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CHARACTERISTICS OF LIMESTONES FROM SADOVENI-LIVENI, BOTOŞANI COUNTY

BY

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Abstract. Natural building material’s study – stone, clays, balast – represent an important aim for the civil engineers, the researchers and also for building material’s producers. In the Jijia river rehabilitation project was analysed many stone sources from different points of interest: geological, deposits quantities, environmental impact, acces possibilities. Botoşani county has some small ballast deposits, natural local reserves being hard to extract, but also some rich zones in natural stone at the surface of the ground. Sadoveni-Liveni zone could be exploited with minimal investments, based on laboratory analysis and determinations. The results of the study (geologic, petrographic, mechanical characteristics, the interest domain) was delivered to the local communities.

Key words: reinforced concrete slit walls; pushover analysis; nonlinear cyclic analysis; energy dissipation.

1. Introduction

Natural stone was the first building material with which was created from simple forms – defending walls, closing walls for the caves, etc., to the

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religious monumental buildings (temples, churches, cathedrals, sanctuaries – s. Figs. 1 and 2), or civil buildings (amphitheatres, fortress, bridges, railways, etc. – s. Fig. 3) (Brânzilă, 1997; Mackler, 2004).


Fig. 1 – Pyramid from Ghizeh.

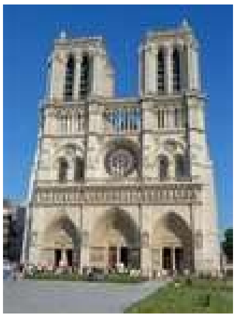
Fig. 2 – Notre Dame de Paris Cathedral.


Fig. 3 – Stone bridge from South of France.

In Romania, the stone was used from the ancient times: Sarmisegetusa religious complex (Fig.4), the churches from Bucovina and Vâlcea, defending fortress from Transilvania, near the Prut and Nistru rivers, Cernavodă bridges, etc. (s. Fig. 5,…,7).


Fig. 4 – Sarmisegetusa Complex.


Fig.5 – "Trei Ierarhi" Church from Iaşi.


Fig.6 – Neamț Fortress (restored).


Fig.7 – Stone Bridge from Borsec.

The stone reserve from Romania are various, from the compact limestone varied coloured (Vaşcău, Moneasa), marble (Ruşchiţa), Măcin granite, volcanic tuff from Bacău and Bistriţa Năsăud county, the stone pits and ballast deposits from the rivers were exploited from ancient times (Kourkoulis & Stavros, 2006).

By instead of the ages, the stone must be considered as an actually building material: as bulk stones for the foundations and masonries, as plates for pavements or veneering, as pieces (paving blocks) for roads, slabs or aggregates for mortars and concretes, clays for ceramic products.

Along the time, stone become raw material for the building materials industry: plaster from gypsum, lime from limestone, cement from clay and limestone, ceramic products from clay, etc.

The usage of the aggregates from stone pits and from the rivers offers to local workers a cheap building material, durable and, most important, natural contributing to the durable development process "I build today, I think to the future".

Fig.8 – Stone pit.

Fig. 9 – Ballast extraction.

The natural stone reserves from Moldova are dispersed on all the territories and, many times, are presented so that the exploitation must be at the surface of the ground, without decovering but in absence of the access roads, deficiency which could be removed by stone pit exploitation (Figs. 8 and 9).

The stone reserves from Moldova are varied: limestone in Bucovina, andesite in Călimani, volcanic tuff in Bacău and Neamţ, grit stone along the Prut river, many ballast deposits on the Moldova and Siret rivers, many clay deposits used to ceramic products or as a binder in masonry.

2. The Defining of the Studied Zone

The Moldavia Plateau is laying from the left-side of the Siret River to the Nistru, forming a distinct geological identity by genesis and exploitation possibilities. The mantle of the plateau was formed by precipitation and biological transformations, so that the crypto-crystalline structure give the possibility to be exploited and used in natural stage or thermal transformed. From the terrain observations was established that the analysed rock was locally used to the foundations, strengthening and retaining walls, underground workings, etc.

The stone resources analyse of the Central Moldova is imposed like a necessity because the zone has not other building material sources, in the contexts of the infrastructure development, of the rehabilitation/consolidation of the existing structures and of the general effort by using the natural/ecological materials integrating the durable development system.

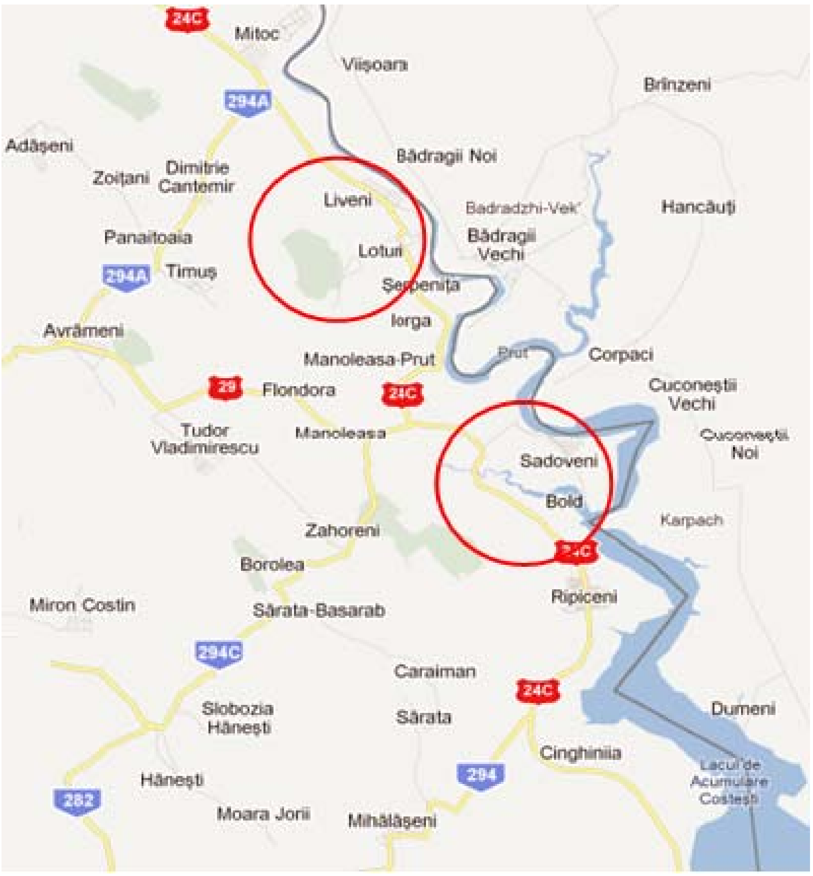

Fig.10 – Studied zone (Liveni-Sadoveni, Botoşani county).

Sadoveni-Liveni zone is placed in the right-bank of the Prut river, has no mass materials for building (ballast) because the Prut (frontier river) cannot be exploited as a building materials sources. In the same time the existing aggregate in the proximity zones of the Prut is strongly „infested" with natural organic and powdery materials and, in case of the organised exploitation will be imposed supplementary costs (for washing and sorting).

The natural stone must be analysed by two different hypostases namely

a) The origin rock petrographically, mineralogical, structural and mechanic characterization.

b) Laboratory tests and characteristics determinations on the specimens depending on the types of the products (pieces, hollow stones, etc.) and the using domain (masonries, roads, aggregates, etc.).

To characterize the rocks was choosen two specific zones for the specimens harvesting: at the North by Săveni (denoted by "sample no. 1") and the West by Liveni (denoted by "sample no. 2". The samples was cropped by digging under the corrupted zone of the rock deposits (Fig. 10).

3. Petrographic and Mineralogic Analysis of the Extracted Samples from the Considered Zones

In order to characterize (petrographically and mineralogically view point) were analysed pieces of the stone in "fresh" breach (petrographic analyse – Fig. 12) and in polarizing light (microscopic analyse – Fig. 11) thin plates extracted from the specimens (SR EN 932-1, 1998; SR EN 933-2, 1998;SR EN 933-3, 1998; ASTM D2938-71a; SR EN 12407, 2002).

For petrographic analyse were used lens, having sizing factor 2,5...5X K, and for mineralogical analyse was used the polarising microscope MC2, connected to the computational system, in order to obtain the images in natural and polarized light.

Fig.11 – Petrographic analysis with lens.

Fig. 12 – Thin plates and imagines obtained at microscope.

A. For the sample no. 1.

a) *Petrographic characteristics*

The sample 1 is a sedimentary rock formed by cementing of the quartz-sand and calcite. Has a fine grained shape, compact, hard, grey-green coloured.

Could be seen some small “lamelibranhiatous” fossils.

The specimen breach is irregular. The “fresh” breach’s surface has a glassy bright texture from quartz fragments. The texture is compact, thin vacuole, because of the dissolution and totally removing of the chalky shells. The empties so formed take the shape of the shells having the length about 2… 4 m and thickness about 0.5 mm (even smaller) (SR EN 12440, 2001).

b) *Mineralogical characteristics*

Mineralogical compounds:

a) quartz, 20%;

b) quartzite fragments, 40%;

c) feldspaths, 5%;

d) chalcedony, 3%;

e) potash mica, 2%;

f) cement calcite, 30%.

Based on the obtained results by petrographic and mineralogic analysis, the sample could be considered as a litharenitic gritstone (SR EN 12440, 2001; SR EN 12670, 2002).

B. For the sample no. 2

a) *Petrographic characteristics*

Sedimentary rock has a dark-grey colour, glassy bright texture, with irregular breach. Rock’s breach is chippy. The rock doesn’t has any fracture. The compounded minerals don’t show any preferential orientation. The rock’s texture is compact.

b) *Mineralogic characteristics*

Mineralogic compounds:

a) calcite, 60% from rock’s mass;

b) chalcedony, 30% from rock’s mass;

c) quartz, 5% from rock’s mass;

d) feldspaths, plagioclase, 2% from rock’s mass.

Calcite appears having a large crystal shape and mostly micro grained. In both cases has a powerfull refractivity and multi-coloured iridescence. Chalcedony represents almost 30% from rock’s mass, in shape of a siliceous sponge ears. Transverse sections through the ears show a radial distributed chalcedony, having a corrugated extension. In longitudinal section the chalcedony fibres are perpendicular on the era’s wall (SR EN 12440, 2001).

Quartz is represented by hypidioshaped grains with corrugated extension. The rock hasn’t fracture.

Based on the obtained results by petrographic and mineralogical analysis, the sample could be considered as a limestone with siliceous sponge ears (SR EN 12440, 2001; SR EN 12670, 2002).

4. Laboratory Determinations Regarding Structural Characteristics

From the harvested samples was made, by cutting and finishing, specimens in cubic shape having 50 mm, the side prisms with 40 × 40 × 160 mm and plates with 200 × 200 × 20 mm (Fig. 13), which was puted to the following tests (Groll *et al*., 2001):

a) Specific mass (specific density) (SR EN 1936, 2000).
b) Apparent Volume Mass (apparent density) (SR EN 1936, 2000).
c) Water apsorbtion (SR EN 13755, 2002; SR EN 1925, 2000).
d) Water waste.
e) Apparent porosity.
f) Compression strength (Groll *et al*., 2001).
g) Bending strength (Groll *et al*., 2001).
h) Freeze–thaw behavior (ASTM D5312-92; EN 12371, 2002).
i) Atmospheric actions behavior.

Other characteristics were computed (compactness, total porosity, closed porosity, hardness, etc.) (SR EN 1097-1, 1998) based on the experimental values (briefly shown in what follows).

Fig. 13 – Samples types used for the laboratory tests.

a) *Specific mass* (*specific density*)

It was used the picnometer's method on the grounded material on and 03 sive sifted.

Average density ρ = 2.714 g/cm^3 = 2,714 kg/m^3

b) *Apparent volume mass*

The tests were performed on a constant mass dry material and, also, on dry and paraffinic rock specimen (cubic specimens) using a hydrostatic balance (Table 1).

Table 1
Apparent Densities of the Tested Specimens

No.	Apparent density, [g/cm^3]		Apparent density, [g/cm^3]	
	Sample 1		Sample 2	
	wet specimens, ρ_{as}	dry and paraffinic specimen, ρ_{ap}	wet specimens, ρ_{as}	dry and paraffinic specimen, ρ_{ap}
1	1.894	2.085	2.542	2.495
2	1.893	1.880	2.433	2.697
3	1.892	1.982	2.661	2.639
4	1,902	1.860	2.574	2.644
5	1.886	2.119	2.514	2.501
	Test's average		Test's average	
	1.893	1.985	2.545	2.595
	Average apparent density ρ_a = 1.94 g/cm^3 = 1,940 kg/m^3		Average apparent density ρ_a = 2.57 g/cm^3 = 2,570 kg/m^3	

c) *Water apsorbtion*

Testing method was performed taking into account the available norms, at the normal temperature and air pressure and on the wet specimens used to determine the apparent density obtaining the following results:

S a m p l e 1: average value: a_1 = 14.201% (on mass).

S a m p l e 2: average value: a_1 = 2.630% (on mass).

d) *Apparent porosity*

The test was performed on wet specimens, used to determine the apparent density. The following results were obtained:

S a m p l e 1: $n_1 = a_1\rho_{as} = 14.201 \times 1.893 = 26.882\%$;

compactness: $C = \frac{\rho_a}{\rho} \times 100 = \frac{1.939}{2.670} \times 100 = 72.622\%$;

total porosity: $n = 100 - C\% = 100 - 72.622\% = 27.378\%$.

S a m p l e 2: $n_1 = a_1\rho_{as} = 2.630 \times 2.532 = 6.659\%$;

compactness: $C = \frac{\rho_a}{\rho} \times 100 = \frac{2.531}{2.722} \times 100 = 92.983\%$;

total porosity: $n = 100 - C\% = 100 - 92.983\% = 7.017\%$

Mechanical characteristics were determined with the MT100 universal testing machine (for compression strength) and with Frühling-Michaelis instrument (for bending strength).

e) *Compression strength* (Tables 2 and 3)

S a m p l e 1: wetting coefficient $\eta_s = \frac{392 - 360}{392} \times 100 = 8.2\%$.

Table 2
Compression Strengths for the Specimens from Sample 1

Specimen	Dry state			Saturated state		
	N_r, [daN]	A_0, [cm^2]	σ_{rec} daN/cm^2	N_r, [daN]	A_0, [cm^2]	σ_{rec} daN/cm^2
1/5	10,200	25.2	405	9,350	25.4	368
2/6	9,450	25.4	372	8,800	24.9	354
3/7	9,900	24.9	398	9,450	25.2	375
4/8	10,000	25.4	393	8,650	25.3	342
Total	–	–	1,568	–	–	1,439
Media	–	–	392	–	–	360
Maximum	–	–	405	–	–	375
Minimum	–	–	372	–	–	342

S a m p l e 2: wetting coefficient $\eta_s = \frac{207-188}{207}\times 100 = 9.1\%$.

Table 3
Compression Strengths for the Specimens from Sample 2

Specimen	Dry state			Saturated state		
	N_r, [daN]	A_0, [cm^2]	σ_{rec} daN/cm^2	N_r, [daN]	A_0, [cm^2]	σ_{rec} daN/cm^2
1/7	4,950	24.3	204	4,640	25.1	185
2/8	5,000	25.2	198	4,800	24.8	194
3/9	5,460	25.3	216	4,370	25.4	172
4/10	5,275	25.0	211	5,125	25.,5	201
5/	5,340	25.4	214	–	–	–
6/	4,960	24.8	240	–	–	–
Total	–	–	12,438	–	–	752
Media	–	–	207	–	–	188
Maximum	–	–	216	–	–	201
Minimum	–	–	198	–	–	172

f) *The strength at freeze/defreeze test*

It was used a refrigerator case having an electronic set-up to the testing conditions: humidity 99%, temperatures –20^{0}C and +20^{0}C and the obtained results are shown in Tables 4 and 5 (sample 1) and 6, 7 (sample 2).

Table 4
Mass Losses after the Freeze/Defreeze Cycle Determined on the Specimens from Sample 1

Specimen	m_1, [g]	m_2, [g]	m_3, [g]	μ_g, [%]
9	331.04	337.90	334.45	1.04
10	320.10	327.15	324.00	0,98
11	318.15	325.05	321.30	1.17
Total	–	–	–	3.19
Average	–	–	–	1.06

Table 5
Wetting Coefficient Values after Freeze/Defreeze Cycle Determined on the Specimens from Sample 1

Specimen	Dry state			Saturated state			
	N_r, [daN]	A_0, [cm^2]	σ_{rec} daN/cm^2	N_r, [daN]	A_0, [cm^2]	σ_{rec} daN/cm^2	η_g, [%]
1/9	10,200	25.2	405	8,775	25.1	350	–
2/10	9,450	25.4	372	8,330	25.4	328	–
3/11	9,900	24.9	398	9,025	24.8	364	–
4	10,000	25.4	393	–	–	-	–
Total	–	–	1,568	–	–	1,042	–
Average	–	–	392	–	–	347	11.4

Table 6
Mass Losses after the Freeze/Defreeze Cycle Determined on the Specimens from Sample 2

Specimen	m_1, [g]	m_2, [g]	m_3, [g]	μ_g, [%]
11	320.05	326.80	322.90	1.22
12	316.25	323.35	316.85	2.03
13	308.85	314.70	308.10	2.14
14	311.55	318.15	312.15	1.92
Total	–	–	–	7.31
Average	–	–	–	1.83

Table 7
Wetting Coefficient Values after Freeze/Defreeze Cycle Determined on the Specimens from Sample 2

Specimen	Dry state			Saturated state			
	N_r, [daN]	A_0, [cm^2]	σ_{rec} daN/cm^2	N_r, [daN]	A_0, [cm^2]	σ_{rec} daN/cm^2	η_g, [%]
1/11	4,950	24.3	204	4,234	25.2	168	–
2/12	5,000	25.2	198	4,420	25.4	174	–
3/13	5,460	25.3	216	3,675	25.7	143	–
4/14	5,275	25.0	211	3,704	25.2	147	–
5/-	5,340	25.4	214	–	–	–	–
6/.-	4,960	24.8	200	–	–	–	–
Total	–	–	1,243	–	–	632	–
Average	–	–	207	–	–	158	23.6

g) *Specimen test to the bad weather*.

Specimens was exposed (on plate shape) to the action of dust, ultraviolet rays and were not concluded any changes of colour or composition.

5. Conclusions

1. The laboratory test performed in order to obtain a geological, mineralogical, structural and textural characterization of the analysed samples

sustain the position of it in the sedimentary rocks category, formed by precipitation and biogenesis, having medium hardness (because of the feldspaths and calcite presence, with neutral to basic pH), with a un-orientated structure, crypto-crystalline and weak layered and vacuole texture.

2. Based on the interpretation of the laboratory tests values performed in order to determinate the mechanical characteristics of the samples harvested from two locations, the limestone from Sadoveni-Liteni could be registered in heavy rocks category, porous, weak absorbent, having small mechanical strength.

3. Based on the inspection of considered locations could conclude that

a) limestone from Sadoveni-Liveni perimeter is easy to exploit because the zones area composed from many uncovered surfaces, with numerous fissures, cracks and dislocations which permit the exploitation of the stone without mechanical digging or with explosives;

b) the studied zones is easy to exploitation, accessible, with minimal investments and planning, so that the extracted stone must be a local building material used as bulk stones for the foundations and masonries, as plates for pavements or veneering, as pieces (paving blocks) for roads, slabs or aggregates for mortars and concretes, clays for ceramic products.

4. The results of the characteristic laboratory tests and the site inspection of the studied perimeter were materialized in analysis and test official reports and these ones will be finalized in a National Agreement of the limestone from the Sadoveni-Liveni.

5. The limestone deposits development could be performed with minimal investment by burning the rocks at $1,100^0$C temperature, in a relative reduced time, obtaining a hydraulic lime utilized in foundation or in masonry practice; the embedded energy to produce such a building material is reduced because the calcium carbonate and silica dioxide have a natural chemical activity in crypto-crystalline and amorphous stage.

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CARACTERISTICILE ROCILOR DIN PERIMETRUL SADOVENI-LIVENI, JUDEŢUL BOTOŞANI

(Rezumat)

Studiul materialelor naturale ca surse de materiale pentru construcţii – piatra, argila, balastul – a fost în atenţia constructorilor, a producătorilor de materiale pentru construcţii şi a cercetătorilor din cele mai vechi timpuri. In proiectul de amenajare a râului Jijia s-au analizat mai multe surse de piatră în ceea ce priveşte natura geologică, rezervele, impactul asupra mediului, căile de acces. Judeţul Botoşani este sărac în produse de balastieră, resursele locale fiind greu de exploatat, cu un conţinut mare de

argilă şi nisip foarte fin, dar prezintă şi zone cu piatră naturală de suprafaţă. Zona Sadoveni-Liveni poate fi exploatată cu investiţii minime, fapt constatat in baza analizelor şi determinărilor de laborator pe roca de provenienţă, punând astfel la dispoziţia comunităţilor locale rezultatele, domeniile de utilizare a calcarelor şi prezumtivele zone de exploatare.