

INFLUENCE OF ENGINEERING GEOLOGICAL FACTORS ON THE CHOICE OF WAY OF AN UNDERGROUND WORKING

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ABSTRACT

Article defines the term "competent rock mass". Taking the definition as a criterion, a classification for the contour stability of an underground opening is proposed. Engineering- geological aspects, influencing rock mass competency are discussed.

On the base of analysis of rock mass competency, general principals of tunnel rout choice, support systems and tunnelling technologies are proposed.

To drive an underground working is a challenge to nature. It leads to instantaneously stress release of contour of the opening and change of natural field of stresses in the rock mass. Under certain geological conditions, this could cause serious problems in driving and maintaining the underground workings, such as:

- rock bursts;
- rock falls or cavings;
- floor heaving or rock squeezing;
- water inflow: dripping, inrush, impoundment;
- inrush of quicksand.

All this leads to higher costs of construction and maintenance, accidents and manlife losses even to impossibility to use the working.

Forecasting and avoiding or minimizing the influence of the above mentioned adverse events could be reached only as a result of careful engineering- geological investigations and correct estimation the obtained information about the way underground working is to follow.

The underground construction terminology includes the term "competent rock mass", not giving definition about it. We suggest for competent rock mass to understand such one, which assures stable condition of the opening without any support during all the time of it existence. In other words an opening is stable if there are not any fragments to split and fall from the contour of the working and convergencies can not be observed without any instrumentation.

Rock masses poses different competency and it is result from the geologic and technical conditions. On this basis the authors propose to classify them into four classes:

- **competent** - as they were defined above. If they are mine workings, no need of support. If they are tunnels because of

the higher safety standards and longer service period, support is shotcrete or even cast in situ concrete;

- **of middle competency** - the contour of the opening is stable for a period from a week up to several months. After that period from the back and the walls small or not so small rock pieces split and fall and small rock cavings are possible. The radial convergencies of the contour are from 0 to 2 cm. The more often used supports are shotcrete, combination of rock bolts and shotcrete or cast in situ concrete with some higher load bearing capacity than in previous class;

- **of low competency** - rock mass assures stability of the contour from a day to a week. In such rock mass, if permanent support is built in above- mentioned period, temporary support is not necessary. The convergencies of the contour could reach for the boundary period values of 10 cm. In this conditions supports must poses high bearing capacity, or to be yielding ones (with predetermined yield);

- **incompetent** - rock masses, in which the contour is stable from 0 to 24 hours. In them radial convergencies of up-heaving or rock squeezing reach tens of centimeters or even could lead to total closure the opening. In the same class are the high water bearing rock masses, in which water or quicksand inrush is possible. Driving mine workings in such conditions is possible by using temporary or fore supports or by using not conventional technologies (earth pressure balance machines, rock freeing or grouting e.t.c.). Supports must be with maximal bearing capacity (and yielding ones in development mine workings), in water bearing rocks- impermeable.

Rock mass competency is influenced by many factors: genesis, mineral staff, rock properties, folding, faulting and fissuration, water logging, natural field of stresses, tectonic disturbances and many other factors.

Analysis of above mentioned factors permits, by rational choice the way working must follow, to avoid or minimize their unfavorable influence on rock mass.

One of the most important factors concerning rock mass competency is the origin of rocks. The best conditions for tunneling propose igneous rocks. Intrusive ones poses high strength, and negligible porosity. They are resistant against weathering, particularly if they content abundant quantity of quartz. Some lower competency poses extrusive rocks. Their porosity is bigger, strength lower and permeability higher.

Sedimentary rocks, in accordance with their mineral staff, cementing material and degree of lithification are taking place in all four classes of competency. Monomineral rock masses of limestone, plasterstone and rock salt assures enough competency to a definite depth. For clastic rocks, the most important thing, influencing rock mass stability is the binding matter. If binding material is silica, rock mass could be as competent as igneous one. In lowering order could be mentioned carbonate and hematite cement. The worst competency could be waited from clay binding, especially in the cases, when rock contains abundance of water or quicksand.

For clayey rock masses very important factor is the degree of lithification. The higher degree of lithification, the higher density, the better binds between particles, the more competent rock mass.

Igneous and sedimentary rocks could be altered by metamorphism or metasomatism. In general if an igneous rock passes trough metamorphism, the competency of the rock mass gets lower because of anisotropism, lamination, changes of mineral staff. A typical example is alteration of granite into gneiss.

Just the opposite, if a sedimentary rock passes metamorphism, as a result of recrystallization processes, rock mass upgrades its properties. Good examples are marbles, clay schists, and calcareous shales.

More of metasomatic changes lead to deterioration of rock mass stability. Argillization, pyritization, chloritization, propilitization are processes which alter low resistant to hydrothermal impact rocks into clayey minerals.

Dolomitization of carbonate rocks leads to higher rock porosity, and if later they are put under weathering, in certain geological conditions- to disintegration to sand.

Quartzitization of sedimentary rocks is allays a reason for better competency of the rock mass.

Fissuration and jointing strongly deteriorate rock mass stability. Reasons for rock fissuration and jointing are too much: rock origin, tectonics, weathering, conditions of lava cooling, metamorphism, metasomatism, tunneling technology. The exiting jointing planes lead to increasing filtration properties, make rotation and tangential convergences of rock blocks much easier.

The influence of fissuration and jointing on rock mass competency is in functional relations with natural field of stresses and roughness of jointing planes. This influence is minimal if there are high compressive stresses perpendicular to jointing planes and the surface of above- mentioned planes are rough.

In this sense, unfavorable are geologic conditions, where above- discussed stresses are tension ones or negligibly small compressive.

In a jointed rock mass, competency is a function of the angle between the direction of tunnel axis and direction of jointing planes. The most favorable is the case, when the angle between them is about 90°. Less favorable are the cases in which tunnel axis and jointing planes are parallel. The worst situation is when tunnel axis crosses jointing planes at 60°- 80°.

When a rock mass consists of strong, brittle rocks at depth over 800- 1000 m, its natural jointing assures energy dissipation as a result of rotation and displacements of rock blocks, forming the contour of the opening. By this way danger of rock bursts and rock spitting is lower.

But it is well- known fact, that going to depth intensity of fissuration becomes smaller and smaller, and width of fissures negligible narrow (in other words possibilities for rotation an displacements of rock blocks are very small) and the danger of rock bursts increase, especially in the area with compressive stresses concentration. In smaller depth rock bursts are connected to older rock formations and areas with stress concentration as a result young folding or residual stresses from older tectonic processes.

The practice showed, that not allays enough attention is paid to this question. Later it becomes a cause for larger tunneling time, higher cost and useless risks. A bad example of such an error is Western tube of Vitinya tunnel. Improper placement of tunnel way caused many rock falls, additional expenses and risks for supporting occurred cavings, longer period for tunnel construction, higher cost of maintenance. Nowadays the water, infiltrating trough concrete lining will destroy it in very short time.

Another reason for bad rock mass competency is weathering. Weathered rocks become much more fractured, water impermeable and less stable. Buried weathered rocks could be found in bigger depth in earth crust. Tunneling and later maintenance in such conditions are more expensive.

What are leading requirements for the choice of the way tunnel is going to follow?

Everything must start with a profound engineering- geological prospecting of the region. It must find all factors, influencing rock mass competency, such as: geological formations, post-genetic geodynamic processes and changes, caused into rocks: folding, faulting, weathering, underground water, jointing e. t. c.

Discovered tectonic forms must be discussed in aspect natural stress field. If safety standards for the future working are too high, quantitative results of earth crust stresses must be obtained.

It is advisable to be avoided all zones, where the rock mass is incompetent or of low competency. Usually, this zones are in connection with dynamically fed water bearing strata or quicksand, rocks undergone metasomatic changes, clastic rocks on low degree of lithification with clay binding between particles.

The way, tunnel is going to follow must avoid areas with highly developed fissuration systems. If this is not possible, the best decision is tunnel to intersect jointing planes at right angle. Going back to Vitinya tunnel example, we can say that the length of the working was quite enough faulted zone to be avoided or crossed at right angle.

When working is at shallow depth and must cross jointed rock, the rout it must follow should be laid in areas, where horizontal compressive stresses are maximal and their direction is perpendicular to the jointing planes. But if there is a danger of rock bursts, just the opposite- the way, tunnel should follow must be led in distressed areas, proposing possibilities for potential deformation energy dissipation.

It is not advisable to drive a working trough buried weathered rocks. Possibilities should be searched to go round them.

In coal mines at great depth in hard, strong host rock good results are obtained when future tunnel way is previously undetermined and after dome of equilibrium formation, underground working is placed into the distressed zone, near the top of natural arch.

Choice of the tunnel rout must be made on the basis of minimum two well analyzed in engineering- geological aspect variants, brought roughly to full cost, including the risk estimation (as in financial, so in safety aspects). For an example, in ore mines, exploiting vein deposits, always must be compared variants: in vein working, or stone drift.

Good results offers the system "engineering", which unites designing and driving the working. It permits if unfavorable geologic circumstances occur during tunneling, rational correction to tunnel road to be introduced.

Never should be forgotten the fact, that correct choice of the way tunnel must follow is possible, if specialists, engaged with designing and driving it poses certain level of qualification. This may be impose the need for some changes into educational programs of mine specialists and engineering- geologists too, where more profound study of hard rock to be included.

CONCLUSION

The analysis of engineering- geological factors, influencing radically rock mass stability permits the specialists to create rational choice of the rout an underground working must follow. This will assure minimal risks, costs and good standards of safety during tunneling and exploitation period of the working.

REFERENCES

- Ломтадзе, В.Д. 1986. Инженерная геология месторождений полезных ископаемых. Недра, Л.
Мюллер, Л. 1971. Геология скальных массивов. Мир, М.
Wahlstrom, E. E. 1973. Tunneling in Rock. Elsevier, L.

*Recommended for publication by Department
of Underground Construction, Faculty of Mining Technology*