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EFFECTS OF WEATHERING ALTERATION ON THE MECHANICAL BEHAVIOUR OF THE KAVALA GRANODIORITE (N. GREECE)

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ABSTRACT

The effect of weathering alteration on the mechanical behaviour of the Kavala granodiorite is investigated and a mathematical expression of this correlation is given. The collected samples are examined mineralogically by means of polarized microscope and X-ray techniques and their weathering degree is estimated. Then the physical features of the rock (bulk specific gravity and water absorption) as well as the mechanical properties (compressive strength and Young´s modulus) are determined. Diagrams showing the change of the water absorption versus the weathering index and the bulk specific gravity, the change of the resistance in compressive strength and the elastic modulus verus the water absorption and the weathering index and finally the change of the elastic modulus versus the resistance in compressive strength are given. At the end the examined physicomechanical behaviour and the resistance of the Kavala granodiorite in relation to its weathering degree are expressed in relative mathematical regressions.

ΣΥΝΟΨΗ

Εξετάζεται η επίδραση του βαθμού αποσάθρωσης πάνω στη μηχανική συμπεριφορά του γρανοδιορίτη της Καβάλας. Δίδονται διαγράμματα που δείχνουν τις σχέσεις που συνδέουν το βαθμό αποσάθρωσης, το ξηρό φαινόμενο βάρος, την υδροαπορροφητικότητα, την αντοχή σε μοναξονική καταπόνηση και το μέτρο ελαστικότητας του Young. Τέλος η εξεταζόμενη φυσικο-μηχανική συμπεριφορά και αντοχή του γρανοδιορίτη της Καβάλας σε σχέση με το βαθμό αποσάθρωσής του εκφράζεται με τις παρακάτω μαθηματικές συναρτήσεις:

Β.ΧΡΗΣΤΑΡΑΣ, Α.ΚΑΣΩΛΗ-ΦΟΥΡΝΑΡΑΚΗ & Ε.ΜΩΡΑΙΤΗ

ΕΠΙΔΡΑΣΗ ΤΟΥ ΒΑΘΜΟΥ ΑΠΟΣΑΘΡΩΣΗΣ ΣΤΗ ΜΗΧΑΝΙΚΗ ΣΥΜΠΕΡΙΦΟΡΑ ΤΟΥ ΓΡΑΝΟΔΙΟΡΙΤΗ ΤΗΣ ΚΑΒΑΛΑΣ (Β.ΕΛΛΑΔΑ)

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$$Ab = 0.2 + 4.48\ (1/Ip) \quad \mu\varepsilon \quad r = 0.995$$

$$Ab = 23.82 - 8.77\ d_{110^o} \quad \mu\varepsilon \quad r = -0.992$$

$$\sigma = 925.4\ Ab^{-0.7} \quad \mu\varepsilon \quad r = -0.982$$

$$\sigma = 162 - 597\ \ln(1/Ip) \quad \mu\varepsilon \quad r = -0.999$$

$$E = 194732\ Ab^{-1} \quad \mu\varepsilon \quad r = -0.988$$

$$E = 44047\ (1/Ip)^{-0.97} \quad \mu\varepsilon \quad r = -0.997$$

$$E = 33770\ e^{0.0016.\sigma} \quad \mu\varepsilon \quad r = 0.999$$

'Οπου Ab: υδροαπορροφητικότητα, 1/Ip: δείκτης αποσάθρωσης, d_{110^o}: ξηρό φαινόμενο βάρος, σ: αντοχή σε μοναξονική θλίψη, Ε: μέτρο ελαστικότητας Young, και r: συντελεστής συσχέτισης.

1. INTRODUCTION

The effect of weathering alteration on the mechanical behaviour of the rocks has been the subject of investigation for many workers. Studies have been made on different kinds of rocks such as granites, basalts or metamorphic occurrences.

Increasing weathering processes and the weathering susceptibility of common rock forming minerals has shown that feldspars (particularly plagioclases) are one of the minerals that initiate mineral weathering in rocks, with micas and other easily altered minerals following.

The importance of feldspars as an indicator of the extent of weathering has been recognised in engineering classification of weathered granite.

Moye's (1955) classification of weathered granites of the Snowy Mountains, Australia, considered the weathering and decomposition of feldspars as one of the factors needed for the recognition of the different grades. The classification of Tuxton and Berry (1957) as well as that of Little (1969) on Hong Kong granites, considers the partial or complete decomposition of feldspars as a useful index of the mechanical grading of weathered rocks. Such changes have also been considered by Newbery (1970), Dearman (1974,76), Dearman et al. (1978), Malomo (1980), Baudracco et al. (1982).

In the present paper the effects of minerals alteration on the mechanical properties of the Kavala granodiorite are investigated trying to establish a mathematic correlation between the alteration degree and the rock resistance, which might help to the knowledge of the rock's behaviour in the constructions or in its use as a construction material.

2. PETROGRAPHY

The granodiorite of Kavala belongs to southern part of the Greek Rhodopian massif. On the petrography and geomorphology of the Kavala occurrences as well as the Symbolon series many authors have worked as Cvijic (1908),Erdmannsdoerfer (1925), Osswald (1938), Schulze (1937), Geogriadis (1954), Fischer (1964), Kronberg (1966) and Kokkinakis (1977).

The examination of the collectd samples revealed under the microscope the following:

The texture is that of a dynamic metamorphosed granodiorite with coarse grains of the original igneous rock and foliation due to limited deformation. The coarse grains are separated by a fine grained schistose matrix. The coarse grains, anhedral in shape (rounded or elongated) belong to feldspars (potassium and pla-

Ψηφιακή Βιβλιοθήκη "Θεόφραστος" - Τμήμα Γεωλογίας. Α.Π.Θ.

gioclase) and quartz, presenting almost in their total undulatory and patchy extinction. The minerals show strain effects (bending, twinning, alteration, fracturing). Recrystallization is monr and limited to some of the quartz and mica.

The mineralogical composition is:quartz, feldspars (microcline, orthoclase, albite, oligoclase), biotite (quite often altered to chlorite), and muscovite, as main minerals. Sphene, allanite, apatite, garnet and opaque minerals participate in minor quantities.

The rock samples were collected from lacations showing a gradual degree of alteration. The alteration was expressed by kaolinization and sericitization of the feldspars, chloritization of biotite and fracturing (not oriented microfractures) of the rock because of the altered minerals and the stress that effected the whole body. All the above resulted in a more or less loose connection of the grains effecting correspodingly the mechanical resistance of the rock sample.

3. MATERIALS, METHODS AND TEST RESULTS

This study was made in samples from six locations (1-6) of the same bulk, showing a grdual alteration degree. The sample collection was made according to the following criteria:

a) Each of the six samples must present a different and uniform alteration degree.
b) The examined specimens must not show macroscopic fractures or other surfaces of discontinuity.
c) The degree of alteration.

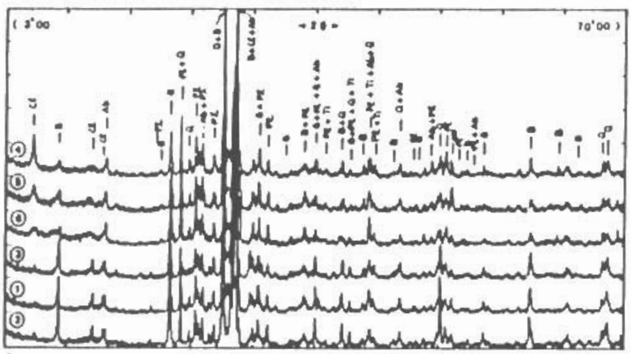

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Fig. 1. X-ray difraction patterns of the six granodioritic rock samples. B = Biotite, Cl = Clinochlore, Q = Quartz, Ab = Albite, Pl = Plagioclase, Ti = Sphene

Σχ. 1. Ακτινογραφικά διαγράμματα των έξι γρανοδιοριτικών δειγμάτων. B = Βιοτίτης, Cl = Κλινόχλωρο, Q = Χαλαζίας, Ab = Αλβίτης, Pl = Πλαγιόκλαστο, Ti = Τιτανίτης

Ψηφιακή Βιβλιοθήκη "Θεόφραστος" - Τμήμα Γεωλογίας. Α.Π.Θ.

Thin sections were prepared and examined under the polarized microscope. With the aid of a swift point counter the percentage of the unaltered and altered parts of each rock sample was determinded. XRD patterns with the use of a SIEMENS diffractometer, Cu Ka radiation (I.G.M.E., Athens) were for each sample and the mineralogical results are presented in Fig. 1.

The rock was also studied concerning its physical features (bulk specific gravity and water absorption) and its mechanical behaviour (compressive Strength and Young´s modulus). The tests were made in cylindric specimens of diameter 2.4 cm and height 4.8 cm (diameter /height = 1/2). For this purpose the core drill of the Geophysical Laboratory was used. The mean value of three tests (Table 1) were used in relative diagrams and mathematical expressions representing the change of the mechanical behaviour of the rock according to its alteration degree were deduced.

One problem that we faced was the arithmetical expression of the alteration degree. According to Irfan and Dearman (1978) the relation

$$Ip = \frac{\%\ \text{unaltered minerals}}{\%\ \text{altered minerals + microfractures}}$$

can be used for the quantitative determination of the weathered granites. In our study we considered the relation 1/Ip as more indicative of the directly expressed rock alteration and we called it "weathering index".

Water absorption The water absorption (Ab) as well as the bulk specific gravity (d_{110^o}), at 110^o C) of the specimens were estimated according to the ASTM-C 97-47. From the diagram a of Fig. 2 its deduced that the rock Ab increases with increase of the weathering index with a correlation coefficient r = 0.995 according to the linear regression Ab = 0.02+4.48 (1/Ip)

Tab. 1. Experimental data of the physical and mechanical features of the Kavala granodiorite

Πιν. 1. Πειραματικά δεδομένα των φυσικών και μηχανικών ιδιοτήτων του γρανοδιορίτη της Καβάλας

Spec.	unaltered minerals %	altered minerals+microfractures %	Ip	1/Ip	d_{110^o}(g/cm^3)	Ab%	σ(Kg/cm^2)	E(Kg/cm^2)
1	93.45	6.65	14.38	0.07	2.66	0.41	1725	$5.50X10^5$
2	90.23	9.77	9.24	0.11	2.65	0.48	1504	$4.00X10^5$
3	84.20	15.80	5.33	0.18	2.64	0.68	1194	$2.30X10^5$
4	68.60	31.40	2.18	0.45	2.48	2.22	639	$1.00X10^5$
5	63.00	37.00	1.70	0.59	2.43	2.68	487	$0.78X10^5$
6	58.00	42.00	1.38	0.72	2.33	3.16	342	$0.55X10^5$

The water absorption also shows a negative linear correlation with the bulk specific gravity (d_{110^o}) of the rock (Fig. 2b) according to the regression Ab = 23.82-8.77d with r = -0.992.

Ψηφιακή Βιβλιοθήκη "Θεόφραστος" - Τμήμα Γεωλογίας. Α.Π.Θ.

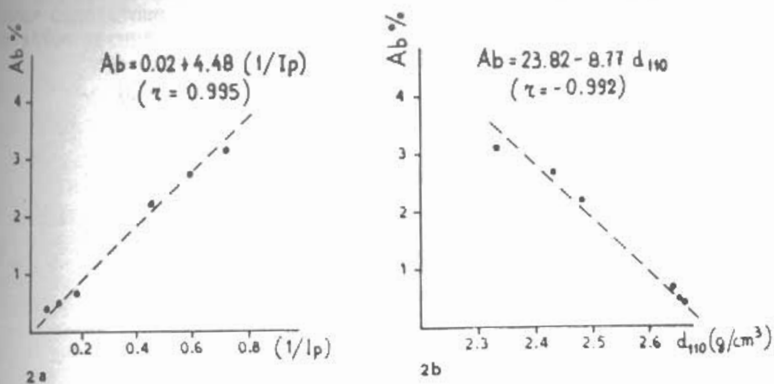

Fig. 2. Diagrams showing the change of the water absorption of the Kavala granodiorite versus the weathering index (α) and the bulk specific gravity (b).

Σχ. 2. Διαγράμματα μεταβολής της υδροαπορροφητικότητας του γρανοδιορίτη Καβάλας σε συνάρτηση με το βαθμό αποσάθρωσης (α) και το ξηρό φαινόμενο βάρος (b)

Compressive strength. The resistance of the specimens regarding the compressive strength (σ) as well as the determination of Young´s modulus (E) were made according to the ASTM C 170-50 and D 3148-72. For this purpose the compressive strength apparatus ($Load_{max}$ = 10 tn) of the Polytechnic School of Thessaloniki, was used.

From the tests it resulted that the rock resistance in uniaxial loading (Fig. 3a,b) and the Young´s modulus (Fig. 3c,d) show a negative logarithmic change versus the change of the weathering index ($1/_{Ip}$) and the water absorption(which expresses the porosity of the rock).
These changes are given by the following regressions:

$\sigma = 925.4XAb^{-0.7}$ (r = - 0.982)

$\sigma = 162\text{-}597\ \ln(1/_{Ip})$ (r = - 0.999)

$E = 194732\ Ab^{-1}$ (r= - 0.988)

$E = 44047\ (1/_{Ip})^{-0.97}$ (r = - 0.997)

Ψηφιακή Βιβλιοθήκη "Θεόφραστος" - Τμήμα Γεωλογίας. Α.Π.Θ.

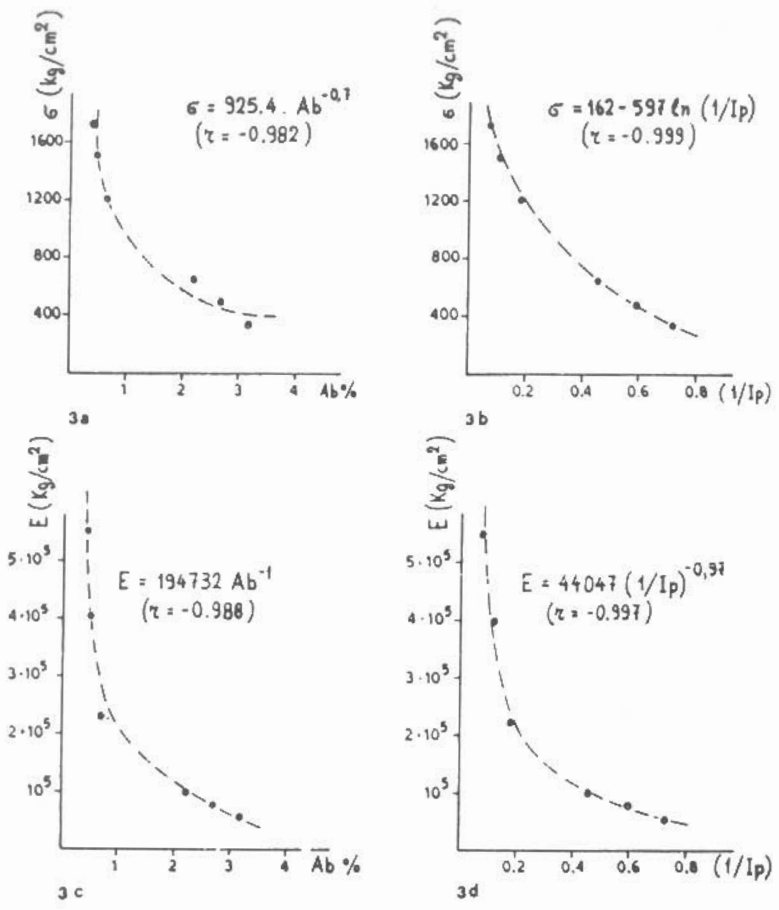

Fig. 3. Diagrams showing the change of the resistance in compressive strength (a,b) and the elastic modulus (Young's modulus c,d) versus the water absorption and the weathering index of the Kavala granodiorite .

Σχ.3. Διαγράμματα μεταβολής της αντοχής σε μοναξονική καταπόνηση (a,b) και του μέτρου ελαστικότητας (Young's modulus c,d) σε συνάρτηση με την υδροαπορροφητικότητα και το βαθμό αποσάθρωσης του γρανοδιορίτη της Καβάλας.

It must be noticed also that as it is seen in the diagrams of Fig. 3, a very slight increase of the weathering index and the water absorption of the rock results in the abrupt decrease of the mechanical resistance, which is more obvious in the less weathered specimens.

Ψηφιακή Βιβλιοθήκη "Θεόφραστος" - Τμήμα Γεωλογίας. Α.Π.Θ.

Furthermore, it is noted that for parts of the rock the cnange of the elastic modulus, E, is not linear to the resistance of the rock under conditions of uniaxial loading (Fig. 4) but it shows a logarithmic relation according to the equation

$$E = 33770\ e^{0.0016\ \sigma} \qquad (r = 0.999)$$

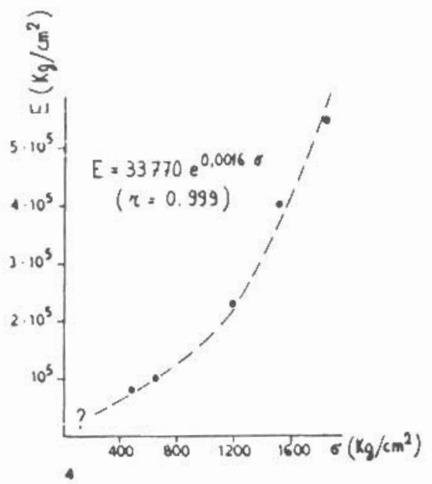

Fig. 4. Diagram showing the change of the Young's modulus versus the resistance in compressive strength of the Kavala granodiorite.

Σχ.4. Διάγραμμα μεταβολής του Young's modulus σε σχέση με την αντοχή σε μοναξονική καταπόνηση του γρανοδιορίτη της Καβάλας.

4. CONCLUSIONS

From the above study and the elaboration of the experimental data we deduced the following:

a) The physico-mechanical behavior and the resistance of the Kavala granodiorite changes with its weathering degree according to the following regressions:

$Ab = 0.02 + 4.48\ (1/_{Ip})$ with $r = 0.995$

$Ab = 23.82 - 8.77\ d_{110^o}$ with $r = -0.992$

$\sigma = 925.4\ Ab^{-0.7}$ with $r = -0.982$

$\sigma = 162 - 597\ \ln(1/_{Ip})$ with $r = -0.999$

Ψηφιακή Βιβλιοθήκη "Θεόφραστος" - Τμήμα Γεωλογίας. Α.Π.Θ.

$$E = 194732\ Ab^{-1} \quad \text{with} \quad r = -0.988$$

$$E = 44047(1/_{Ip})^{-0.97} \quad \text{with} \quad r = -0.997$$

$$E = 33770\ e^{0.0016.\sigma} \quad \text{with} \quad r = -0.999$$

b) In relatively unaltered parts of the rock a slight increase of the weathering index causes a great decrease of the mechanical resistance, a fact that marks the significance of the mineralogical situation of the rock in engineering applications.

Finnally, we conclude that the above data make easy a first estimation of the mechanical behavior of the Kavala granodiorite according to its mineralogical examination and the weathering degree.

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Ψηφιακή Βιβλιοθήκη "Θεόφραστος" - Τμήμα Γεωλογίας. Α.Π.Θ.