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# A Quantitative Classification of the Weathering and Weatherability of Rocks

## Classification quantitative de l'état d'altération et de l'altérabilité des roches

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### Summary

Parameters making possible a quantitative classification of the degree of weathering and of the weatherability of rocks are defined by the author. Rapid and simple testing methods are described. The author claims that this new method represents a considerable technical advance, supplying a solution to problems which have so far been insoluble, difficult or uncertain. He suggests some practical applications of the parameters defined.

### 1. Introduction

When the mechanical characteristics of a heterogeneous rock formation are studied, tests are carried out at various points, the results obtained being then extended to rocks of similar type.

For that purpose the area being studied should be zoned, the points apparently most suitable for tests being then selected in each zone. So far both zoning and selection of testing sites have been carried out by inspection.

If the heterogeneity merely consists in the existence of rocks of different types (e.g. granite and schist), this method is sufficiently objective to be acceptable. If, however, the heterogeneity is due to the existence of "differently weathered" rocks — which is nearly always the case — the method is unsatisfactory because the liability of error is very high, while the results obtained, given their subjective character, are difficult to understand and to interpret.

It therefore seems advisable to replace the subjective methods so far used in the determination of the "degree of weathering" in rocks by new objective methods.

Thus in the characterization of a rock, e.g. a granite, the indication "much" or "little" weathered should be replaced by a number objectively describing that "degree of weathering".

The author defines parameters which enable objective classifications to be made of the "degree of weathering" and of the "weatherability" of a rock.

### 2. Qualitative definitions of the degree of weathering and of the weatherability of a rock

In order to facilitate the present study, two different types of weathering are considered :

Type I : weathering excluding cracking of any kind.

Type II : weathering consisting exclusively of cracking.

### Sommaire

L'auteur définit dans cette communication des paramètres permettant une classification quantitative de l'état d'altération et de l'altérabilité des roches. Il indique la technique des essais, assez simples et rapides.

L'application de ce nouveau procédé dans la Mécanique des Roches permettra sans doute un progrès considérable, car elle rendra possible l'étude de problèmes que, jusqu'à présent, on ne savait pas résoudre et celle d'autres dont la résolution était compliquée ou peu claire.

Il présente également des suggestions sur l'application des paramètres définis et donne quelques exemples d'application.

Different parameters are defined for each type without any limitation whatsoever; if both types of weathering are simultaneously present both types of parameters can be simultaneously applied. The following definitions are independent of the above distinction.

*Degree of weathering of a rock*—A certain volume of a given rock is said to be more weathered than another volume of the same rock, if the mechanical characteristics of the former are lower.

*Weatherability of a rock*—A rock is said to be more weatherable than another if, both having been subjected to the same weathering agencies during the same time, the degree of weathering is more advanced in the former.

### 3. Quantitative definitions of the degree of weathering and of the weatherability of a rock

As regards type I weathering it was observed long ago that as a rock is being weathered, the moisture content of a saturated sample of this rock keeps increasing whatever the saturation method used (1). Now this increase is roughly a maximum for a quick absorption test consisting in soaking a previously dry stone by immersion.

It was observed, likewise, that the apparent dry unit weight of a rock decreases as type I weathering progresses (1).

In fact as type I weathering proceeds in the rock, its void ratio increases due both to the expansion of the rock itself (2) and to the partial dissolution of its components (2).

Thus, although apparently any of the parameters can be used for classification, the former will be preferred for the following reasons :

1. It is easier to determine in the laboratory.

2. It enables a more accurate distinction to be made between soils and rocks.

3. It does not require special precautions in the study of rocks undergoing volume changes due to moisture exchange (2).

As for classification in type II weathering, it will suffice to measure the cracks (3).

In conformity with the above definitions, weatherability is expressed by the rate of change of the parameters defining the degree of weathering, no new concepts being introduced.

### 3.1. Parameters of state $i_I$ and $i_{II}$ :

These parameters corresponding to, respectively, type I and type II degree of weathering are defined as follows.

(a) *Parameter of state  $i_I$* —The numerical value of  $i_I$  is the percentage of water absorbed by the rock in a quick absorption test, divided by its dry weight.

Calling :

$P_1$  : the dry weight of a rock sample (oven-dried at  $105 \pm 2^\circ \text{C}$ );

$P_2$  : the weight of the same sample saturated by quick absorption;

$$i_I = \frac{P_2 - P_1}{P_1} \times 100.$$

The time required for saturating a rock sample by quick absorption is a characteristic of the rock for samples with the same volume and shape, its value depending on the degree of weathering.

For different samples weighing from 150 to 250 grams, values very near saturation can be obtained by quick absorption tests lasting from 1/2 to 1 1/2 hours.

The duration of the quick absorption test shall be fixed for each rock according to the accuracy required in the determination of  $i_I$ , it being advisable to keep it constant in the tests. The time required to dry a sample in the oven is also a characteristic of the rock, for equal shape and volume of the samples and similar drying conditions. In a well-ventilated oven, a sample can be dried in about 2 hours, it being advisable to take the precautions indicated above regarding this period of time.

The following are necessary and sufficient conditions for  $i_I$  to be considered really satisfactory for characterizing type I weathering in a rock :

1. A one-one relationship should exist between  $i_I$  and the mechanical strength characteristics  $R_x = R_x(c, \varphi)$ , on one hand, and between  $i_I$  and the modulus of elasticity  $E$ , on the other, i.e. :

$$E_x \rightleftharpoons i_I \rightleftharpoons R_x(c, \varphi)$$

$\alpha$  : name of the rock

2. The range of values  $i_I$  for a given rock must be extensive enough, i.e. it shall enable a clear distinction to be made between any type I degrees of weathering.

As verified tests, these conditions are satisfied within the precision required for practical purposes by schists, graywackes, granites, diorites and lime.

(b) *Parameter of state  $i_{II}$* —Regarding weathering consisting exclusively of cracks, the very important case of surfaces forming continuous or almost continuous diaclasses which may originate slides are not discussed below, as they have to be dealt with by other methods. The only case to be considered

below shall be that of a formation cut by systems of diaclasses, which on the whole do not form very extensive surfaces with peculiar characteristics.

Contrary to  $i_I$ ,  $i_{II}$  is a vector magnitude which nevertheless in practical instances can almost always be replaced by the corresponding scalar magnitude.

$\alpha_x$ ,  $\alpha_y$  and  $\alpha_z$  being the linear dimensions of the diaclose openings along three orthogonal axes per unit length,

$$i_{II} = (\alpha_x + \alpha_y + \alpha_z) \times 100,$$

i.e., roughly the void ratio.

In the majority of cases, it will be convenient to separate  $i_{II}$  into two parts  $i'_{II}$  and  $i''_{II}$ , corresponding to the diaclasses respectively with and without fill, so that  $i_{II} = i'_{II} + i''_{II}$ . The value of each of these parts will be determined as indicated for  $i_{II}$ . A ruler will be very useful in this connection for measuring the cracks.

3.2. *Parameters  $j_I$  and  $j_{II}$* —The numerical values of these parameters are equal to the figures representing the change of the degree of weathering in a given time (brought about by natural or artificial methods) divided by that same interval of time.

Hence

$$j_I = \frac{\Delta i_I}{\Delta t}$$

$$j_{II} = \frac{\Delta i_{II}}{\Delta t}$$

The values of  $j$  will be comparable only if weathering conditions are the same during  $\Delta t$ . Additionally it is convenient that the intervals of time  $\Delta t$  corresponding to the values of  $j$  to be compared be of the same order of magnitude and small in comparison with the intervals of time required for the transformation of the unaltered rock into a soil under the action of the same weathering agencies.

The latter is a necessary condition since, as experience has shown, parameters  $j$  do not remain constant for the same rock permanently subjected to the same weathering conditions.

## 4. Application of the method

### 4.1. Instances of application :

The relationship between the boring resistance of a schist and the parameter of state  $i_I$  is presented in Fig. 1. The boring resistance is expressed by the number of turns required by a drill to penetrate a certain length into the schist, under the action of a given load.

Figs 2, 3 and 4 show the relationships between  $i_I$  and the resistance characteristics of a granite (4), (5).

The results presented in Fig. 4 correspond to extremely weathered granites. In order to give an approximate idea of that degree of weathering, it will suffice to mention that a granite for which  $i_I = 10$  can be easily disintegrated by hand.

A value of  $i_I$  was determined for each tested sample, from which comparatively accurate could be drawn. The results presented in Fig. 4 display a considerable dispersion for high values of  $E$ , what is understandable, since a hardly visible crack, which may be produced while the sample is being prepared, suffices to decrease  $E$  a good deal.

The results presented were obtained in laboratory tests carried out for Hidroelectrica do Cavado.

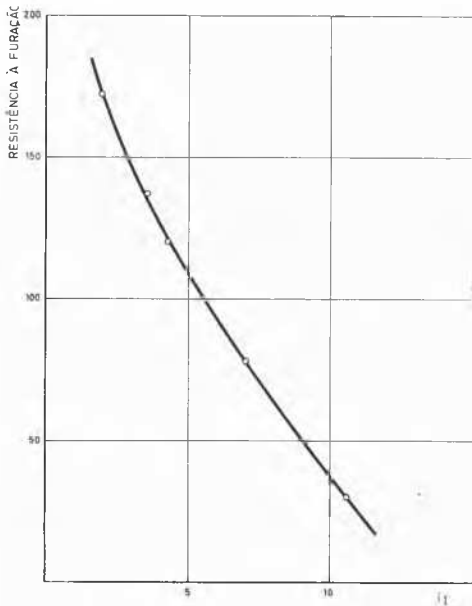


Fig. 1 Relationship between the boring resistance and the parameter of state  $i_I$  for a schist.  
 Relation entre la résistance au forage d'un schiste et son paramètre d'état  $i_I$ .

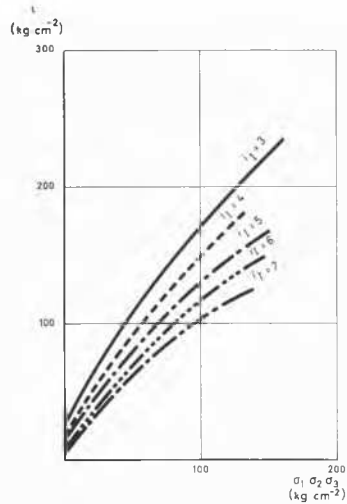


Fig. 2 Intrinsic curves of a granite in function of the parameter of state  $i_I$  (tests carried out on samples with a 35 mm diameter).  
 Fig. 2 Courbes intrinsèques d'un granit en fonction du paramètre d'état  $i_I$  (essais sur des éprouvettes de 35 mm de diamètre).

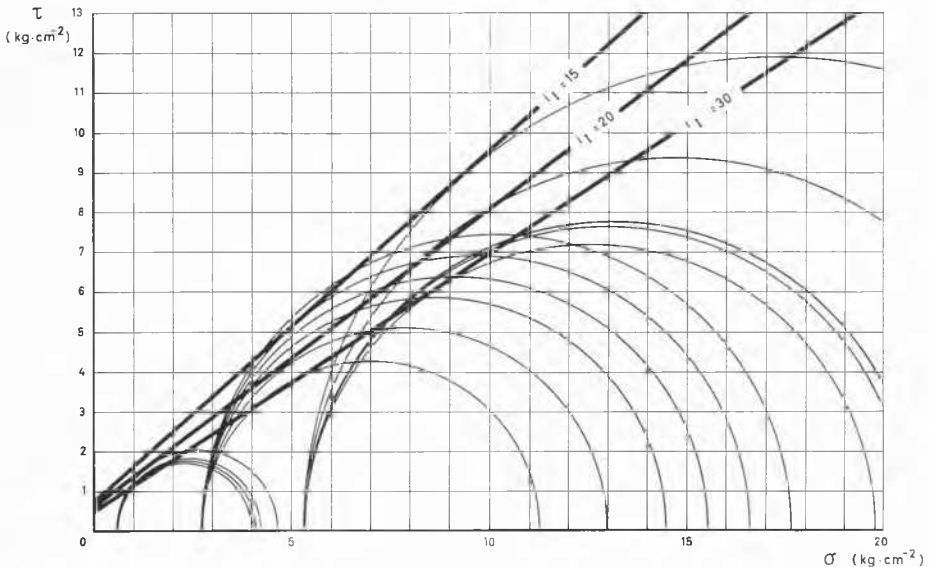


Fig. 3 Intrinsic curves of a granite in function of the parameter of state  $i_I$  (tests carried out on samples with a 20 cm diameter).  
 Courbes intrinsèques d'un granit en fonction du paramètre d'état  $i_I$  (essais sur des éprouvettes de 20 cm de diamètre).

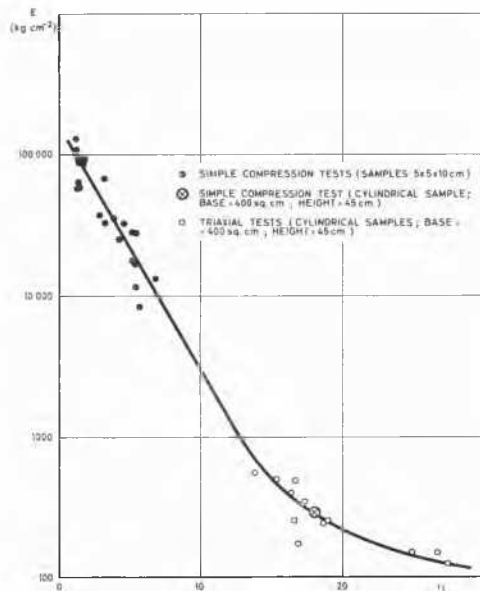


Fig. 4 Relationship between the modulus of elasticity  $E$  and the parameter of state  $i_j$  for a granite.

Relation entre le module d'élasticité  $E$  d'un granit et le paramètre d'état  $i_j$ .

#### 4.2. Rock surveys :

So far, the methods in use in Soil Mechanics enabling a satisfactory classification of soils to be made are not applicable to rocks.

The exploration of extensive areas and a very accurate zoning in rock surveys is now possible by means of very simple determinations making use of parameters  $i$  and  $j$ .

4.2.1. *From the points of view of strength and deformability*—A precise definition of the mechanical characteristics of rocks, notably their strength and deformability, can be easily obtained by classifying the rocks with the help of the parameters  $i$  and  $j$ .

4.2.2. *From the point of view of permeability*—Data required for studying problems connected with permeability can also be obtained on objective grounds by means of the parameters  $i_{11}$  and  $j_{11}$  determined either directly by the above method or indirectly by means of other tests to be described elsewhere. In some particular cases (notably in the study of rock grouting) frequency curves of the linear dimensions of the diaclose openings will also be required.

#### 4.3. Acceptance of stone for civil engineering structures :

The parameter  $i_j$  makes possible a very quick and accurate control of stone products for construction works, leaving no doubts regarding the grounds for rejection. Given its simplicity, the test can be carried out in a large scale at negligible cost.

#### 4.4. Criteria for judging the mechanical characteristics of artificial stones :

It seems possible to use the parameters  $i_j$  and  $j_j$  for studying the mechanical characteristics of artificial stones as well as for natural stones.

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