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THE ENGINEERING GEOLOGICAL PROPERTIES OF THE TRIASSIC DOLOMITE OF THE STEFANI AREA (GREECE) IN RELATION TO ITS SUITABILITY IN SKID RESISTANT PAVEMENT SURFACE CONSTRUCTION

INAPTITUDE DES DOLOMIES TRIASIQUES DE STEFANI (ATTIQUE, GRÈCE) À ÊTRE UTILISÉES COMME GRANULATS POUR CHAUSSÉES EN RAISON DE LEUR GLISSANCE

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Summary

The Engineering Geological properties of the Middle-Upper Triassic Dolomite have been studied as far as the suitability of its aggregates in the skid resistant pavement surface construction is concerned. Representative dolomite samples have been collected from the Stefani quarry, described in detail in terms of rock mass and rock material, and analysed chemically. Its petrography and thermo-differential analysis have also been included.

Among the tests performed were physical properties tests, shape indices tests, mechanical properties and wear resistance tests, and weathering simulation tests.

The investigations finally showed that it is a chemically and mineralogically pure, massive, strong, wear and weathering resistant, but, however, polishing susceptible, dolomite rock. Therefore it is not very suitable for the skid resistant pavement surface construction.

Résumé

On a étudié les propriétés des dolomies du Trias moyen et supérieur de la région de Stefani en Attique et on a examiné leur utilisation comme granulats pour chaussés non glissantes. Des échantillons représentatifs des dolomies des carrières de Stefani ont été étudiés du point de vue chimie, minéralogie et pétrographie.

Parmi les essais qui ont été faits on signale les essais pour la détermination des propriétés physiques et mécaniques, les essais pour les indices de forme, pour la résistance à l'usure et à l'altération.

L'interprétation finale a donné comme résultat que la dolomie étudiée est chimiquement et minéralogiquement pure, massive, dure, de bonne résistance à l'usure et à l'altération, mais pourtant facilement polissable. Donc cette dolomie n'est pas utilisable comme granulats de chaussées antiglissantes, surtout sur les tronçons où les exigences sont importantes (virages etc.).

Introduction

The strata of the Middle-Upper Triassic are well exposed in the area of Stefani in Attiki, Greece. The rocks vary in thickness, having a maximum thickness of 350 metres.

Dounas mapped the wider region (1969), and divided the strata into three lithological units : Limestone, Dolomitic Limestone and Dolomite.

Dolomite rock has been quarried in the Stefani area for aggregate production. Despite the local importance of the quarring industry, there is very little published (with the exception, of G. Marinos) on the chemistry and petrography or the geotechnical properties of the Middle Upper Triassic Dolomite. This paper is mainly concerned with the determination of the engineering geological and geotechnical properties of the Stefani Dolomite, which are primarily relevant to the suitability of its aggregates in the construction of skid-resistant pavement surfaces, as well as its chemistry and petrography.

Background geology

The wider region of the studied dolomite quarry in Stepani, belongs to the Subpelagonic zone of the Hellinic Geotectonic zonal scheme (Tataris, 1967; Aubouin, 1958). The general geological succession in this wider region, is shown in Figure 1.

The dominantly marine 350 m thick Middle-Upper Triassic Dolomite complex, deposited about 180 million years ago, is underlain by the Lower-Middle Triassic sandstone, limestone, chert, shale and tuff complex and overlain by the marine Upper Triassic, greyish black limestone complex.

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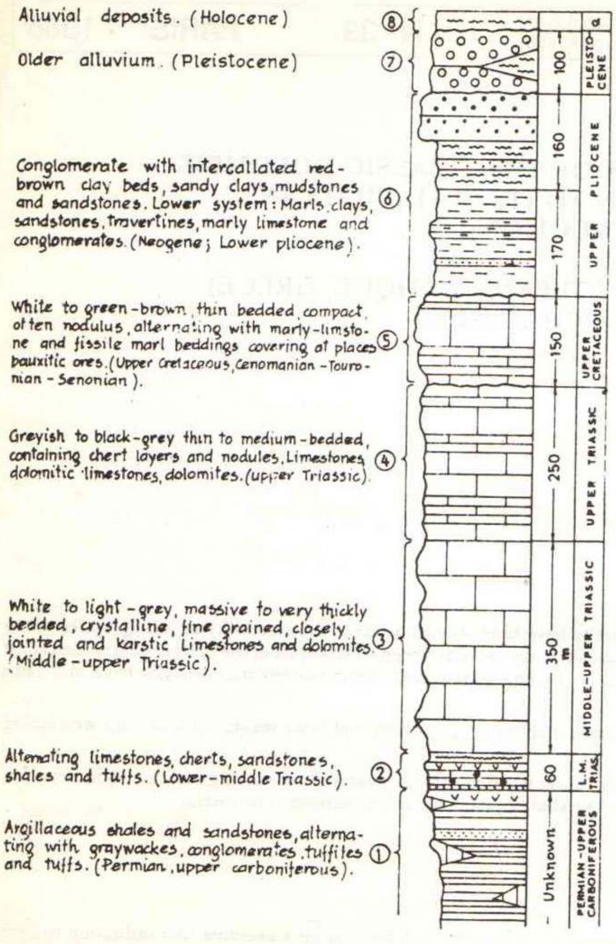

Fig. 1 : General columnar section of the studied area. (after A. Dounas).

The dolomite complex is a neritic to abyssal zone sediment (Maratos, 1972) consisting of limestones, dolomitic limestones and dolomites. The complex being massive to thickly bedded, crystalline, with closely spaced joints and fractured in places and the limestones being karstified. The dolomite varies in thickness within the complex and outcrops in numerous locations in the region, one of which is in the quarry of Stefani.

During the Alpine (mainly, Palaeokimmerian phase and Pyrenian paroxysmic phase during Raitian and Priambonian age respectively) orogeny, the area suffered two periods of compressional stress both dominantly from Southeast to Northwest causing Southwest-Northeast trending folds very well developed in the region around Stefani village. As a result of these stresses the rocks in the area were tilted and folded and in places even overfolded. In many localities there is major overthrust fault movement, as well as normal faulting.

As the main material quarried is dolomite, special emphasis has been placed in obtaining certain geotechnical properties of the dolomite rock.

Engineering geological description

Careful examination of the quarry faces has produced the following rock description according to the scheme proposed by the working party report (Anon. 1972) "White to light grey, fine grained, massive to very thickly bedded, generaly closely spaced joints, but in places the rock is fractured, fresh, pure, DOLOMITE, very strong, with a moderately to highly permeable rock mass.

Mineralogy and petrography

The microscopical investigation on thin sections carried out by Fekeldjiev (1984) revealed the following : the rock is practically monomineral. It consists of carbonate-dolomite type and is characterized by the following refractive indices:

$N_o = 1{,}675 \qquad N_e = 1{,}495 \qquad N_o - N_e = 0{,}180$

The carbonate crystals vary in size, the largest being up to 1,5 mm and they are cemented together by means of very fine grained carbonate substance up to 30 microns in size. These fine cementing crystals are slightly coloured to a yellow hue, due to presence of ferrous oxides and hydroxides.

There are also small visible quartz grains up to 20 microns very rarely dispersed, in the dolomite as well as separate muscovite scales. Finally the dolomite is micritic in texture with most of the grains showing a rhombic shape.

Chemical analysis

The total chemical analysis of the dolomite rock has produced the following composition :

$S_iO_2 = 0{,}27$ %	$Al_2O_3 = 0{,}14$ %		$Fe_2O_3 = 0{,}05$ %
TiO_2 = traces	$CaO = 31{,}02$ %		$MgO = 21{,}23$ %
h.loss = 47,09 %	$S = 0{,}06$ %	and	$P = 0{,}13$ %

From the chemical analysis the following percentages are considered — $CaCo_3$-$MgCO_3$ — according to the DIN 55919 "Dolomit" requirements:

	Stefani Dolomite	DIN 55919
1. $CaCO_3$ content	55,49	min 33 %
2. $MgCO_3$ content	44,32	min 44,5 %
3. $CaCO_3 : MgCO_3$ ratio	1,25	1,18-1,24
4. P.H.	9,28	8-10,5

Therefore comparing the chemical composition of this dolomite with the International Standards, we conclude that it is of very high quality, characterized by a high basic material content and high purity.

Heating behaviour

A differential thermal analysis has been carried out on a dolomite sample of 1 600 mg in weight, by Domishliarova (1984) using a Derivatograph-1 500 °C of MOM production.

The differential thermal curve (1) shows three endothermal and one exothermal effects (see Fig. 2). The first endothermal effect begins at 62 °C, peaks at 180 °C and terminates at 222 °C. This is due to the dissociation of water from the mechanical bond existing in the raw material.

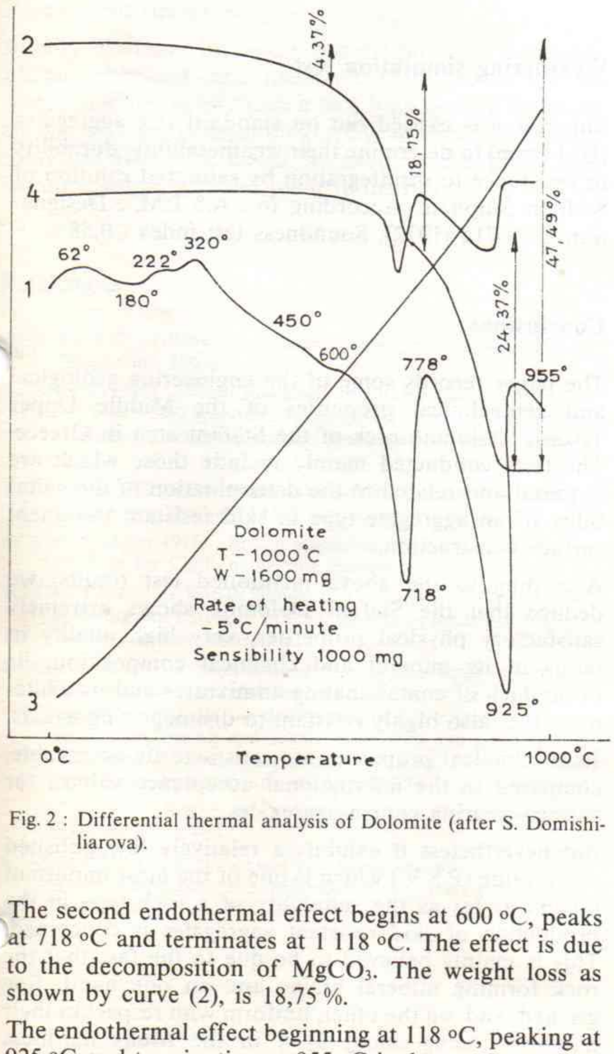

Fig. 2 : Differential thermal analysis of Dolomite (after S. Domishiliarova).

The second endothermal effect begins at 600 °C, peaks at 718 °C and terminates at 1 118 °C. The effect is due to the decomposition of $MgCO_3$. The weight loss as shown by curve (2), is 18,75 %.

The endothermal effect beginning at 118 °C, peaking at 925 °C and terminating at 955 °C is due to the decomposition of $CaCo_3$. The weigh loss is 24,37 % (see curve 2).

The exothermal effect at 320 °C is due to the burning of the organic admixtures contained in the raw material.

Curve (3) shows the temperature rise and curve (4) is the Dolomite identification curve confirming that the investigated material is dolomite.

Determination of the degree of whiteness

A whiteness analysis performed by Vladimirova (1984), shows that the dolomite has quite a high degree of whiteness as follows:

Sample	Reflection coefficient %			Calculated whiteness W %
	blue filter	green filter	red filter	
Dolomite	67,9	70,3	74,3	70,7

Its whiteness, 70,7 % is higher than the ordinary dolomites having up to 66-67 % whiteness (Vladimirova, 1984).

Aggregate macroscopic description

The aggregate tested exhibits the following description : (according to B.S. : 5930: 1981 § 44,2). "White to light grey, fine grained, sedimentary cryptocrystalline, fresh, forming a rough surface, angular aggregate of DOLOMITE".

Physical properties tests

The physical properties of the dolomite were determined according to the following International Standards.

a) Bouyancy method, B.S. : 812 : Part 2 : 1975

b) Mercury displacement method. I.S.R.M. (Anon 1979)

c) Mineral grain specific gravity. B.S. : 1377 : April 1975 and the results are as follows:

1) Bulk density: $e = 2{,}950 gr/cm^3$

2) Water absorption (by dry mass) = 0,364 % (by volume) = 1,05 %

3) Saturated relative density $e_{sat} = 2{,}930 gr/cm^3$

4) Dry relative density $e_d = 2{,}919 gr/cm^3$

5) Mineral grain density $e_s = 2{,}9547 gr/cm^3$

6) Total porosity $n = 1{,}21$ %

7) Effective porosity $n_{eff} = 1{,}05$ %

8) Void Ratio: $e = 1{,}22$ %

9) Saturated moisture content: $W_{sat} = 0{,}364$ %

10) Degree of saturation: $S_r = 87{,}81$ %

11) Quick absorption index: $I_{QAI} = 0{,}328$ %

12) Determination of clay, silt and dust in aggregates (decantation method) = 0,13 %.

Shape index tests

These tests included the determination of flakiness and elongation indices as well as the angularity number.

The indices determine the representative shape of the articles of an aggregate, which in turn affect: the ease of handling of a mixture of aggregate and binder (i.e. the workability of asphaltic concrete or concrete). The resultant stability and shear strength of mixture that rely on the interlocking of the particles. The design of mix proportions between aggregate and binder and finally and most important, the achieved surface texture depth. (S.T.D.) of the resulting pavement surface, constructed using the aggregates.

It is obvious then, that angular cubical particles are generally desired to permit development of ease of handling, high shear strength, stability and mainly the appropriate surface texture depth of the pavement surface. All the required tests were performed according to B.S. : 812: part 1: 1975 in aggregate grading: 10-14 mm.

1) Aggregate flakiness index: F.I = 12,6 %
2) Aggregate elongation index: E.I = 20,9 %
3) Aggregate angularity number: A.N = 11,29 %

Mechanical properties tests

The mechanical properties of a material identify the behavioural characteristics of the material when subjected to applied static and dynamic forces.

There are a number of mechanical properties but some of the more common ones are: strength, stiffness, ductility and hardness. These properties can be inferred to by the following tests, conducted either on aggregates or cores.

The following tests were conducted either on aggregate sized 10-14 mm or on rock cores Ø 38 mm and length 76 mm, according to International Standards: I.S.R.M. suggested methods, and B.S.: 812: Part 3: 1975.

1) Aggregate crushing value A.C.V = 18,1 %
2) Aggregate impact value : A.I.V = 22,6 %
3) 10 %fines Aggregate crushing value: 10 % fines A.C.V = 200 kN
4) Dry unconfined compressive strength $\sigma_d = 118{,}4\ MN/m^2$
5) Saturated unconfined compressive strength $\sigma_s = 175{,}8\ MN/m^2$

Wear resistance tests

Wear resistance is the ability of the surface of the aggregate to resist being worn away by rubbing and friction produced by externally applied forces which result in the polishing, wearing and rounding of the aggregate.

Aggregates used in pavement surface layers should have resistance to polishing and wear by motor vehicle tyres and should wear nonuniformly to promote the skid resistance of the pavement surface.

The wear resistance tests determine the degree of polishing and wear of the aggregates being subjected to abrasion, abrasion with impact, polishing and attrition.

These tests are designed so that they simulate the way with which the aggregates of a pavement surface become worn away and polished under the real conditions of abrasive smoothing action of the tyres of traffic.

The results of these tests can be correlated, with a satisfactorily high correlation coefficient, to the expected value of pavement surface Sideway Force Coefficient (S.F.C.) under various conditions : of traffic volume, season of a year and temperature, motorway geometric characteristics, road category and site e.t.c.

These tests include :

1) Los Angeles abrasion test. According to : A.A.S.H.T.O. Designation T9674. Coefficient Los Angeles = 32,6 %;

2) Aggregate Abrasion Value. According to : B.S. : 812. Part 3 : 1975. A.A.V. = 10 %;

3) Polished stone value. According to : B.S. : 812. Part 3 : 1975 P.S.V. = 43.

Weathering simulation test

This test was carried out on standard size aggregates (10-14 mm) to determine their weatherability, durability or resistance to disintegration by saturated solution of Sodium Sulphate. According to : A.S.T.M. : Designation C 88-71a (1972), Soundness test index : 0,58 %.

Conclusions

The paper records some of the engineering geological and geotechnical properties of the Middle Upper Triassic Dolomite rock of the Stafani area in Greece. The tests conducted mainly include those which are required and related to the determination of the suitability of an aggregate type in skid resistant pavement surface construction.

According to the above mentioned test results, we deduce that the Stefani Dolomite shows extremely satisfactory physical properties, very high quality in terms of its mineral and chemical composition, its purity-lack of contaminating admixtures-and its whiteness. It is also highly resistant to disintegrating agents.

Its mechanical properties are satisfactorily acceptable, compared to the international acceptance values, for surface wearing course aggregates.

But nevertheless it exhibits a relatively low polished stone value (P.S.V.) which is one of the most important factors as far as the suitability of a rock type in the production of skid resistant aggregates is concerned. This is mainly believed to be due to the fact that the rock forming mineral grains are, on one hand, fine grained, and, on the other, uniform with respect to their hardness (being about 3,5-4 in the Mohs hardness scale).

Interpreting the above mentioned we come to the conclusion that if a pavement surface layer is constructed, using the Stefani Dolomite aggregates in the appropriate grading, this surface will adequately retain its constructed Surface Texture Depth (S.T.D.) over its anticipated service life even under heavy traffic conditions.

This consequently means that the surface's Sideway Force Coefficient (S.F.C.) values (skid resistance) will be held approximately constant with the increase of the vehicles'speed in wet road conditions, during the normal life span of the pavement surface.

However the pavement surface will generally exhibit a relatively low Sideway Force Coefficient (S.F.C.) as reflected by the relatively low polished stone value (P.S.V. = 43) of the Dolomite aggregate.

Therefore such a pavement surface would not be suitable for dangerous and motorway sites prone to skidding and hence not skid-resistant. According to the pavement site classification schemes as first proposed by the Marshall Committee in 1970 and later modified by Salt and Stratkowski in 1973, the Stefani Dolomite aggregates can be successfully used for the surfacing of a pavement site of category C (easy).

Finally it should be noted that all physical, petrographical, chemical and mechanical properties of the Stefani Dolomite establish it as a high quality dolomite by the international bibliography and standards, and therefore this rock could be used in the glass, fine ceramic, refractory and paint industries.

References

1. A.A.S.H.T.O. (1974) : « Los Angeles abration test » A.A.S.H.T.O. Designation T9674.
2. ANON (1967) : British Standards Institution. British. Standard No 1984 : 1967 specification for gravel aggregates for surface treatment (including surface dressings) on roads. London (B.S.I.).
3. ANON (1972) : « The preparation of maps and plans in terms of Engineering Geology » Q.Jl. Eng. Geol. Vol. 5, 293-381.
4. ANON (April 1975) : British Standards 1377 « Methods of test for Soils for Civil engineering purposes » B.S.I. London.
5. ANON (1975) : « British Standard 812 : Parts 1,2,3. Methods for sampling and testing of mineral aggregates sands and fillers » British Standard Institution. London.
6. ANON (1979) : « International Society for Rock Mechanics Commission on standardization of laboratory and field tests. Suggested Methods for determining water content, porosity, density, absorption and related properties and swelling and slake durability index properties. Int. J. Rock. Mech. Min. Sci. and Geomech. Abstr. Vol. 16, pp. 141-156.
7. ANON (1981) : British standards 5930. « Code of practice for site Investigations » B.S.I.
8. AUBOUIN, J. (1958) : « Essai sur l'évolution paléogéographique et le développement tectorogénique d'un système géosynclinal. Le secteur grec des Dinarides (Hellénides) B.S.G.F.., 8 Paris.
9. BROWN, E.T. (1981) : « Rock characterization : testing and monitoring I.S.R.M. suggested methods » Pergamon press.
10. DOUNAS, A. (1971) : « La géologie de la région située entre Meghara et Erythra ». Thése. Athènes (en grec).
11. FEKELDJIEV, G., DOMISHLIAROVA, S. and VLADIMIROVA, N. (1984) : « Mineralogical and petrographical analysis and heating behaviour of the Greek Dolomite » Sofia, private communication.
12. C.U.GILES (1957) : « The skidding resistance of roads and the requirements of modern traffic » Proc. Inst. Civ. Eng. 6, 216-249.
13. J.E.GRAY qnd F.RENNINGER (1966) : « The Skid-Resistant Properties of Carbonate Aggregates » H.RR No. 120 U.S.A.
14. A.HAMROL (1961) : « Quantitative classification of the weathering and weatherability of Rocks » 5th Int. Conf. on Soil. Mech. and Found. Eng. Paris.
15. HOSKING, J. (1970) : «Road aggregates and their testing. One day symposium on Quarrying, Bristol University.
16. HOSKING, J.R. (1976) : « Review of TRRL research (1969-1975). Field testing and aggregates » TRRL.
17. HOSKING, J.R. (1973) : « The effect of aggregates on the skidding resistance of bituminous surfacing: factors other than resistance to polishing » Dept. of the Environment TRRL Report L.R 553.
18. MAPATOS, G.M. (1972) : « La géologie de la Grèce ». Editions de géotechnique. Athènes (en grec).
19. MARINOS, G. (1951) : « Le bassin de lignite de Megharar » I.C.E.Y. Identifications géologiques 3, p. 1-14. Athènes.
20. N.C.H.R.P. : Report 37 1967 : « Tentative skid-resistance requirements for main rural Highways » Highway Research Board U.S.A.
21. SALT, G.F. and SZATOWSKI, W.S. (1973) : « A guide to levels of skidding resistance for roads ». Dept. of Environment, TRRL Laboratory Report L.R 510.
22. SZATOWSKI, W.S. and HOSKING, J.R. (1972) : « The effect of traffic and aggregate on skidding resistance of bituminous surfacings » Department of Environment, TRRL Report L.R. 504, Crowthorne.
23. SZLAVIN, J. (1974 α) : « Relationships between some physical properties of rock determined by laboratory tests Int. J. Rock Mech. Min. Sci. Vol. II, pp. 57-66.
24. TATARIS, A. (1976) : Réflexion au sujet de la structure de la région délimitée par : Sraramaga-montagne d'Aegaleo, Pirée. Athènes (Attique) (en grec).
25. TATAPIS, A. (1967 β) : « Recherche récentes sur la structure de l'île de Salamina et de la région située en face de Pérana ». Cahier E.G.E.. Tome VII, Nº p. 36-51. Athènes (en grec).