PILLARS OF THE *earth*

Erik Anderson, Hexagon Mining, USA, explains how the room and pillar method of mining can continue to be effective with new modelling technologies.

As industrial demand drives mining companies further below the surface in search of coal, conventional stripping methods for extraction are becoming economically unviable. The understanding and improvement of traditional underground mining methods will continue to keep coal one of the most affordable fuels on the market. The most common and generally most cost-effective underground method for mining coal is the room and pillar method. Room and pillar is ideal for flat-lying tabular coal beds. The capital costs are lower than other methods and generally require less development before production.

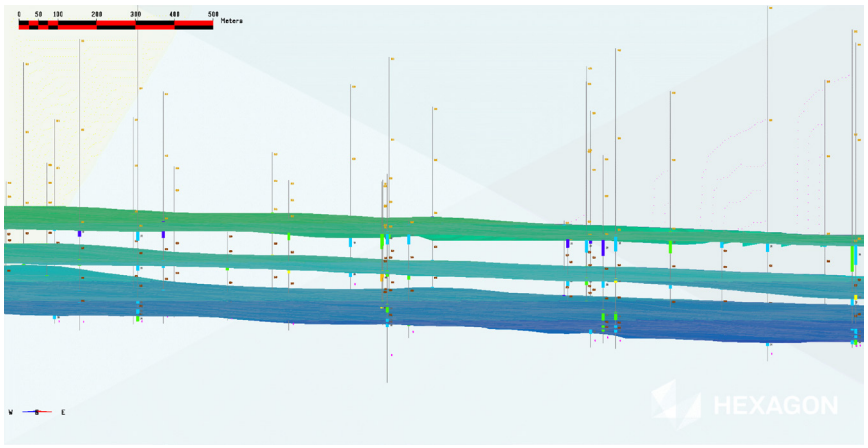

Figure 1. GSM model.

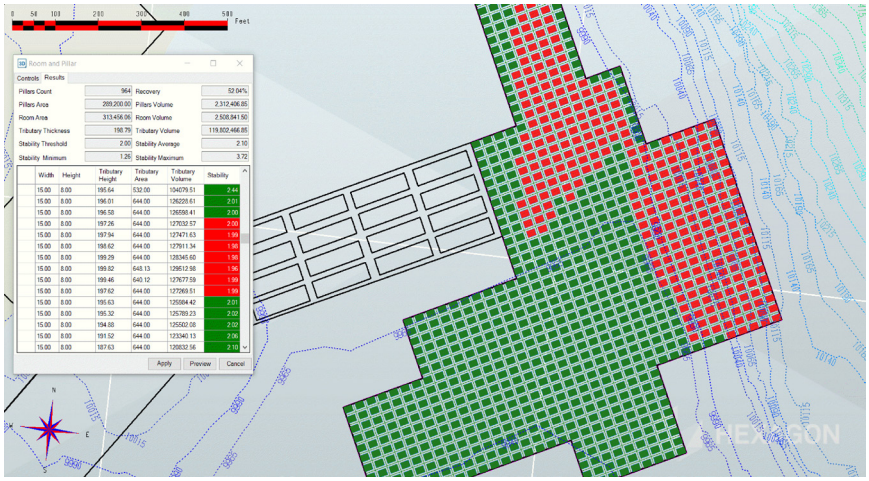

Figure 2. Room and pillar tool.

Room and pillar is one the oldest underground mining methods, and involves driving a series of parallel entries into the coal seams and incrementally connecting these entries with perpendicular cuts to form a grid (sometimes cuts are angled to create chevrons or a v-shaped pattern). The 'pillars' between the entries are load bearing and support overlying strata above the extraction area or 'room,' preventing it from collapse.

Techniques have progressed from developing workings on the fly to systematically planning pillar layouts that maximise extraction recoveries and minimise unplanned subsidence. Hexagon's mine planning software models coal deposits, tests pillar design strategies and evaluates extraction scenarios.

Coal models

Building a coal model combines the art of geologic interpretation with the science of geostatistical interpolation using raw drill hole data. Multiple ore percent 3D block models (complex coal) and gridded seam models (GSMs) are common ways of representing this information.

Multiple ore percent 3D block models are used for coal deposits with a series of faulting and folding that creates complex geology. The method uses equal size blocks to store the percentages from the seam(s) that intersect them. This allows for reporting accurate seam tonnages, but precision is compromised because the exact seam locations in the blocks are not stored.

GSMs are common for modelling stratiform deposits, which are generally more applicable for room and pillar mining. Unlike the block model, GSMs vary in length or effective thickness in the z dimension. This allows for better modelling precision, but some accuracy will be lost in the 'gridding' process which applies averages to the surface elevations.

After the initial geologic and economic model has been created and the mining method has been determined, the next step is to begin drafting an overall design. Mine design and modelling is an iterative process that is often adjusted after production begins and new information about the deposit becomes available.

Room and pillar

The company's MinePlan room and pillar tool can quickly manipulate pillar layouts and uses the tributary method to verify a user-defined design threshold. The design threshold – or so-called 'factor of safety' – is the pillar strength divided by the applied pillar stress.

The σ_z, vertical stress is a product of the γ, overburden weight and z, overburden thickness or vertical distance from the surface to pillar.

The σ_p, pillar stress is a product of the vertical stress and the ratio of the $(W_p + W_0)^2$, tributary area and the W_0^2, pillar area.

Pillar strength is often harder to determine than pillar stress because it more heavily depends on rock characteristics. It is also usually derived by performing a series of compressive strength tests and then fitting the results to a linear or power model for prediction.

- Linear equation: $P_s = K[A+B(w/h)]$.
- Power equation: $P_s = K(w^a/h^b)$.
- K is related to pillar material strength (MPa, psi).
- A, B, a, b are all empirically derived constants.
- w is the pillar width (m, ft).
- h is the pillar height (m, ft).

Strength has also been determined by the relationship of historical pillar information. This is described in Salamon and Munro's case study on 'size effect' constants determined in South African coal mines.

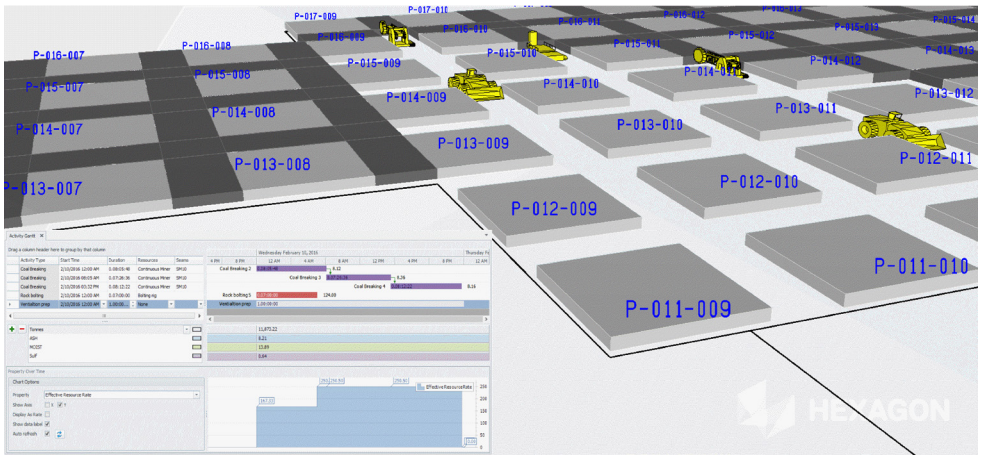

Figure 3. HxGN MinePlan Activity Scheduler offers the task-based scheduling approach needed for room and pillar mining.

The room and pillar tool is used to summarise room recovery based on the ratio of pillars to entries, as well as stability and threshold averages. More importantly, the tool highlights pillars not meeting the threshold, so pillars can be resized to improve safety.

Figure 2 shows a design where multiple pillars failed as the elevation to the surface was too much to guarantee a threshold of twice the strength over the stress. Increasing the size of the pillar will resolve that, however the seam recovery will also decrease. Balancing pillar size and maximising the extraction ratio is the goal of a good design.

Scheduling

The next step after creating a solid mine design is to assemble a schedule with practical extraction sequences that hits production targets and equipment capabilities. Underground scheduling is always challenging because of the many potential mining directions and many moving parts needed to ensure structural integrity and proper ventilation. To better address these challenges, a new task-based scheduling approach is now popular with underground mine planners.

HxGN MinePlan Activity Scheduler is an activity-based Gantt scheduling tool covering the three fundamentals for creating a task-based schedule:

- Activities: the work or task being completed. This includes undercutting, drilling, blasting, loading and bolting.
- Properties: attributes that help describe an activity, such as tonnes, quality, panel or duration.
- Resources: equipment or personnel being used to complete an activity, such as continuous miner, jumbo, rock bolter or blast crew.

The user-defined environment allows activities and resources to be scheduled if a rate or duration estimate can be made. These activity / resource durations can be derived in many ways from tonnes per day to a rate of advancement on a face. Activities are often represented by geometry, and spatial referencing can be used to automatically create dependencies between them. Dependencies can also be created manually in the Gantt or viewer, which makes the scheduling process interactive.

The integration with reserves ensures all applicable tasks list a summary of material and grade read directly from the economic model, which is either GSM or block model. After the initial sequences are defined, material is routed to destinations based on material cutoffs, hauling and target constraints within a given period window. If destination constraints are not met or equipment is over-allocated, these issues will be identified in the schedule and the sequences adjusted accordingly. The activity scheduler in Figure 3 shows work completed by a continuous miner and rock bolter happening in a specific mining sequence represented in the Gantt, as well as a summary of tonnes and ash percentage of each.

Once a planner is satisfied with their schedule, they must effectively communicate the plan to operations. This can be challenging as information is easily lost or misinterpreted during the hand-off process. The company leverages its knowledge of both planning and operations to help mines master short interval control. The cyclical process comprises the following:

- Complete a mine plan.
- Push a series of planned activities to the fleet management system.
- Dispatch prioritises and rearranges tasks to handle execution based on planning recommendations.
- Operators work on assignments and progress is tracked through onboard systems.
- Planners pull task progress at any time directly from fleet management and can apply changes to their schedule.
- Progress is updated in the planning schedule, allowing planners to better react to downstream dependencies.
- Planners can address changes in schedule to meet production targets.
- Repeat.

Conclusion

In conclusion, it is clear that room and pillar will continue to be a cost-effective method for mining coal. New technologies allow mines to better estimate, model, plan and execute the extraction of deposits. WC