MinE 611 Advanced Ground Control
Fall 2008

Four Major Topics:

A. Geology
B. Pillar
C. Roof Bolting
D. Shield

A. Geology

1. S. S. Peng and G. L. Finfinger, Geology, Roof Control and Mine Design, Coal Age, December, 2001, p. 29-31.
2. N. N. Moebs and J. L. Ellenberger, Geologic Structures in Coal Mine Roof, USBM, RI 8620, 1982, p. 16.
3. P. W. Jeran and J.H. Jansky, A Guide to Geologic Features in Coal Mines in the Northern Appalachian Coal Basin, USBM IC 8918, 1983, p.16.
4. N. N. Moebs and R. M. Stateham, Coal Mine Roof Instability: Categories and Causes, USBM, IC 9076, 1986, p.15.

Geological Anomalies

Fractures
- **Faults**
  - Normal
  - Reverse
  - Thrust
- **Slips**
- **Joints** in rocks
- **Cleats** in coal
- **Slickensides**
- **Hill Seams**

Paleochannels (Sandstone Channels or **Rolls)**
Scours
Washouts
Pinchouts
Clay Veins (spars**)**
Stackrock
Kettlebottom (Horseback)

Homework #1

A report on geologic effect in coal mine ground control, after having reviewed the above-listed 4 papers, consists of the following items:

1. Summary - a summary of all the 4 papers including objectives and major conclusions.
2. Important items of information that you learn from these papers.
3. Your questions that include:
   a. those items that you do not understand.
   b. those items that you do not agree.
   c. Any others.

The report must address all the three items above and must be at least 2 pages long, 12-point font, double spaced with maximum 1-in margin on the top and bottom of the page.

B. Pillar

1. 1. P. Tsang, S. S. Peng, and K. Biswas, Current Practice of Pillar Design in US Coal Mines, *Mining Engineering*, December 1996, p. 55-60.
2. C.T. Holland, Mine Pillar Design, *Mining engineering Handbook*, SME, 1972, p.13.96-13.107.
3. Z. T. Bieniawski, A Method Revisited: Coal Pillar Strength Formula Based On Field Investigations, in *Proceedings of the Workshop on Coal Pillar Mechanics and Design, USBM, IC 9315,* 1992, p.158-165.
4. S. S. Peng and D. Dutta, Evaluation of Various Pillar Design Methods: a Case Study, in *Proceedings of the Workshop on Coal Pillar Mechanics and Design, USBM, IC 9315,* 1992, p.269-276.
5. K. F. Unrug, S. Nandy, and E. Thompson, Evaluation of the Coal Strength for Pillar Calculations. *SME Transactions, V. 280,* p. 2071 - 2075.
6. C. Mark, Pillar Design Methods for Longwall Mining, *USBM, IC 9247,* 1990, p. 1 - 27.
7. B. J. Madden, Long Term Stability of Board and Pillar Workings, *Symposium on Construction Over Mined Areas, Pretoria, South Africa*, May 1992, p. 37 - 49.
8. J. N. Van der Merwe, Coal Pillar Life Prediction in the Vaal Basin, South Africa, Proceedings of the 17th Int'l Conf. On Ground Control in Mining, Morgntown, WV, 156-161
9. K. Biswas and S. S. Peng, Study of Weathering Action on Coal Pillars and Its Effects on Long-term Stability, *Mining Engineering*, January 1999, p. 71 -76.

Methods of Evaluating the Usage of Ground Control Technologies

1. By literature search
2. By field survey of actual application

Due to the large gap between theoretical solution and mine production application, the two methods could produce vast different results.

US Mining Method

Room and Pillar Mining with or without pillar extraction since coal mining began.
Longwall Mining began mainly in the 1970's

Current Practice of (Stiff) Pillar Design in US Coal Mines (See Paper No. 1 above)

* No individual pillar failure occurred. But massive pillar failures in a panel/section or panels/sections had been recorded.
* Definition of "pillar failure."
* Yield pillar 28-30 ft for 2-entry system in the West
  20 ft for 4-entry system in the East

Coal Pillars

1. By objective

Chain pillar: *a block of coal left in its nature state to support the overburden roof and protect adjacent entries.*

Barrier pillar: *A block of coal left in its nature state to isolate the effect of failure/mining of an adjacent section or sections*.

Outcrop barrier pillar - *pillar left to avoid punching out into atmosphere and prevent impounded water from blowing out.*

2. By mechanism

Stiff (Abutment) pillar: *pillar strength is larger than the expected applied load on it.*

Yield pillar: *pillar strength is less than the expected applied load on it. A yield pillar is designed to yield at proper time and transfer proper amount of load to adjacent supporting blocks of coal.*

Pillar Design Method for Stiff Pillars

1. Conventional formula for individual pillar - *homogeneous materials and uniform loading on pillar only*
   a. Holland formula
   b. Bieniawski Formula
2. Semi-conventional method for group of pillars - *homogeneous materials but nonuniform loading on pillar only*
   a. ALPS by Mark
   b. Wilson and Carr's yield-stiff-yield
3. Mine structural Analysis - *non-homogeneous materials and nonuniform loading on roof, pillar & floor and their interaction*
   Computer numerical analysis of coal mine structure, e.g. longwall panel & R&P sections.

Historical Development of Stiff Coal Pillar Design Formulae/Methods

1. 1960's - 1970's : Holland formula
2. Late 1970's and early 1980's:
   * Introduction of Bieniawski (for R&P) and Wilson and Carr (for longwall) formulae
   * Began emphasis of 2-D and then 3-D mine structure analysis by S. Peng, etc.

3. Late 1980's/early 1990's
    * ALPS
4. Mid 1990's - 3-D mine structural analysis

Historical Development of Yield Coal Pillar Design Formulae/Methods

1. 1960's and early 1970's: Holland's yield pillar concept
2. Early 1980's: Wilson and Carr's yield-abutment-yield pillar for the East
3. 1960's - present: evolvement of 2-entry experimental yield pillar in the West
4. 2003: Morsy's yield pillar design

Time Element

Does coal pillar strength change with time ? Does coal deteriorate time ?

* There exits literature with conflicting conclusions
* Coal block in Mt Hope, WV standing since 1939
* Coals are resistant to water and weathering, but weathering of partings with time that affects coal strength ?

Homework #2

This Homework consists of several reports due in separate dates depending on class progress. For content and format of the report, please refer to Homework #1, p.2

C. Roof Bolting

1. S. S. Peng, Fully-grouted Resin Bolts vs. Tensioned Bolts, COAL AGE, Vol. 108, No. 10, Nov/Dec 2003, p. 40-41.
2. A. Yassien, Y.Q. Zhang, J. S. Han and S. S. Peng, Comparison of Some Aspects of Bolting Mechanisms Between Fully-grouted Resin and Tensioned Bolts in Underground Mine Entries. Proceedings of 21st Conference on Ground Control In Mining, 2002, pp. 114-125.
3. Y. Zhang and S. S. Peng, Design Consideration for Tensioned Bolts. Proceedings of 21st Conference on Ground Control in Mining, 2002, pp.131-140.
4. S. P. Signer and J. L. Lewis, A Case Study of Bolt Performance in a Two-entry Gateroad, Proceedings of 17th Conference on Ground Control in Mining, 1998, pp. 249-256.
5. S. P. Signer and R. Rains, Effects of Bolt Spacing, Bolt Length, and Roof Span on Bolt Loading in a Trona Mine, Proceedings of 20th Conference on Ground Control in Mining, 2001, pp. 302-308.
6. W. J. Gale and M. W. Fabjanczyk, Application of Field Measurement Techniques to the Design of Roof Reinforcement System in Underground Coal Mines,
7. W. J. Gale, Design Considerations for Reinforcement of Coal Mine Roadway in the Illawarra Coal Measures. The AusIMM Illawarra Branch, Ground Movement and Control Related to Coal Mining Symposium, August 1986.

Lecture Note

Type of Bolts

* by mechanism - two basic types of bolts
    Mechanical anchor vs fully-grouted resin bolt (Type A vs Type B)
    (Tensioned vs non-tensioned bolts)
* enhanced point-anchored bolts for heavy-duty high pre-tension application (Type C)
* combination of tensioned and non-tensioned resin grout (Type D)

Four Types of Roof Bolts

A. Mechanical Anchor Bolt
Conventional (Tensioned) Bolt
Mechanical Bolt
Point-anchored Bolt

It is for strong and medium-strong roof rocks and installed with pre-tension. It is simple and easy to install. It works mainly by suspension effect. Final installation torque requirements are in CFR 75-201.

B. Fully-grouted Resin Bolt
Resin Bolt
Rebar Bolt

It works on all types of roof strata and employs both suspension and beam building effects. It is installed without pre-tension.

C. Resin-Assisted Mechanical Anchored Bolt
Combination Bolt
Double-Lok Bolt
Hy-tec Bolt
Instal Bolt
Cable Bolt

It is a high capacity tensioned bolt designed for heavy duty use, for instance, thick weak roof or areas subject to high abutment pressures.

Cable bolts are made of 7 high-strength wires (6 outer wires wound around a center core) installed with/without pre-tension for extra-heavy duty applications.

D. Torque-Tension Bolt
Tensioned Rebar Bolt

It can be installed two ways: as a fully-grouted bolt with two sets of resin; the top one shorter but faster curing while the lower one longer but much slower curing so that there is a pre-tensioned built up with installation. It combines the advantage of both the fully-grouted resin bolt and mechanical anchor bolt. The second installation method is with a resin anchor only at the top and then tensioned after the resin has cured.

Other Types of Roof Reinforcement

Cable Bolt
Cable Sling
Truss

Theory of Roof Bolting

1. Suspension
2. Beam Building
3. Keying

D. Shield

1. S. S. Peng, Longwall Mining, 2nd edition Chapter 5, Shield Supports - General & Chapter 6, Shield Supports - Design/Selection, 2006, p. 127-248.
2. S. S. Peng, S. M. Hsiung and J. H. Jiang, Method of Determining the Rational Local Capacity of shield supports at Longall Faces, the Mining Engineer, V. 147, n. 313, October 1987, p.161-167.
3. S. S. Peng, Design of Active Horizontal Force for Shield Supports for Controlling Roof Falls. The Mining Engineer, June 1990, p. 457-461.
4. S. S. Peng and J. S. Chen, Control Method of the Unsupported Area between Canopy Tip and Face line in Longwall Faces Under Weak Roof Conditions. The Mining Engineer, v. 151, n.363, December 1991, p. 179-183.
5. S. S. Peng and J. S. Chen, Determination of Floor Pressure Under the Base Plate of Powered Support. The Mining Engineer, v. 152, n. 378, March 1993, p. 246-250.
6. S. S. Peng, What Can a Shield Leg Pressure Tell Us ? COAL AGE, V. 103, N. 3, March 1998, p.54-57.

Types and Evolution of Powered Support for Longwall Mining

a. Frame: 1951 - 1984
b. Chock: 1960's - 1980's
c. Shield: 1975 - present
  i. By number of legs
    * 2-leg shield
    * 4-leg shield
  ii.By shield canopy tip locus
    * caliper

* lemniscate

d. Chock-shield: 1980's - 1990's.

Lecture Notes - Powered Support

* Two Types of Modern Shield Support
* Statistics of Support Type by Year
* Statistics of Support Capacity by Year
* Major specifications of 2-leg shield
* Ranking of Powered Supports