May 31, 2017

ROOM AND PILLAR DESIGN RECOMMENDATIONS AGAINST SURFACE SUBSIDENCE – PROPOSED BROOK MINE, SHERIDAN, WY

1. ROOF ENTRY FAILURE ANALYSIS

   a. Stoping potential should be evaluated by an accepted equation for the room (entry) and pillar configuration with parameter values representative of the cave-in material.

   b. If stoping height exceeds the ground surface from 1.a., assess whether a rock bed of sufficient strength, thickness, and durability exists to bridge the underlying upward propagation of the cave over the long term. Bed should be at least 2 ft. thick.

   c. If there is no “bridging” overburden rock bed, reduce extraction height and/or width until the potential stoping height is less than the mine depth.

   d. Where there are vertically stacked entries, perform surface subsidence evaluation similar to the above, but consider cumulative extracted height with mine depth of the lowest mined seam where no “bridging” bed is present above in the overburden.

2. PILLAR FAILURE ANALYSIS

   a. Determine vertical pressure on pillars. Account for arching pressures which may be present from varying pillar width and stacking of pillars from multi-seam mining and changing overburden depth.

   b. Determine the maximum extraction height of the coal seam and range in pillar widths for mining under consideration. Appropriately reduce the pillar width which would be affected by the softening/deterioration of any clay parting.

c. Based on testing, determine the appropriate overall large scale cube strength of the seam to be mined. Appropriately reduce the coal strength for any clay partings based on thickness and long term strength of the parting(s).

d. Utilize the Mark-Bieniawski equation to determine the pillar strength assuming the coal strength determined in 2.c.

e. Use appropriate stability factor (or safety factor) for long term stability to determine minimum pillar dimension against failure from outright crushing.

3. ROOF/FLOOR BEARING FAILURE ANALYSIS

a. Delineate roof and floor extending to two times the width of the immediate pillar into durable and non-durable layers using appropriate slake durability testing and classification. Areas of core recovery losses should be considered non-durable rock.

b. Where the rock is appropriately classified as durable to two times the width of the immediate pillar (i.e. potential shearing zone), that roof or floor is considered durable. Where the vast majority of the rocks classify as non-durable over this distance from the pillar, the roof and/or floor is considered non-durable. Where potential shearing zone contains significant amount of non-durable and durable materials, the bearing state is considered mixed.

c. Because the thickness of a specific non-durable zone can play a key role in the bearing strength of the roof or floor, the thickness should be assumed at the value unlikely to be exceeded. A durable rock zone should not be assumed if it is less than 2 ft. in thickness in any location in the area under consideration.

d. For durable roofs or floors:

i. The average rock strength is determined by an ample number of representative tests which appropriately measure uniaxial compressive strength (averaging assumes reasonable tested strength variation).

ii. The average rock mass strength is then determined by appropriately considering the degree of fracturing in the rock.

iii. Utilizing the classical bearing capacity formula for foundations resting on uniform cohesive medium, the ultimate pillar bearing pressure is determined for the roof and floor using the pillar plan dimensions. The cohesion strength of the bearing zone is taken as one half the average rock mass uniaxial compressive strength determined in 3.c.ii.

iv. The minimum sized pillar is determined for the long term assuming sufficient data has been collected, for the durable roof or floor zone by considering a safety factor of 3 and a pillar pressure based on 2.a.

e. For non-durable roofs or floors:

i. The strength of the non-durable rock must be considered over the short and long term as these rocks by definition deteriorate over time. In the short term, the average, representative compressive strength of the fresh rock at its natural moisture should be determined from an ample number of tests throughout the potential shearing zone. For the long term strength, the non-durable rock will revert to a soil-like consistency and thus drained friction and cohesion values representative of this state should be established from adequate testing of the specific stratum under consideration.

ii. For short term roof or floor bearing, these fresh non-durable rocks (unexposed to groundwater) should behave more as a rock and consequently rock fracturing should be appropriately accounted for in determining the rock mass strength. Obviously, in the long term, the effect of rock fracturing can be discounted as the non-durable rock will be soil-like.

iii. For a reasonably uniform non-durable in the potential shearing zone, the classical bearing capacity formula for foundations resting on a uniform medium can be used to determine the ultimate bearing pressure for the roof and floor and the plan pillar dimensions. The cohesion strength of the bearing zone is taken as one-half the average rock mass strength determined in 3.e.ii. In the long term, the same equation can be used to determine the ultimate bearing capacity.

   Where two distinct non-durable zones with different strengths are present, utilize the appropriate foundation bearing relationship for this condition in either the short or long term.

iv. The minimum sized pillars are determined, assuming sufficient data has been collected, by considering a safety factor of 3 for the roof, 3 in the short term, and 2 in the long term for the floor.

f. For durable rock over non-durable rock, or non-durable over durable rock:

   i. Representative strengths of distinct durable and non-durable zones within the potential shearing zone are determined as respectively given above.

   ii. The ultimate bearing roof or floor capacity should be determined by appropriate relationship which represents the non-durable and durable conditions present.

   iii. Both short term and long term safety factors should be determined to establish the minimum acceptable pillar width. For roof condition, the short and long term safety factor should be 3. For the floor, a factor of safety of 2.0 should be used for all cases.

4. The above recommendations assume that no significant engineering geological features are present, and that a sufficient number of borings were performed, to where it is unlikely that more adverse ground conditions remain unknown.