❖ UNDERGROUND ROCK REINFORCEMENT

Primary rock reinforcing elements stem from two groups:

- those inherent in the rock mass, mobilized by well engineered excavation schemes, and;
- artificial support elements, installed as a supplement to the rock

➢ Rock Mass Inherent Support

Each rock mass has specific characteristics. Some of these characteristics can be mobilized to assist in support of an opening constructed in the mass. On the other hand, certain characteristics, if not respected, will almost certainly doom an opening to failure.

For example, consider a very shattered rock mass, with fragments on the order of 0.5-1.5 cm (0.2-0.6 in) with weak carbonate cement along the fracture surfaces. Mining is to be conducted less than 150m (500 ft) below surface. The following two approaches could be followed:

- *the "holistic" approach*. Recognizing that there exists a support potential to the rock mass in the angularity of the rock fragments coupled with a weak joint infill cement, a mining/excavation procedure is chosen to maximize this potential. The opening shape is optimized to maintain, as near possible, compressive stresses around the opening. This would consist of a strongly arched back with a relatively equidimensional height/width relation. Some outward arching of the ribs may even be considered. Actual excavation would consist of either mechanical excavation (road header) or carefully planned and executed drilling and blasting such as not to disturb the surrounding rock. This would be followed immediately by shotcrete, or a similar spray on surficial support agent to assist in the rock retaining its original character. A neat, clean, non-failing opening would likely be the result of this program.

- *the standard approach*. The rock would be considered "bad rock". No changes would be made in the excavation profile, which would likely be a flat-backed, straight ribbed shape. Drilling and blasting would not be modified. In fact, in most cases, the round wouldn't even be painted on the face. Rib and back holes would look out into the rock mass, especially the corner holes. When the blast was detonated, the weakly cemented bonds within the shattered rock mass would be broken. Overbreak would be considerable, along with an irregular excavation profile. Support would lag behind the round, allowing stress action to cause more internal failure in the rock mass. When finally installed, the rock support would likely consist of split sets and screen (mesh). This does not protect the surface from weathering/air slacking, nor does it restrain the surface and protect the rock mass from further internal failure. The result is a ragged, overbroken opening with rock bagging the mesh on the back and a irregular profiles.

> This opening will have an inherent risk of continual raveling and substantial failure. In addition, re-hab work will likely only be effective with removal of the already installed support (mesh and bolts), as the rock itself cannot be seen behind the failed rock on the screen.

From this rock mechanics observation standpoint, it is relatively simple to see which approach should be chosen. A little engineering forethought coupled with the miners', and management's, agreement would allow a relatively low cost, potentially long lived, efficient opening to be constructed in what would be considered "bad rock". The lack of the aforementioned would not only cost time and money, but result in a questionable opening; one that would likely be a drain on resources in the future.

Many such examples can be given, ranging from changing excavation profiles, to changing excavation orientations, to changing excavation sequences, to changing excavation techniques, to allowing rock failure and supporting the failed mass, etc. All require an understanding of the rock mass and the ability, and will, to capitalize on any inherent conditions that will allow the rock to support itself.

This technique of attempting to determine inherent rock mass support characteristics prior to excavation is highly recommended for all rock excavations. It is potentially the lowest cost rock support available and will in all cases result in the minimum rock support possible being installed. While compromises will have to be made with production concerns, maximizing the inherent rock mass support characteristics should never be ignored.

➢ Artificial rock support

Artificial rock support is any support applied to rock to restrain/retard failure. This can be as simple as gob fill in a stope to as complicated as face shields in an underground longwall mine.

▪ *Passive vs. active rock support*

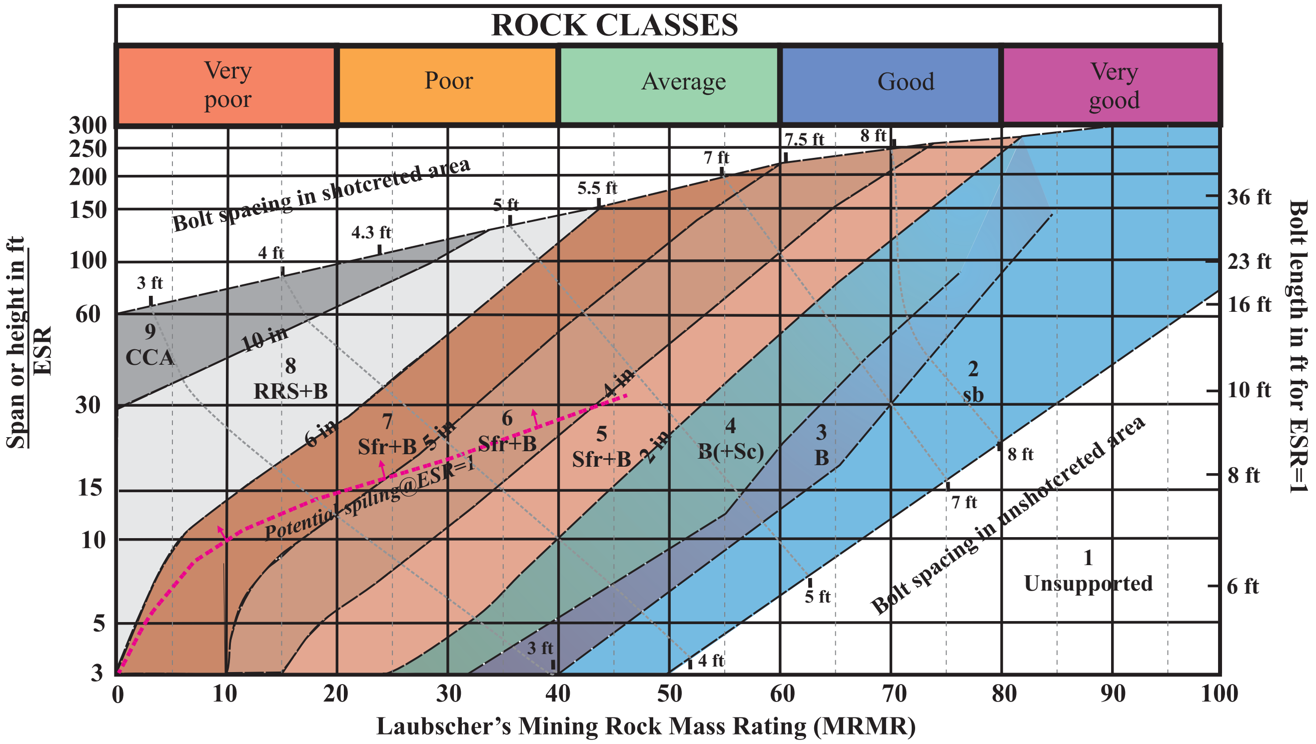
Artificial rock support, according to conventional thinking in the rock mechanics profession, belongs to two classes; active and passive support.

Passive support consists of any artificial rock support that requires rock displacement in order to function.

Active support, on the other hand, is supposedly any artificial rock support installed with a pre-determined load. In other words, a force is applied to the rock prior to rock displacement. A conventional example of this is tensioned bolts and cables.

Rock support calculations can be conducted utilizing statistically generated rock masses, in a similar fashion as depicted for our pit slope designs. Alternatively, rock mass rating systems can be utilized for design. A modified diagram, useful for design, is given as Figure I1.

For more detailed design information, please see our course at http://www.edumine.com



REINFORCEMENT CATEGORIES:

1) unsupported
2) spot bolting, **sb**
3) systematic bolting, **B**
4) systematic bolting,
   (and unreinforced shotcrete, 1.5 - 4 in), **B(+S)**
5) Fiber reinforced shotcrete and bolting, 2 - 4 in, **Sfr+B**
6) Fiber reinforced shotcrete and bolting, 4 - 5 in, **Sfr+B**
7) Fiber reinforced shotcrete and bolting, 5 - 6 in, **Sfr+B**
8) Fiber reinforced shotcrete>6 in, reinforced ribs of
   shotcrete and bolting, **Sfr**, **RRS+B**
9) Cast concrete lining, **CCA**

Stress and lithology induced adjustment

Clean, shattered rock (rubble):	RMR=RMR
Clay altered rock or gouge:	RMR=1.15RMR-9.1
Sandy, disintegrated, clay free rock:	RMR=1.27RMR-16.4
Mixed clay and boulders:	RMR=1.36RMR-24.3

These adjustments apply below RMR=50. For cases where RMR<15, the adjustments are uncertain. According to Barton, the Stress Reduction Factor may vary from 0 to greater than 100. This would result in an adjustment to the RMR varying from 0 - 1000%. Unless the ground is running or extremely squeezing, the above adjustments should give an adequate representation to stress levels approximating a depth of 600-800 ft below surface.

Weathering

Degree of weathering	*1/2 yr*	*1yr*	*2yr*	*3yr*	*4+yr*
fresh	100	100	100	100	100
slight	88	90	92	94	96
moderate	82	84	76	88	90
high	70	72	74	76	78
complete	54	56	58	60	62
residual soil	30	32	34	36	38

Remember that the weathering adjustment should be proportional to the actual weathering for the supported rock, i.e. shotcrete supported rock tends to weather less than exposed rock.

Blasting effects

Techniques	*Adjustment, %*
Boring	100
Smooth-wall blasting	97
Good conventional blasting	94
Poor blasting	80

The above diagram and adjustments are a combination of the MRMR system(D.H. Laubscher; A geomechanics classification system for the rating of rock mass in mine design; J.S. Afr. Inst. Min. Metall, Oct. 1990) and the revised NGI Q system (Barton, N., Grimstad, E.; The Q -system following twenty years of application in NMT support selection,Felsbau, 1994). The transformation from RMR to Q was by the equation:

$$Q = 10^{((RMR-43.5)/20.25)}$$

Adjustments for smaller openings have been made to the system by the author based on Mathis and Page, 1995.

Orientation

Number of joints defining the block	*Number of faces inclined away from the vertical*				
	70%	75%	80%	85%	90%
3	3		2		
4	4	3	2		
5	5	4	3	2	1
6	6	5	4	3	2,1

Adjustment for shear zone orientation (orientation w/respect to heading bearing)
0-15 degrees = 76%
15-45 degrees = 84%
45-75 degrees = 92%

FIGURE I1

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