Best Practices
Ground Control for Deep Cover Coal Mines

Coal mines in many regions of the United States are operating under increasingly greater depths. These greater depths translate to higher stress levels that require special precautions to ensure ground stability.

Vertical stress in coal measure rocks tends to increase at a rate of about 1.1 psi for every foot of overburden. Thus, at a depth of 1500 feet, the vertical stress before mining is about 1650 psi. The development of mine entries disturbs the original stress distribution and at greater depths concentrates a high stress in the rock surrounding the entries and in the coal pillars.

Geology - high stresses associated with deep cover can create a variety of unstable ground conditions. The nature of the instability is largely dependent on local geologic conditions.

- ✓ If the roof and/or floor geology is weak, roof falls or excessive floor heave are likely to occur. Mine planning can mitigate some problems but additional roof support (e.g. bolts and surface control measures) also may be required.
- ✓ If the roof and floor geology is strong, conditions may be conducive to coal bumps or bounces. Mine planning is important in all deep cover operations but it is critical in strong strata and even more so in multiple seam and/or retreat mining scenarios.
- ✓ If the coal seam is high, pillars are prone to rib sloughing. The direction of the face cleat with respect to entries and crosscuts often influences the type of failure, creating for example, vertical slabs of coal along pillar ribs or triangular slabs from pillar corners.

Multiple Seam Mining – mine entries that are developed above or below other workings may be exposed to vertical stress concentrations. These concentrations are most prevalent when gob-solid boundaries or isolated barriers associated with retreat mining are encountered.

- ✓ Deeper cover translates to higher total vertical stress levels that can create multiple seam interactions even when interburden thickness is substantial.
- ✓ The direction of mining can influence the degree of multiple seam interaction. Mining from the gob to the solid generally results in lower stress concentrations than from the solid to the gob.
- ✓ The type of remnant pillar structure (gob-solid boundary or isolated barrier) in overlying or underlying workings influences the degree of multiple seam interaction. Isolated barriers cause more ground control problems than gob-solid boundaries.

Retreat Mining – the extraction of coal pillars/panels in retreat mining operations creates abutment stresses adjacent to gob areas. **Under deep cover**, special precautions are required to accommodate these elevated stress levels. Precautions for room and pillar retreat mining can be divided into two main categories: global stability (prevention of pillar failure due to bumps, collapses and squeezes) and local stability (prevention of roof falls in the working area). Global stability is addressed through proper mine design. Local stability is addressed through the installation of roof bolts, use of standing support such as mobile roof supports or posts, and an adequately sized final pillar stump.

- ✓ In room-and-pillar retreat mining operations, it is imperative to consider the stability of barriers that separate panels in addition to the stability of pillars adjacent to the retreating gob line.
- ✓ Geologic features such as faults, sandstone channels and zones of increased jointing that concentrate stresses or fracture the roof should be mapped on development prior to retreat mining activity. This will allow for the timely installation of additional roof support or changes to the retreat mining plan.
- ✓ Since retreat sections are subjected to abutment stresses just like longwall headgate and tailgate entries, the level of roof support installed should be enhanced (e.g. longer bolts, stronger bolts and/or a denser pattern).
- ✓ As cover increases, the magnitude of the stress increases and the distance that front abutment stresses transfer outby the pillar line also increases. It is important that supplemental roof support be installed prior to any stress increase, ideally upon development.

Mine Planning/Pillar Design – mine planning is important in all mines but especially so in deep cover operations. The use of empirical design programs such as the Analysis of Retreat Mining Pillar Stability (ARMPS) and the use of numerical modeling software such as LAMODEL can be a great asset.

- ✓ Regardless of the particular software employed, care must be taken to ensure that appropriate input values are used. Some programs have “built-in default input values” (e.g. coal strength and rock density). A decision to use mine specific information instead of the defaults should be weighed carefully. In addition, actual in-mine conditions and ground control history should be used to validate/calibrate any analysis.
- ✓ A review of the ground control history of nearby mining operations under similar ground conditions can be invaluable, especially for new mines or for existing mines expanding into new reserves.

Longwall Mining – longwall mining under deep cover also requires special precautions to be taken in response to the elevated stress levels encountered.

- ✓ Gate entry chain pillars must be properly designed to achieve roof/floor stability and mitigate bumps. In some instances, yield pillars have been effective to deter bumps. However, in the deepest operations, **barrier pillars** have been required between panels to limit stress levels in the work areas.
- ✓ **Installing guards** on longwall face equipment has proven effective in reducing injuries due to forcible ejection of coal from the face. This added protection includes belt guarding hung from the longwall shields, metal guarding attached to the panline, face sprags on longwall shields, and deflector plates installed on the shearer.
- ✓ **Personal protective equipment** such as helmets with face shields and body armor (e.g. chest protector and shin guards) can provide personnel with an additional level of protection.

- ✓ **Administrative controls** that keep personnel out of certain bump prone locations during the mining cycle can be implemented. One example of such a precaution is to not allow personnel in the headgate or tailgate entry (for a specified distance outby the longwall face) when the shearer is cutting within a designated distance of the headgate or tailgate entry. Another example is to keep personnel on the longwall face a specified distance away from the shearer while it is cutting, unless they are located behind the shearer, as in the case of the shearer operator.
- ✓ **Relocation of operator control stations** or the installation of additional control stations can reduce exposure of personnel to high-risk locations during regular operations and maintenance procedures by allowing tasks to be performed from a remote (safer) location.
- ✓ The feasibility of installing cameras and lights on the shearer is being evaluated at one deep cover longwall operation. If successful, this would allow for remote operation of the shearer from a control station outby the longwall face.

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