Geotechnical and petrographic properties of carbonate sedimentary rocks from Sasaj region (Ionian Zone) and their use as aggregates for road pavement

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Abstract

This paper is a part of the master's thesis with the title "Geotechnical and petrographic properties of carbonate sedimentary rocks from different zones of Albania regarding their use as aggregates for road pavement" where this topic presents a particular method of study of limestones and dolomite aggregates from the point of view of their petrographic characteristics, the petrography being an important working tool which proves to be indispensable alongside the classical geotechnical study currently used in Albania.

Our work was born from the need to demonstrate that the studies carried out by engineering, geotechnics and geomechanics should not lack synthetic reports on the different types of aggregates used in Albania, especially those of carbonate origin.

Moreover, our goal was to take a step forward to fill this gap by accurately correlating the general geological knowledge and the lithological and petrographic characteristics of carbonate rocks with the engineering properties of the aggregates produced from these types of rocks.

It is well known that petrography is focusing on details invisible to the naked eye, and therefore, for rock materials selected for the production of aggregates, this microscopic analysis is also necessary, as well as other laboratory analyses, if necessary to verify the stability of these aggregates.

Concretely, in this paper we will present a part of our results which show the methods which we used in the analysis of materials from samples of carbonate rocks coming from Sasaj region, one of the four carbonate rock formations that we studied in our master thesis, these formations belonging to four different geological tectonic zones of Albania: Mirdita, Albanian Alpes, Kruja and the Ionian zones.

The complete material will be the subject of a more detailed paper for a high-impact international journal.

Keywords: *aggregates, road pavement, petrography, carbonate rocks, geotechnical properties, optical microscope, binocular, Ionian, Sasaj.*

Introduction

Industrial limestones constitute a particular sub-category of geomaterials widely used in the construction industry as well as road pavement aggregates. The selection of these rocks as construction materials is done on the basis of their quality, with the most viable ones being chosen mainly on the basis of their chemical properties, and after that they are analyzed from a geotechnical and petrographic point of view.

The use of these aggregates in road pavements depends on the shape, classification and lithological composition of the rock material, as well as their physical, mechanical and chemical properties, and for this, an in-depth study of these rock aggregaates is necessary on the basis of The mechanical behavior of rock aggregates is particularly influenced by their textural and mineralogical characteristics as well as their geotechnical characteristics. The latter are related to their resistance, i.e. the resistance they present to the requirements based on which it is recommended or not to use it as a raw material for construction.European International Standards.

The results of various international specialized studies regarding the problem of carbonate aggregates show that the lithology and petrography are the main factors that influence the physical and mechanical properties of these rocks. So, based on this fact, it can be said that the methods of their study from the geotechnical point of view should be closely related to the petrographic study of these rocks.

Carbonate rocks are included in the group of sedimentary rocks together with marls, siliceous rocks, gypsum, clays, siltstones, sandstones, conglomerates, gravels, sands, etc. The limestones and dolomites are classified as carbonate rocks.

These sedimentary rocks are used as building stones, so they are natural materials widely used in the construction of foundations and walls of houses, for the construction of roads, bridges, dams, for squares pavement, sidewalks, as well as decorative materials, sculpture, for interior and exterior design of buildings, floors and artistic works.

The origin of carbonate rocks is chemical, biochemical and organic. In Albania, these rocks represent about 60% of the all sedimentary rocks. According to the studies conducted by the Albanian Geological Service, more than 100 sources of carbonate rocks have been identified throughout the country, with a total of about 800 million cubic meters of reserves. These sources are mainly represented by limestones with a high level of purity (CaO content greater-than 53.5%) and high physic-mechanical indicators (fig. 1).

FIGURE 1. Schematic map of the distribution of carbonate rocks in our country.

But the of carbonate rocks as aggregates in road paving has not found the right use in Albania. However, the importance of the reserves and above all, the damage caused to the environment by the use of river gravels underline the need for using the aggregates of carbonate origin as a qualitative alternative to river gravels.

The geographical position and geological setting of the region under study

From geographical point of view, the studied samples presented in this paper were taken from the carbonate rock formations located near the village of Sasaj, which administratively belongs to the Prefecture of Vlora, municipality of Himara, administrative unit of Lukovë (fig. 2).

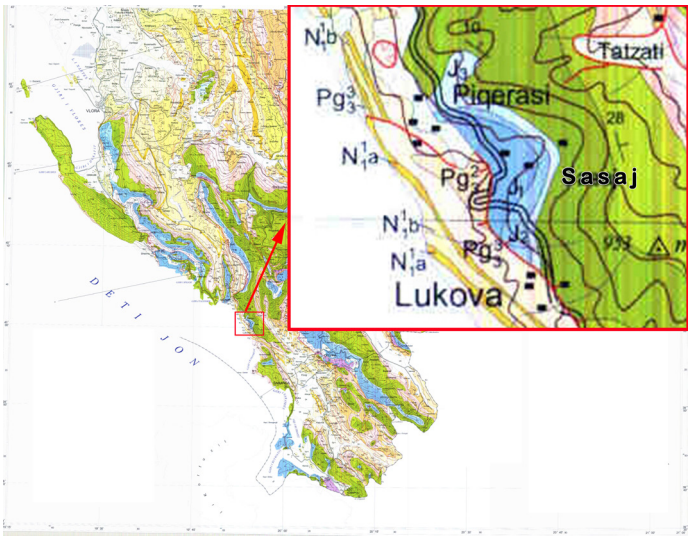

FIGURE 2. Geological map of the study area and its position on the geological map of Albania (South)

From geological point of view, the region belongs to the Ionian tectonic zone (fig. 3), which is part of the western zone of the external Albanides. Within this zone are included the next subzones: the western or Çika subzone (including the Dukat syncline belt and the Çika anticlinal belt), the central or Kurvelesi subzone (including the Shushica syncline belt, the Kurvelesi anticline belt and the Memaliaj syncline belt) and the Eastern subzone or Berat (including the Berat anticline belt and the Përmet syncline).

The carbonate rock formations of Sasaj are part of Kurveleshi subzone and their geological ages are Cretaceous and Paleogene. The samples taken for our

study belong to the Lower Eocene (Middle Paleogene, Pg2) which according to the geological map of Albania consists of biomicritic and turbiditic limestones (Xhomo et al. 2002, 2010).

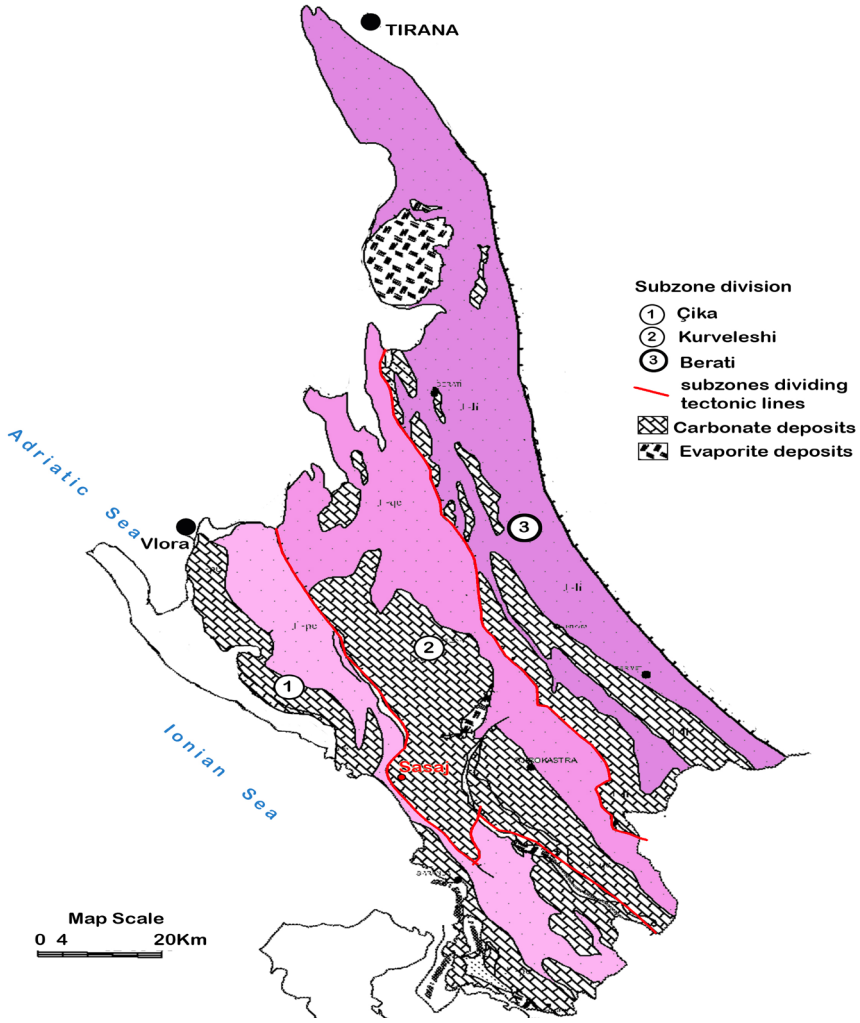

FIGURE 3. The position of the Ionian zone and its divisions into tectonic subzones (belts).

Literature review

The invention of cement and concrete in the 19th century greatly increased the demand for natural aggregates, and with the development of the construction industry, their widespread use increased exponentially. Currently, large volumes

of aggregates are used, where for example, the average consumption of aggregates in the European Union in 2007 was 24 million USD. Thus, 1.4 km of two-lane highway requires 75,000 tons of aggregates, while a two-floors building requires 400 tons.

Aggregates are extracted from the crushing of various rocks such as limestone, basalt or granite (fig. 4) and are divided into two categories:

- **natural aggregates** - which are obtained from the fragmentation of massive rocks (sedimentary, igneous and metamorphic) and unconsolidated sediments (accumulated in rivers, lakes and seas) which are created by natural weathering and/or of alteration.
- **recycled aggregates** - which are produced by recovering certain materials from demolition, road paving and other industries.

FIGURE 4. Aggregates of different rocks. Limestone (a), basalt (b), granite (c)

To carry out quality work, the rocks from which the natural aggregates are derived must fulfill the following qualities:

- homogeneous, uniform and compact structure;
- homogeneous color and petro-mineralogical composition;
- low water absorption and low modification of characteristics under the action of water;
- minimal brittleness to withstand traffic load and maintain the angular shape without rounding;
- lack of decomposable minerals (pyrite, limonite or soluble salts);
- they do not contain microcrystalline or amorphous siliceous which reacts with cement alkalis (if used in the presence of cement);

Limestone aggregates are commonly used in road construction and roadside ditches to drain the runoff water. There they are an ideal alternative to gravel for use as stable layers on the surface of secondary roads, sidewalks, cycle paths and car parks Recognized for being strong and durable, limestone aggregates greatly

facilitate water drainage and also have a fairly low cost compared to other non-porous surfaces such as asphalt or concrete.

In the classification of carbonate rocks are included (1) **Limestone**, a sedimentary rock mainly composed of calcium carbonate (CaCO3), which can be of mainly organic origin, but also of chemical origin; (2) **Dolomite, a** rock with similar sedimentary characteristics to limestone, in which the mineral called dolomite [CaMg(CO3)2] predominates and is mainly formed by the early replacement of the carbonate fraction under the action of magnesium-rich waters; (3) **Chalk** which is a very fine limestone, of organic origin. It is the dominant carbonate of the Cretaceous of Europe and North America, from which comes the name of the Cretaceous period (Kreide – chalk *germ.*).

Other rocks with a carbonate composition are **marls** (with a carbonate composition of 35-65%) and **travertines** (formed by the chemical precipitation of calcium carbonate minerals from fresh waters).

Limestones are classified in two categories: Folk classification and Dunham classification where Folk (1959) proposes a classification based on the type and size of the grains (fig. 5), while Dunham (1962) is taking into account the depositional texture of rocks as the basis for classification (fig. 6).

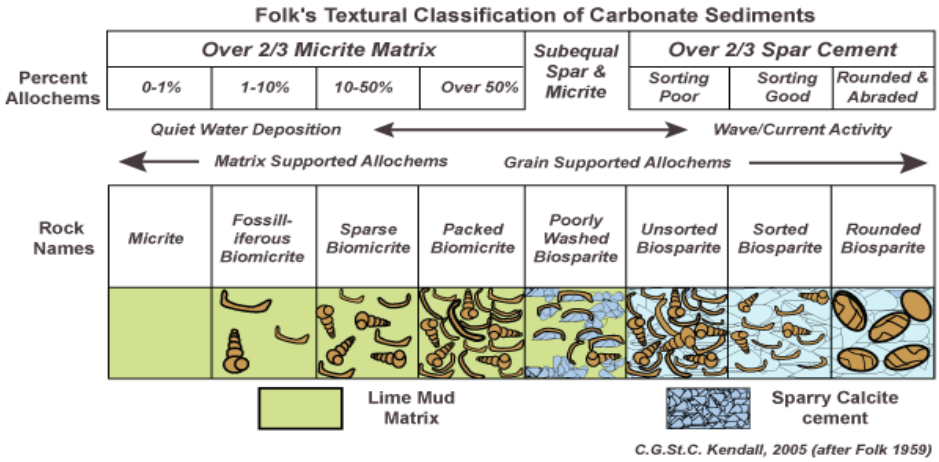

FIGURE 5. Limestone classification according to Folk, (1959)

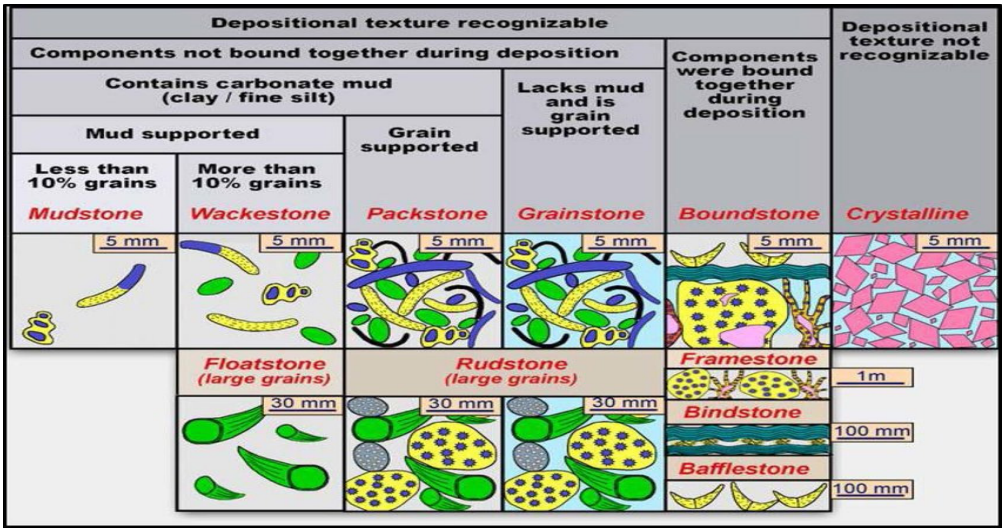

FIGURE 6. Limestone classification according to Dunham, (1962)

Road construction in history has gone through several stages, from the Roman road network to the present day. Granular material (rock aggregate) was first included in the construction of road pavements by John Loudon McAdam, in 1815, in England. He noticed that the small crushed stones were more resistant to the passage of chariots than the large stone slabs, and so he radically changed the foundations of the roads, which had previously been built with large stones which had a high cost. His techniques were applied from 1820 in Australia and the United States and from 1830 in continental Europe. In 1909, the German company AVUS (Automobile Verkehrs und Übungs Strasse GmbH) built a two-lane test road 10 km west of Berlin. In 1945, Germany had approximately 3,800 km of motorways. Later, highways "conquered" the world.

Known collectively as aggregates, these materials are essential for the construction, maintenance and rehabilitation of roads and bridges. Aggregates affect the durability, strength, modulus, thermal properties and important safety properties of running surfaces: friction and traction. To be useful to road agencies, aggregates must first be of sufficient quality to meet initial design needs and long-term life cycle performance objectives.

Ensuring a constant supply of aggregates requires advance planning and balancing a complex matrix of technical, geographic and geological variables and community interests.

Given the above considerations, the topic of our master thesis wants to propose the study of these aggregates from a petrographic point of view.

The used methods and the obtained results

The petrographic examination method was used as a research method in our work. Petrography is a geoscientific branch that aims to provide a description of rocks of different natures by analyzing their structural, mineralogical and chemical characteristics, in order to obtain a classification based on the identified minerals.

The petrographic as well as petrological examination of rock materials used in construction engineering, particularly in the road construction industry, makes it possible to identify the harmful elements or unfavorable characteristics and, in general, to evaluate the suitability for a certain use, in addition to petrophysical and mechanical tests.

Our rock samples were processed in the form of petrographic thin sections and analyzed by using a polarized light optical microscope (fig. 7).

A complete petrographic description includes:

- the description of the (micro-)texture: the size and shape of elements and voids or pores, their orientation, arrangement, etc.;
- identification and description of minerals, the presence or absence of crystallized phases, the presence of pores and micro-pores, cracks and micro-fissures (their opening), organic elements.

In engineering geology, the petrological and petrographic descriptions of a rocky material have specific objectives, the main ones being:

- Identify the presence of harmful components such as: chlorides, sulphates such as gypsum or anhydrite, poorly crystallized phases (silica of flint, for example), sulphides such as pyrite, altered clays, fibrous minerals, etc.
- Highlight the factors affecting the mechanical behavior and/or the stability of the material or of the rock composition: micro-fractures, structural changes, corrosive minerals, soluble minerals, freezing…;
- To place the rock in a classification: generic classifications are important because they provide a common language, a common nomenclature for all earth science professionals.

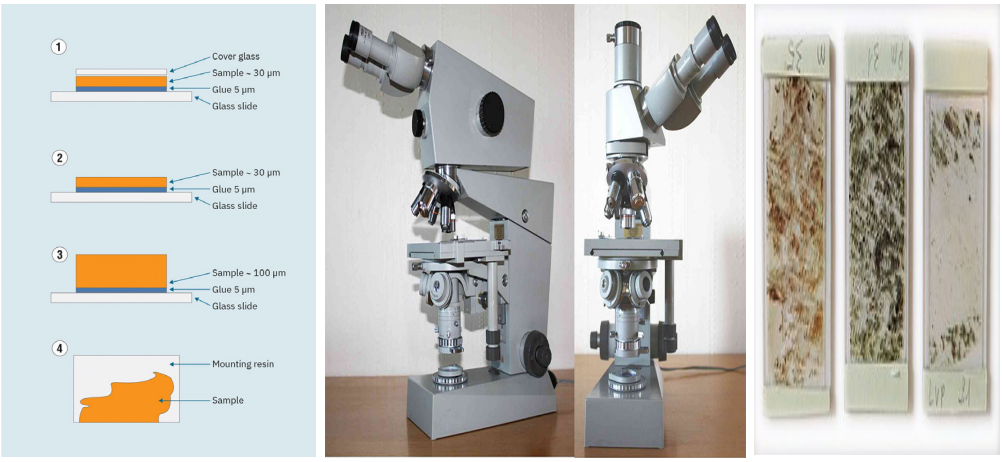

FIGURE 7. The preparation of the thin sections
and the Zeiss microscope with reflected light, used in this study.

For the presented study, thin sections were prepared from rock samples of carbonate rocks of Lower Eocene age, sampled near the village of Sasaj (sample P and sample N). The data are briefly presented below.

Based on the classification according to Dunham (1962), the two thin sections are classified as packestone - bioclastic floatstones (fig. 8.). The microfacies are characterized by a microfauna mainly composed of larger benthic foraminifers: alveolinids, rotaliids such as *Rotalia aff trochidiformis*, discocyclinids, nummulites, miliolids and also planktonic foraminifera. Fragments of echinoderms and micritized bioclasts are also found.

From a morphometric point of view, the components are generally rounded and present different sphercity with sizes between 0.2 mm and 2 cm for the largest grains represented by the larger benthic foraminifera, while the smallest grains are represented by unidentified micritised fragments. In terms of roundness, they have different sphericities: subangular, rounded and well rounded.

The microfaunistic association is typical for the Lower Eocene, more precisely for Cuisian\Ypresian, based on alveolinid foraminifera and *Rotalia aff trochidiformis.*

The rock has no cracks and is quite compact. Both samples are microfacies with a granular support (bioclastic packstone. Therefore, considering the petrographic and petrological characteristics of the rock in terms of microfacies, quite good petrophysical parameters are expected.

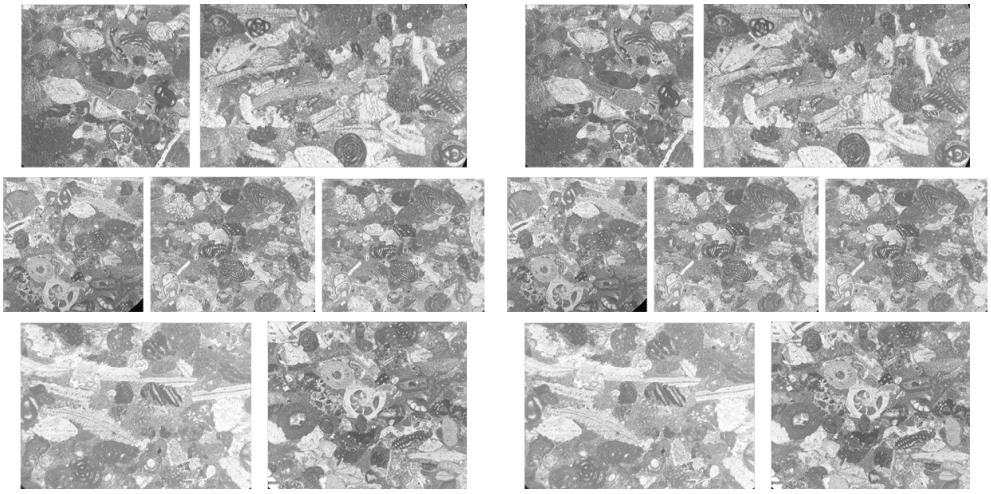

FIGURE 8. Microscopic views of thin sections of sample P (left) and sample N (left), Location, Sasaj (photo source Sokol Marku, personal collection)

Discussion of results and conclusions

The most important physical properties for the industrial use of carbonate rocks include textural composition, porosity, permeability, surface area and pore opening diameter distribution, water absorption and bulk density, hardness; compressive, tensile and shear strength; stiffness and elasticity, refractive properties and thermal conductivity (Harben and Purdy 1991; Bellanger et al. 1993; Winkler 1994). The physical and chemical properties are controlled at least in part by the nature of the microfacies. There are specific correlations between depositional microfacies of the rocks, rock color and amount of non-carbonate content and help differentiate the purity of limestone rocks (Dimke 1997). The relationships between depositional microfacies, diagenesis and porosity explain the types of alteration.

The limestones of Sasaj region are characterized by microfacies of grain-supported type, i.e. with granular support (grainstone or bioclastic packstone) which compared to those with micritic or mud support, i.e. with micritic matrix, are showing optimal petrographic and petrological characteristics, so we could expect better petrophysical parameters than the limestones with micritic support from Lura and Staveci, Mirdita geological zone. In the case of Lura and Staveci, the presence of clay minerals and Fe-Mn minerals has the opposite effect, that is, it causes a decrease in the strength of these rocks, so they are less performant compared to our samples from Sasaj region, Ionian geological zone.

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