In search for realistic tests for determination of durability of waste rock as construction material from metallic mineral deposits

À la recherche des essais réalistes pour déterminer la durabilité des roches stériles comme matériau de construction provenant de dépôts minéraux métalliques

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ABSTRACT: Mining and civil engineering usually involve use of natural rock as construction material for fills. As standard procedure, the rock material to be used for this purpose has to be thoroughly investigated through in situ and laboratory tests in order to confirm its geotechnical suitability for construction. It is highly important to simulate the real conditions at which the materials will be exposed, in order to predict the alteration of the strength and deformation parameters i.e. to define durability with time. In this regard, most relevant tests are considered to be those which involve exposure of materials to real conditions. However, in practice, they are replaced by laboratory tests which cannot simulate the actual mechanical and chemical weathering of the rocks. Moreover, these time-dependent changes are not tested simultaneously or the tests used to determine the weathering resistance are not applicable to all types of rocks. This research is an attempt to suggest modifications of existing tests which determine the weathering resistance of the natural materials, especially for waste rock from metallic mineral deposits, often used for construction of tailing dams. In order to illustrate the effect of the suggested testing procedures, first results from modified slake durability tests are presented.

1 INTRODUCTION

Suitability of rock material used for construction of geotechnical, hydraulic and other structures is frequently analyzed by team of different experts. In case of high-risk structures built of rock, such as tailings dams, the appropriate physical-mechanical properties of the rock need to be constant in time, long after closure of the structure.

One key parameter of the fill constructions is the strength of the placed material. As mining of metallic minerals usually takes place in rocks with igneous origin and such waste material is used to construct a tailing dam, it is very important to define the potential for change of the rock mineral composition, which can result in relatively rapid reduction of the strength properties. The mineral alteration can be caused by mechanical or chemical weathering, which may also occur simultaneously. Hence, the quality of site investigations and laboratory testing is highly significant.

There are "sensitive" rock types which are intact and strong in depth, but, if exposed to exogenous conditions, rapidly change their mineralogical composition.

The most appropriate way of investigating the properties of the materials is to make scaled models which will be exposed to the real conditions expected during exploitation of the structure for a long period of time. However, these tests require a lot of time and resources, thus in practice are replaced by simplified laboratory tests. However, most of these tests are not applicable for altered igneous rocks that are prone to mechanical and chemical weathering, which is consider weakness of the current practice.

2 WEATHERING

Once excavated, more or less, rocks change their physical-mechanical properties as a result of variations in pressure, temperature, moisture and chemistry, ultimately resulting in decomposition, which increases the potential for faster chemical weathering due to increased contact surface.

Only mechanical weathering is characteristic for the areas with dry climate, because absence of moisture prevents chemical weathering or it is minimal (Carroll 1970). Thus, in areas with mild climates these two weathering types are linked.

Certain minerals within the rocks alter and convert from primary to secondary. It is a result of the chemical composition changes of the minerals. In this process certain elements from the rocks dissolve and leach in the surrounding environment by means of seeping precipitation or groundwater flows. The dissolved elements can trigger other chemical reactions or deposit at other locations. The most important aspect of the chemical weathering for this research is the increasing porosity and permeability and thus decomposition which decreases the strength properties and induces greater deformations.

3 WASTE ROCKS OBSERVATION

Ore minerals are always accompanied by minerals that have no industrial value. Therefore, mining metallic mineral deposits always involves treatment and containment of the waste material. In many cases the waste material is also used to build the containing structure. Thus, its properties should be also tested during the investigation processes.

In one case study of investigation of metallic mineral deposit it has been seen that waste material can be strong and intact until exposed to atmospheric conditions when chemical reactions start. The specified case study involves presence of pyrite in rocks of igneous origin, such as dacite, granodiorite and granite, which has not oxidized at greater depths. Considering that the mining should take place in open pit it is expected that the pyrite will start reacting after exposure, producing iron (III) hydroxide, sulfuric acid and ions of hydrogen. The significance of these reactions was proved by monitoring of subjected rock samples to the real conditions near the future mine location. After a year of exposure, decomposition of the material was easily visible (Figure 1).

This was also quantified by comparison of the results of sieve test before / after the exposure to atmosphere (Figure 2).

Figure 1. Comparison of material before and after exposure to exogenous conditions

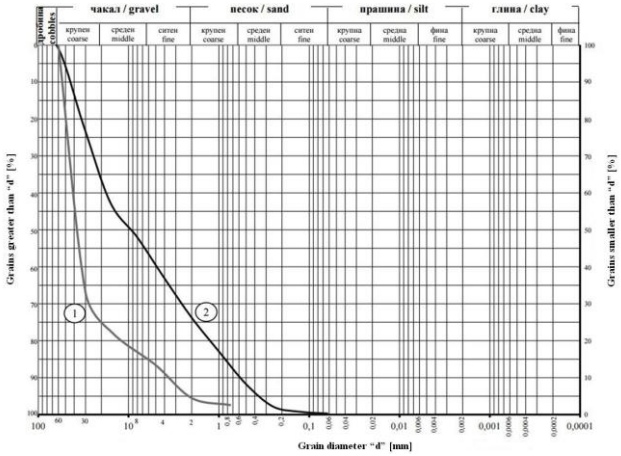

Figure 2. Particle Size Distribution for Sample 1 before (1) and after (2) atmospheric exposure

Based on these observations, it is important that decomposition is also determined by laboratory tests which are discussed in the following chapter.

4 MODIFIED SLAKE DURABILITY TEST

Slake durability test is recommended by the International Society for Rock Mechanics (ISRM 1979), to quantify the decomposition potential of the rocks, through wetting and drying cycles. It has been originally proposed by Franklin and Chandra (1970) for sedimentary rocks with significant presence of clay minerals. Furthermore, it was modified by Richardson and Long (1987) who called it *Sieved slake durability test*.

This test was used in the above mentioned case study in order to quantify the decomposition of the waste rock material, which is supposed to be used as fill for tailing dam. The inadequacy of the slake durability test was proven in absence of more appropriate test for complex mechanical and chemical decomposition of hard rocks. In contrast to the visible weathering of the rock, the lab test showed very high durability index. Thus, a search for realistic tests for determination of rock durability has started.

As first step is suggested modification of the existing slake durability test. It is well known that pyrite reacts when exposed to oxygen and the leaching is induced by seepage. However, laboratory testing is supposed to provide these conditions faster than in reality. Moreover, intense chemical environment causes further decomposition processes of the rocks. Therefore, the following modifications are suggested:

- Use of slaking liquid with true pH value produced by the tested rocks, measured in the field sample after one year of the usual long investigation period,
- Increase of the wetting and drying cycles in order to simulate the long exposure to agents and provide more time for the rocks to start reacting.

5 RESULTS

Slake durability tests were done on several samples by using water as liquid, however increasing the number of cycles from two to four. By comparing the index after the second and the fourth cycle it can be noticed that it decreases as the number of cycles ascends (Figure 3). This leads to the conclusion that the decomposition of the rocks is not stabilized after two cycles. For this reason it is recommended to increase the number of cycles until the index stops decreasing for at least two successive cycles. Additionally, tests were done with slaking fluid of pH value recorded from the leachate of samples exposed to the atmosphere. By comparison of the results, greater reduction of the slake durability index was shown (Figure 3). In order to provide advanced chemical reaction it is advised to keep the rock submerged in the produced chemical solution by the rock, for certain period of time before the test is done, in order to increase the effect of the chemical decomposition.

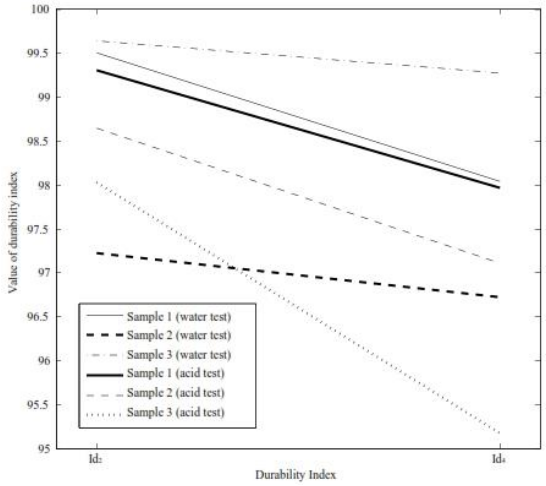

Figure 3.Results from the modified slake durability test

6 CONCLUSION

Exposing waste rock materials to the real conditions and their monitoring is the most relevant procedure to discover their real behavior in time. However, as mine life is usually very short, in relation to the high-risk structures from waste rock, such tests are nearly impossible to be performed. Therefore, it is necessary to establish new approaches for testing of the durability of the waste rock materials, by which they would be exposed to conditions as close as possible to the expected natural ones, in order to achieve more realistic assessment of the actual behaviour of the material within the future geotechnical/ hydraulic structures. The herein presented modifications to the standard slake durability test are an attempt to raise awareness for the need of further development of the standard and even develop new geotechnical laboratory tests for this purpose.

7 REFERENCES

Carroll D. 1970. *Rock weathering*. New York, Plenum Press

Chandra, K. 1970. *Slake durability test for rocks*. M.S. Thesis. University of London, Imperial College, Rock Mechanics Research Report, p. 55

ISRM 1979. Suggested methods for determining water content, porosity, density, absorption and related properties and swelling and slake-durability index properties. Part 2: Suggested methods for determining swelling and slake-durability index properties. International Society for Rock Mechanics.

Richardson, D.N. and Long, J.D. 1987. The sieve slake durability test. *Bull. Ass. Eng. Geol*., Vol. 24, No.2, pp. 247-258.