ON THE CHOICE OF ROCK MECHANICS TESTS

Sur le choix des essais de mécanique des roches
Zur Wahl von Felsmechanischen Versuchen

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SUMMARY:
Sometimes rock mechanics tests which are not the best suited to solve the problems which face the Owner or the Engineer are done. Based on two actual examples, the very different influence each mechanical property of the rock may have depending on the studied variable is shown. The points of view to be considered in the study of these properties are developed. The rock mechanics tests are to be coordinated with the general development of the design.

RESUME:
On signale le fait que parfois les essais réalisés ne sont pas les plus indiqués pour résoudre les problèmes auxquels le maître de l'ouvrage et l'ingénieur doivent faire face. Sur la base de deux exemples concrets on met en évidence l'influence très différente que chaque propriété mécanique de la roche peut avoir selon la variable étudiée. On en déduit les critères à suivre dans l'étude des propriétés mécaniques. Les essais géotechniques doivent être coordonnés avec le déroulement du projet (voir texte français).

ZUSAMMENFASSUNG:
Der Verfasser macht darauf aufmerksam, dass häufig die durchgeführten Versuche nicht die ge-eigneten sind zur Lösung der Probleme, die sich den Bauherrn und den Projektierenden stellen. Aufgrund von zwei konkreten Beispielen wird der sehr unterschiedliche Einfluss hervorgehoben, den jede felsmechanische Eigenschaft auf die untersuchte Variable haben kann. Daraus werden Kriterien abgeleitet, die bei der Bestimmung der felsmechanischen Eigenschaften berücksichtigt werden sollten. Die Versuchsreihe muss insbesondere der gesamten Abwicklung des Projektes angepasst werden.

1. INTRODUCTION

It would certainly be pointless, in front of this assembly, to want to underline the importance of rock mechanics tests, at the time when one designs big works of civil engineering. But, we must recognize that, that which may be evident to us, is unfortunately not yet so to everybody and that very often, outside of our specialized meetings we are faced with a certain ignorance of the possibilities which our discipline really has to offer. Must one add that there's even a lack of confidence in the validity of the results which we can reach as well as in the interest of the measures which we are able to do? Sometimes it is very difficult to convince the owner, of the need to proceed with rock mechanics tests.

It isn't my purpose today to look for the causes of this situation - which I find deplorable - or to know if they are mainly due to a lack of diffusion of the necessary knowledge. Is it necessary then to put the blame on our associations for not having thought sufficiently about spreading our ideas? Isn't it instead the fault of the exaggerated optimism of those who, having only a partial and sometimes wholly theoretical knowledge of the subject, have launched themselves on costly test programs for the owner without knowing how to modify the projects advantageously so as to save or increase its safety through adequate interpretations and practical applications?

Having been charged to intervene in the projects of big, mostly underground works, I have often found myself in front of an owner who had already spent very large sums so as to proceed on useless tests and to whom one could not, at that stage, honestly ask to complete the series with the most important tests, the results of which would be missing thereafter. At that point it is often first of all a question of lack of time.

But, you will understand that, if it is easy to speak out so openly in general, in a specific case, it is far more difficult to frankly tell the concerned people, that up to the last moment, they have wasted their money on uninteresting tests. As a matter of fact,
Given a rock mass and knowing the general outline of the project one intends building, to which single rock mechanics properties to be measured must one give priority? What is the precision which one has to reach on each of the parameters and what is the statistical reliability of the results obtained with a certain number of measures? Again, where is the most suitable place to take samples and realize the tests?

One must not forget that the greatest difficulties are generally caused by such rock characteristics as anisotropy, heterogeneity at small and large scale as well as by the limited knowledge of the geological conditions and the impossibility of reaching each point of the rock mass to take samples or make tests, above all if one deals with underground works.

One must not overlook the fact that, at any rate, the cost of rock mechanics tests should on one hand remain reasonably in proportion to the estimated cost of the work and on the other hand be justified by the advantages which one expects to draw, thanks to a more intensive study of the work. In other words, the price of the gained information should not surpass its value.

In the present conditions of knowledge, it is clearly not possible to give a general answer to a matter so exposed. One can even righteously think that such an answer, which would not be limited to statements of principles without great practical usefulness, does not exist. On the other hand, it should be possible to give useful indications for each single case. These answers will depend on the considered rock mass on one hand and on the idea which one can make oneself about it beforehand and on the other hand, of the type, nature and importance of the work to be built.

In that which follows, we shall see that one will have to consider the type of parameter which chiefly interest the author of the design and the persons in charge of its realization.

With the help of two examples we are going to try to quantify the influence of deformations of a given uncertainty about each mechanical parameter which play a role or of a change of the value of these parameters. So as to do this we will limit ourselves to two existing underground works. It is understood that for other works one must expect different results.

2. FORMULATION OF THE PROBLEM

In a general way, and excluding pure research from our considerations, the question which we are faced with may be formulated as follows.
3. NUMERICAL EXAMPLES

3.1 First example

The first example refers to the section called "Mesozoic" of the St. Gotthard tunnel in Switzerland which has already been object of several publications. I will therefore not enter into details.

The geotechnical parameters retained are the following:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Elastic zone</td>
<td></td>
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<tr>
<td>Rupture zone</td>
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<tr>
<td>Friction angle</td>
<td>28°</td>
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<tr>
<td>Cohesion</td>
<td>40 kN/m²</td>
</tr>
<tr>
<td>Modulus of elasticity</td>
<td>1.10⁴ N/m²</td>
</tr>
</tbody>
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3.2 Second example

The second example refers to the ENEL underground power house at Timpagrande, Italy, which has been excavated in a tectonically broken and partially decomposed granit.

Figure 1 shows a section of the opening with a poured concrete arch and a stabilization of the longitudinal and cross walls with pre-stress anchors.

![Figure 1. Timpagrande power house: simplified cross section](image)

Figure 2. Timpagrande power house; measured and computed deformations of wall displacement

3.3 Influence of the variation of rock mechanics characteristics

With the aim of putting in evidence the influence on deformations of a variation of each mechanic property, we have proceeded with parametric studies. Results for both examples described can be seen in figure no.3.

On the upper part of the figure we have given the main dimensions of the works and the most important rock mechanic parameters. On the lower part of the same figure, we indicate the variations of radial deformations for a change of plus or minus 10% of each of the mechanic properties of the rock masses independently from others.

For the Mesozoic of the St.Gotthard it is noticed that a 10% variation of the modulus
of elasticity, of cohesion, of dilatancy and of the resisting pressure of the lining have only a slight influence on deformations. On the other hand, a variation of more or less 10% of the friction angle leads to differences on deformations which go from -35% to +77%. In this case, for example, the influence of cohesion being modest, there is no interest in spending too much so as to define it precisely. On the contrary, it is justified to urge forward the tests with the aim of finding the friction angle as exactly as possible.

GOTHARD
"MESOZOICUM"
POWERHOUSE OF
TIMPAGRANDA

\[ r_s = 6.5 \, m \]
\[ h = 300 \, m \]
\[ \gamma = 2600 \, kg/m^3 \]

\[ r_s = 13.50 \, m \]
\[ h = 110 \, m \]
\[ \gamma = 2600 \, kg/m^3 \]

**Rock characteristics**

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<tr>
<td>30</td>
<td>28</td>
<td>40</td>
<td>40</td>
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<tr>
<td>0.06</td>
<td>0.03</td>
<td>0.05</td>
<td>0.015</td>
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<tr>
<td>10^{-3}</td>
<td>5 \times 10^{-3}</td>
<td>E MN/m²</td>
<td>4 \times 10^{-3}</td>
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<td>-</td>
<td>-</td>
<td>DIL %</td>
<td>-</td>
</tr>
</tbody>
</table>

**Figure 3.** Influence of a variation of plus or minus 10% of the geotechnical values in two underground works.

The situation is very different in the case of the Timpargrande power house.

As a matter of fact, on the same figure you see what follows. Since a 10% variation of cohesion, of the modulus of elasticity, of dilatancy and of the pressure of the anchorings have a slight influence, the change of the friction angle has an influence of 20% but it does not reach by far that which has been observed for the St. Gothard. The established difference between the two cases, regarding the influence, is explained by the fact that the angles are very different (28° and 40°).

In general, we can say that when the friction angle is low one should measure it with an even greater precision at least when one deals with underground works.

One will again notice how in one case as in the other, the rock weight has a clear influence but this is a value easy to define with precision. It isn't evidently the same thing for the natural stress field notably if it has been disturbed. We know the problems that will then arise.

Taking the risk of displeasing certain negative-minded people who are fanatics of elasticity, I want to emphasize that in the two cases studied, the deformations depend much more on the angle of friction than on the modulus of elasticity.

4. CONCLUSIONS

In this way these two simple examples show how the influence of an uncertainty on a single rock mechanics property varies very much according to the problem to be solved and to the nature of the studied rock; while a 10% variation of the coefficient of friction can, for example, increase the deformations by a 20 or a 80% according to the case. On the contrary, the exact value of cohesion is of very small interest in these two examples.

The considerations which we have made up to now, refer only to the influence of the different properties on deformations at the wall of the excavation. If one studies other variable such as load on the lining, forces of the anchorings or deformations in other places, their sensibility to the variations of the rock properties will again be different.

Moreover, so as to simplify this report, we have not mentioned the rheological parameters, that is to say, the effect of time, which to say the truth, is a matter of utmost importance which will never be repeated sufficiently.

It seems to me that by following these parametric studies, we may arrive to the conclusion that it is necessary to coordinate the tests, the development of the project and the rock mechanics analysis with the greatest care. In other words, one must avoid proceeding with tests which may prove very costly and
make us wonder afterwards what we can do with them. It is undoubtedly advisable to start the studies on the basis of the estimated provisional values and to determinate as early as possible those which are worth investigating with precision by adequate tests and those which are of secondary importance and could even be ignored.

I join my opinion in this matter to the very pertinent remarks made by our general reporter. Only in this way will we obtain the greatest advantage from tests; thus favouring the owner, the work and in the long run, I believe, rock mechanics itself.

All that I have said is certainly not very new, nor original, but unfortunately one does not take these things into account each time.

I would like to thank the owners of the works who have agreed to the realization and publication of these studies.

Giovanni Lombardi

Bibliography (see French text)
Fig. 43. — Vue intérieure du bâtiment contenant, à Bardonèche, la partie inférieure des béliers, et les réservoirs d'air comprimé, avant leur suppression en 1868.