Underground Mining of Metalliferous Deposits

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Lecture 58

Block Caving II

CAVABILITY ASSESSMENT : CAVABILITY

"Cavability" is defined as a continuous failure of the rock mass until all void space is filled with broken rock. Once draw continues, failure in the cave back continues to propagate.

The cavability of the rock mass is one of the fundamental issues for the current mining method.

The reliable prediction of cavability is critical in determining the undercut dimensions required to initiate and continuously cave an orebody.

Caving in coal has a different purpose. Mostly, it is not for production. Whereas, in hard rock mining, caved ore is our production (Cave Mining : Sublevel caving and Block Caving).

FACTORS INFLUENCING CAVABILITY

- Rock mass strength - IRMR / MRMR
- Hydraulic radius of orebody
- Relevant major structures
- Regional stress
- Induced stress
- Water
- Location of adjacent mining operations
- Scale of adjacent mining operations - heavy blasting
- IRMR / MRMR of orebody and hanging wall
- Stress effects - shear failure, tension or clamping
- Cave propagation - vertical or lateral extension of the cave.
- Geometry of area under draw

Modifications of RMR for Mining

Geomechanical classification system for rocks, RMR was developed by Z.T. Bieniawaski between 1972 and 1973.

RMR system was originally based upon case histories drawn from Civil Engineering.

Laubscher developed the Mining Rock Mass Rating(MRMR) system by modifying the Rock Mass Rating (RMR) system of Bieniawski.

RMR adjusted for mining-induced effects, namely weathering, joint orientation, induced stresses, and blasting.

Parameters of RMR (Bieniawski, 1973):

Six parameters are used to classify a rock mass using the RMR system (Bieniawski):

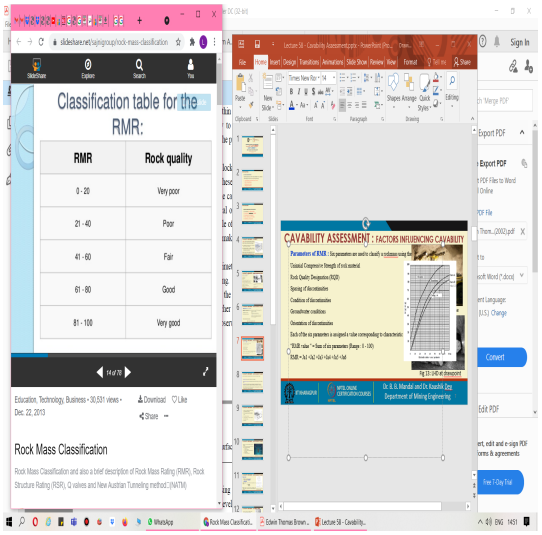
1. Uniaxial Compressive Strength of rock material
2. Rock Quality Designation (RQD)
3. Spacing of discontinuities
4. Condition of discontinuities
5. Groundwater conditions
6. Orientation of discontinuities

Each of the six parameters is assigned a value corresponding to characteristic of rock.

"RMR value" = Sum of six parameters (Range : 0 - 100)

RMR = Ja1 +Ja2 +Ja3 +Ja4 +Ja5 +Ja6

Table 1: Classification table for RMR



Parameters of MRMR (Laubscher, 1990**):**

RMR = IRS + RQD + Spacing + Condition

RMR = *Laubscher's Rock Mass Rating*

IRS = Intact Rock Strength

RQD = Rock Quality Designation

Spacing = Expression for the spacing of discontinuities

Condition = Condition of discontinuities (parameter also dependent on groundwater presence, pressure, or quantity of groundwater inflow in the underground excavation).

MRMR = RMR × adjustment factors

Adjustment factors = Factors to compensate for: the method of excavation, orientation of discontinuities and excavation, induced stresses, future weathering, stress environment, orientation.

Parameters of IRMR (Laubscher and Jakubec, 2000**):**
IRMR = RBS rating + Overall Joint Rating
IRMR = In-Situ Rock Mass Rating
IRS = Intact Rock Strength
= Unconfined compressive strength (UCS) value
derived from testing cores assigned to IRS
RBS = Rock block strength
= IRS × 0.8 × Fracture/Vein Adjustment (F/V) = …MPa

(Dyke, 2008) General regression equation is derived to be used to predict equivalent IRMR values from MRMR values,
IRMR = 1.0376MRMR - 1.3655 [± 0.24]

Hydraulic radius:
The cavability of a rock mass is a function of:
i. Quality of Rock Mass (IRMR/MRMR)
ii. Hydraulic Radius
Hydraulic radius is a ratio of the area over the perimeter of the undercut.

$$H.R. = \frac{Area}{Perimeter}$$

Minimum span is the critical dimension in promoting caving. Hydraulic radius will vary for the same area if the minimum span is decreased.

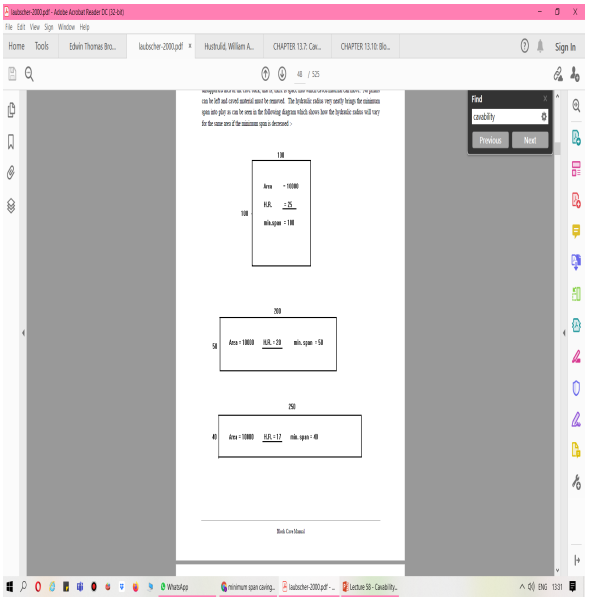


Figure 1. Hydraulic radius vary for the same area if the minimum span is decreased.

Laubscher's Caving Chart

The challenge faced in attempting to develop empirical methods of predicting cavability is to find a means of combining measures of rock mass quality, undercut geometry and induced stresses into one simple and robust tool.
Laubscher (1990) has done this by plotting the value of his Mining Rock Mass Rating, MRMR, against the hydraulic radius, S (area/perimeter), of the undercut which is a measure of the undercut size and shape.

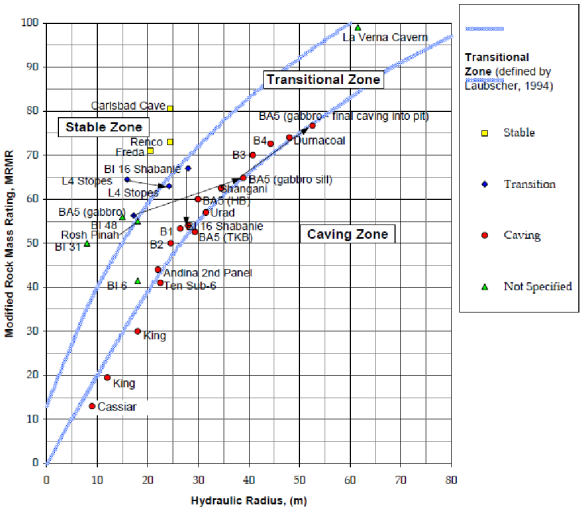


Figure 2. Laubscher's Caving Chart.

Laubscher (1990) proposed this by plotting the Mining Rock Mass Rating (MRMR) against the Hydraulic Radius (H.R.= area/perimeter) of the undercut which is a measure of the undercut size and shape.
There are three zones:

i. Stable zone : Non Caving
ii. Transitional zone : Major collapses or Partially caving
iii. Caving zone : Caving conditions of the blocks or panels

MATHEWS' STABILITY GRAPH :

Mathews' stability graph (Mathews *et al* 1980) is very similar in concept to Laubscher' s caving chart.
It is based upon the calculation of two factors –

i. ***Stability number*** **(N)** = Represents the ability of the rock mass to stand up under a given stress condition.
i. ***Shape factor*** **or hydraulic radius (S)** = Ratio of the area to the perimeter of an excavated surface.

Mathews stability graph contained three zones separated by transitions –

i. Stable zone
ii. Potentially unstable zone
iii. Potentially caving zone

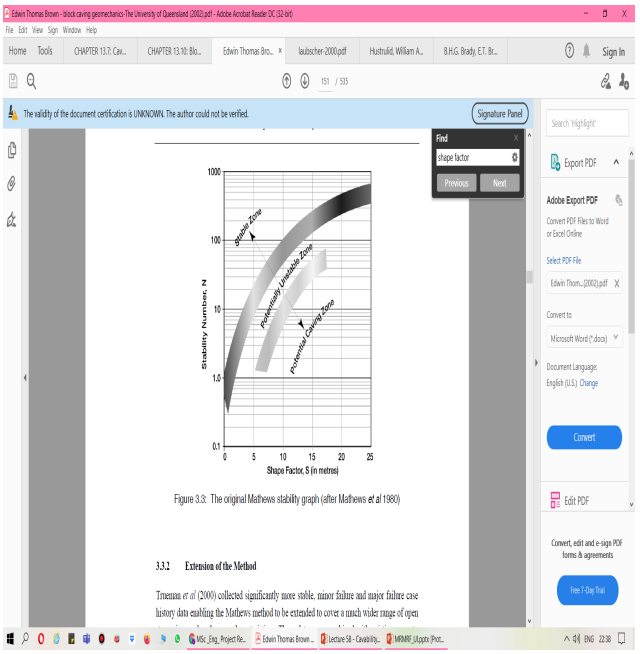


Figure 3. Mathew's stability graph (Mathews et al 1980).

Stability Number (N)

The stability number, N, is defined as

N= Q´×A×B×C

Q´ = Q classification system but assuming the joint water reduction parameter and stress reduction factor to be both equal to one.

A = rock stress factor

B = joint orientation adjustment factor

C = gravity adjustment factor

Shape factor or hydraulic radius (S) = Area/Perimeter

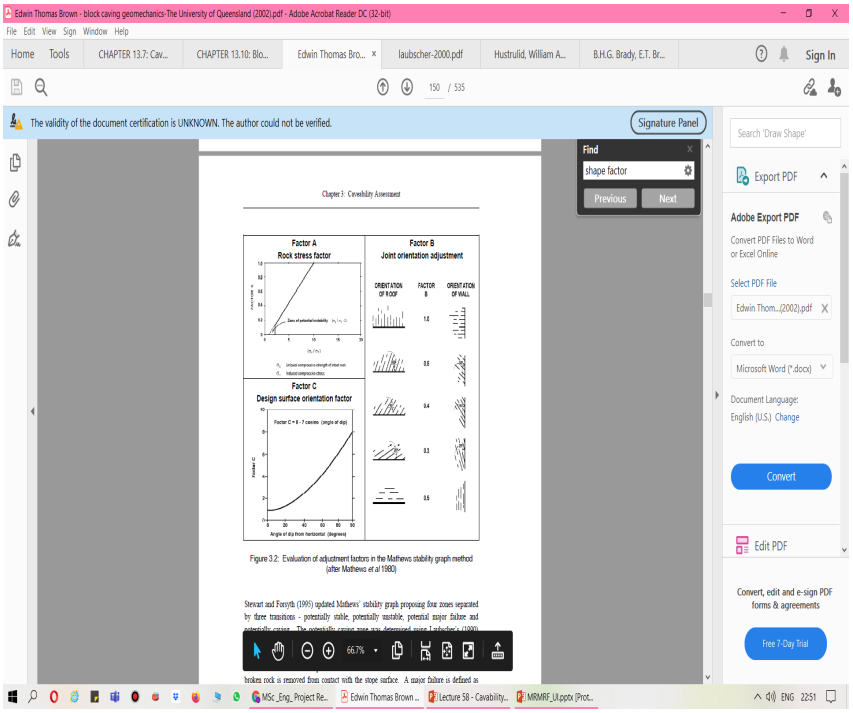


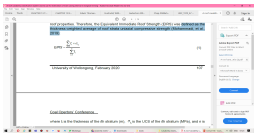
Figure 4. Evaluation of adjustment factors in the Mathews stability graph method (Mathews *et al* 1980).

"CAVABILITY INDEX (CI)" was defined as the summation of ratings for all the parameters to indicate the potential of caving qualitatively.

Laubscher's caving chart which predicts cavability based on the MRMR value and hydraulic radius, has been the major method used internationally to predict cavability in block and panel caving mines.

Obert et al. define the cavability index(CI) using several parameters, including RQD (Rock Quality Designation) and powder factor for secondary blasting.

(Mohammadi, et al., 2019)



where,

t_i = thickness of the i^{th} stratum (m)

σ_{Ci} = UCS of the i^{th} stratum (MPa)

n = number of stratum within the immediate roof.

CAVABILITY INDEX (in Coal**)** is defined as:

where,

w_i = weight of i^{th} parameter,

P_i = rate of i^{th} parameter (0 to 4)

P_{max} =maximum rate of i^{th} parameter (i.e. 4 for all parameters with the exception of joint persistence which is 3).

Cavability Index (CI) represents cavability level of strata within the immediate roof of coal mines. It varies between 5 and 100 and classifies the immediate roof from uncavable to the highly cavable status.

Note: This is only for an example for Coal Mining, but it is not used for hard rock metal mines.