and 60% of the underground coal production was carried out by longwall coal mines. In longwall coal mines, pillar load, deformation and local ground response of the entries are affected by the local geology, in- situ stress state and operational parameters of the mine. Local geology and stress conditions can change drastically from one coal basin to another, or even within the same mine. In addition, longwall gateroad entries are generally subjected to severe mining-induced stress changes due to higher mining-induced load concentrations in the vicinity of the gobs. Between 2011 and 2019, fall-of-ground accounted for almost 30% of the occupational fatalities in underground coal mines, second only to fatalities caused by powered haulage (MSHA 2020). Of these ground- control-related fatal accidents, 25% of them were in longwall mines. Also, for fatalities related to ground control in longwall mines, ***80% of them occurred in areas with roof suppor***t (Sears et al., 2019).
Problem Statement: Entry roof support consists of a combination of intrinsic (conventional roof bolts and cable bolts) and various standing support products especially for longwall gateroads. There are design guidelines for each element but there is no integrated support design platform currently available. Furthermore, much of the intrinsic support design is based on experience or trial and error. There are empirical design guidelines to assist mine engineers to design roof support systems (Mark et al., 2020), but these only consider the ultimate load capacity of the support system with the simplest assumption of dead weight of rock to support. However, these methods cannot differentiate the reinforcement provided by various mechanical responses of different type of roof supports, don't consider failures above the bolted anchorage zone or the stiffness of the support and don't consider the influence of elevated stress conditions due to retreat mining in longwall mines. Therefore, support systems may be under- designed depending on the geological conditions and changes in the stress state. Field measurements together with numerical analysis can be used to include the change in stress state, mechanical response of the support system and geology to the design (Esterhuizen et al., 2021; Haochen and Tulu, 2021; Batchler et al., 2021).
Research Approach: The Ground Reaction Concept in the STOP provides a mechanistic approach to standing support design by correlating the support resistance to the overall ground deformation culminating in convergence of the mine entry. This project proposes to expand the ground reaction concept to include intrinsic support by developing a local roof conceptual model formulated by *roof strata reaction curves* (RSRCs) that would allow the evaluation and selection of the most effective primary and secondary roof bolt system. The goal is to enhance the STOP platform to provide a unified support design tool for both standing and intrinsic support. The research to be accomplished in this project will include:

1) Develop a conceptual model of local roof strata reaction within and near the bolted zone (progressive deformation, delamination, and failure) and the associated intrinsic support response (loading and displacement) as a function of roof geology and mining induced stresses utilizing database of field measurements from different U.S. longwall mines.
2) Develop a suite of geology-dependent local roof strata reaction curves from the database of immediate roof/floor lithologies across U.S. coal fields.
3) Integrate the local roof strata reaction curve concept for intrinsic support into the STOP ground reaction curve (GRC) option.
4) Test and verify unified support design tool with case studies from different longwall mines.

Impact of the Research: The development of a mechanistic intrinsic support design concept will enhance roof bolt selection for particular roof geologies and stress conditions. Furthermore, analyzing the interaction of standing support with intrinsic support will provide a more realistic support system design than provided by separate, independent support design practices. Integrating this new unified approach into STOP will provide a complete support design tool that will be immediately available to the coal mining industry and expected to improve roof support design and the safety of the coal mine workers.