PETROGRAPHIC – MINERALOGICAL ANALYSIS OF AGGREGATES FROM DEVOLL HYDROPOWER PROJECT

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ABSTRACT

The petrographic examination in Devoll aggregates establish whether the aggregate contains chemically unstable minerals such as ***soluble sulfates, unstable sulfides*** *that may form sulfuric acid or create distress in concrete exposed to high temperatures during service, or* ***volumetrically unstable materials such as micas, smectites (formerly known as the montmorillonite-saponite group of minerals or swelling clays****). Specifications has limited the quartz content of aggregates for use in concrete that is subjected to high temperatures because of the conversion to beta-quartz at 573°C (1063°F), with accompanying volume increase. The petrographic tests made on aggregates are based on the American method ASTM C 295, British standard method BS 812: Part 104, European standard EN 932-3.The problems mentioned above are analyzed in aggregates taken from Devoll Hydropower Project.*

Keywords: Devoll Aggregates , Soluble Sulfates, Unstable Sulfides, Petrographic Tests

I INTRODUCTION

Natural aggregates are the most important constituent in many building materials e.g concrete, mortar and roads. Natural aggregates of Devoll Hydropower Project are processed from natural deposits of sand, gravel or crushed rock. The method to describe and classify aggregates is the petrographic analysis. The petrographic analysis is a systematic description method for rocks, minerals and other constituents, usually in hand specimens, thin sections or by use of other analytical methods (e.g. XRF- analysis). The purpose with the petrographic analysis is to obtain information on one or all of the material characteristics: Geometrical–mechanical, physical-and chemical properties, impurities, contamination and very important the rock and mineral content. The rock and minerals constituents are in many cases conclusive for the end use of aggregate.

Petrographic examination in this study identify and call attention to potentially **alkali-silica reactive and alkali-carbonate reactive constituents**, determine such constituents quantitatively, and recommend additional tests to confirm or refute the presence in significant amounts of aggregate constituents capable of alkali reaction in concrete. Alkali-silica reactive constituents found in aggregates include:

opal, chalcedony, cristobalite, tridymite, highly strained quartz, microcrystalline quartz, volcanic glass, and synthetic siliceous glass. Aggregate materials containing these constituents include: **glassy to cryptocrystalline intermediate to acidic volcanic rocks, some argillites, phyllites, greywacke, gneiss, schist, gneissic granite, vein quartz, quartzite, sandstone, and chert.**

Potentially deleterious alkali-carbonate reactive rocks are usually **calcareous dolomites or dolomitic limestones** with clayey insoluble residues. Some dolomites essentially free of clay and some very fine-grained limestones free of clay and with minor insoluble residue, mostly quartz, are also capable of some alkali-carbonate reactions, however, such reactions are not necessarily deleterious.

Here petrographic examination is directed specifically at the possible presence of contaminants in aggregates, such as **synthetic glass, cinders, clinker, or coal ash, magnesium oxide, calcium oxide, or both, gypsum, soil, hydrocarbons**, chemicals which may affect the setting behavior of concrete or the properties of the aggregate, animal excrement, plants or rotten vegetation, and any other contaminant that may prove undesirable in concrete used at Devoll Hydropwer Project.

II MATERIALS AND METHODOLOGY

2.1 Materials

The samples subjected to be tested for Petrographic-mineralogical analysis are listed below:

1. Limestone (873.6 gr).
2. Natural river gravel (732.9 gr.)
3. Gravel 1 (416.8 gr), 1-4-6 mm.
4. Gravel 1 (50 grains, 73.5 gr.), grain size = 8-14 mm,
5. Gravel 2 (30 grains, 235.8 gr.), grain size = 1-2 cm.
6. Gravel 2 (51 grains, 263.3 gr.), grain size = 12.5-20 mm
7. Gravel 2 (12 grains, 518.4 gr.), grain size = 32.5- 45 mm.
8. Gravel 2 [> 32.5-40 mm].

2.2 Methodology

2.2.1 Chemical analysis of samples

Table 1. Chemical composition of aggregates

Main oxides	1	2	3	4
	Natural river sand	Crashed gravel 12-38 mm	Gravel 1	Limestone

SiO_2	53.18	43.25	43.98	2.23
CaO	15.35	23.04	24.01	50.29
MgO	9.10	6.43	5.76	0.77
Fe_2O_3	5.67	4.72	3.80	0.63
Al_2O_3	9.65	13.93	13.54	0.98
SO_3	0.11	0.10	0.13	0.21
K_2O	1.26	1.24	1.24	_
Na_2O	0.82	0.84	0.83	_
LOI	0.25	2.36	2.19	
Total	**95.39**	**95.91**	**95.48**	

Test results for chemical composition of aggregates are realized at FKCF Cement factory, Albania.

2.2.2 Physical analysis of samples

Table 2. Determination of specific density for CRASHED GRAVEL 05-12mm sample

No.	TEST DESCRIPTION	UNITS	SAMPLE	
1	Grain size	mm	05/12	05/12
2	Temperature	ºC	20	20
3	Water density	g/cm3	1.0000	1.0000
4	Sample SSD weight	g	500.10	500.00
5	Pycnometer no.(1000 ml)	ml	1	1
6	Mass of pycnometer + water	g	1,178.60	1,178.60
7	Mass of pycnometer + water+ sample	g	1,493.50	1,494.00
8	Dry mass of sample for absorption test	g	117.20	74.80
9	SSD mass of sample for absorption test	g	115.90	73.90
10	Absorption	%	1.122	1.218
11	**Average absorption value**	%	**1.170**	
12	SSD density (each sample)	g/cm^3	2.700	2.709
13	**SSD density(average value)**	g/cm^3	**2.704**	

Table 3. Determination of specific density for CRASHED GRAVEL 12-38mm sample

No.	TEST DESCRIPTION	UNITS	SAMPLE	
1	Grain size	mm	12/38	12/38

2	Temperature	ºC	20	20
3	Water density	g/cm^3	1.0000	1.0000
4	Sample SSD weight	g	500.10	500.00
5	Pycnometer no.(1000 ml)	ml	1	1
6	Mass of pycnometer + water	g	1,178.60	1,178.60
7	Mass of pycnometer + water+ sample	g	1,496.40	1,494.40
8	Dry mass of sample for absorption test	g	125.00	157.80
9	SSD mass of sample for absorption test	g	124.30	156.60
10	Absorption	%	0.563	0.766
11	**Average absorption value**	%	**0.665**	
12	SSD density (each sample)	g/cm^3	2.743	2.714
13	**SSD density(average value)**	g/cm^3	**2.729**	

Table 4. **Determination of specific density for LIMESTONE sample**

No.	**TEST DESCRIPTION**	**UNITS**	**SAMPLE**	
1	Grain size	mm	0/3	0/3
2	Temperature	ºC	20	20
3	Water density	g/cm^3	0.9975	0.9975
4	Sample SSD weight	g	500.30	500.20
5	Pycnometer no.(1000 ml)	ml	1	1
6	Mass of pycnometer + water	g	1,173.20	1,173.20
7	Mass of pycnometer + water+ sample	g	1,485.00	1,483.00
8	Dry mass of sample for absorption test	g	148.50	150.20
9	SSD mass of sample for absorption test	g	146.90	148.50
10	Absorption	%	1.089	1.145
11	**Average absorption value**	%	**1.117**	
12	SSD density (each sample)	g/cm^3	2.6541	2.6271
13	**SSD density(average value)**	g/cm^3	**2.641**	

Table 5. Determination of specific density for NATYRAL RIVER SAND 0-5mm sample

No.	TEST DESCRIPTION	UNITS	SAMPLE	
1	Grain size	mm	0/5	0/5
2	Temperature	ºC	20	20
3	Water density	g/cm^3	1.0000	1.0000
4	Sample SSD weight	g	500.10	500.00
5	Pycnometer no.(1000 ml)	ml	1	1
6	Mass of pycnometer + water	g	1,178.60	1,178.60
7	Mass of pycnometer + water+ sample	g	1,489.60	1,488.90
8	Dry mass of sample for absorption test	g	107.70	76.10
9	SSD mass of sample for absorption test	g	106.00	74.70
10	Absorption	%	1.604	1.874
11	**Average absorption value**	%	**1.739**	
12	SSD density (each sample)	g/cm^3	2.645	2.636
13	**SSD density(average value)**	g/cm^3	**2.640**	

III RESULTS AND TABLES

3.1 Petrographic Description

Sample 1 – Crushed limestone sand (873.6 grams)

Figure 1 and 2 represent crushed limestone sand, observed optically, with main composition made of totally crushed calcite [$CaCO_3$] represented by beige to yellow color. Limestone grains dimensions range from hundredths of mm (in powder form), which occupies 15% of the total amount, up to tenths of mm which occupies about 55% of the total mass of sample. 35% of remaining mass has non uniform shape with dimensions ranging from 1-3 mm. Minor of clay spots are observed in the limestone grains which gave darker color to the material. By chemical analysis of the sample labeled limestone in Table 1, results that this material content is of pure lime and have calcite main composition.

Sample 1 – River sand (732.9 grams)

Figure 3 shows river sand material optically observed as fractioned scarification material with non uniform shape.

From stereomicroscope observation is concluded that:

a) The size of the granules and aggregates have dimensions ranging from hundredths of mm to powder form, and represent about 10% of the total mass,

b) Consist mainly of aggregates with size ranging to tenths mm, which made up 60% of total amount of sample taken for petrographic test analysis,

c) Grain size of this aggregate range from 1 to 4 mm which represent 30% of the total mass of the sample tested.

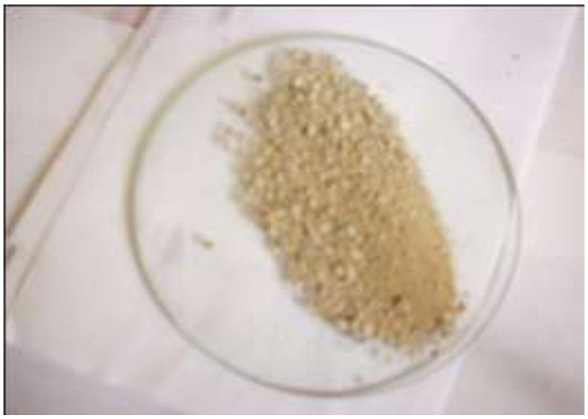


Fig. 1: Natural view of limestone sand. Fractioned, granular calcaleorous material with dimmension ranging from hundretths to tenths of mm. Grain size is 1-3 mm.

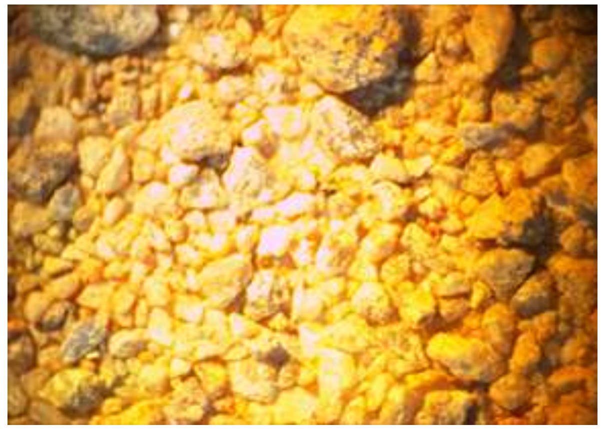


Fig. 2: Limestone sand observed with stereomicrospe apparatus with magnification 8 x. Calcareous granular aggregate represented by beige – yellow colour.

Fig. 3: Natural view of natural sand. Granular fractioned river sand with ferrous pieces represented by green –black colour, pyroxene (silicate), quartz, calcareous – carbonate, metallic grains.

Fig. 4: River sand, observed with stereomicroscope apparatus, with aluminosilicate magnification scale 8x. Chloride aggregates-grains, olivine, pyroxene, olivine – quartz and calcite.

In mineral composition are included: (Figures no.3; 4; 5)

a. Chloride aggregates (aluminum silicates of iron), 34% of total mass represented by color green to darkness.
b. Olivine + Pyroxene (Ca, Fe and Mg silicates) 12% of total mass.
c. Quartz (SiO_2), 35% of the total mass.
d. Fractioned calcite aggregates (Calcite – $CaCO_3$), 13 % of the total mass.
e. Inserted grains of metallic minerals such as magnetite micro grains, pyrite micronic particles etc., made up 3-5%.
f. analysis is applied on river sand sample. All magnetic fractions were split apart and the observation was made with Stereomicroscopes apparatus. During observation are noted fractions of inserted grains – aggregates magnetic fractions of magnetite micro grains.

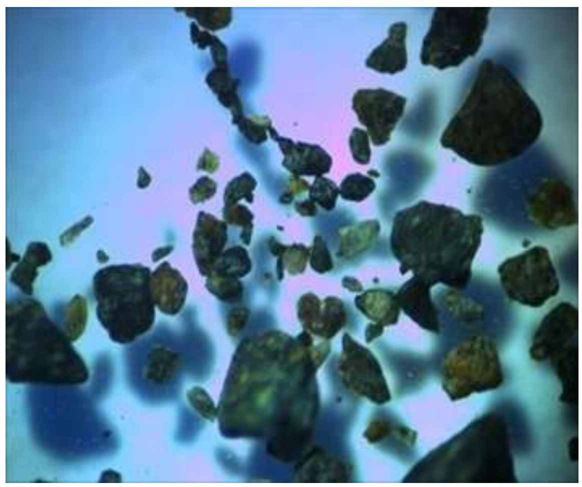


Fig. 5: Magnetic fraction of river sand sample observed with stereomicroscope apparatus, with magnification scale 20x. Inserted aggregate – grains of micro magnetite mineral particles.

We should take in consideration:

First:

Based on ASTM C 295-03 standard requirements is important to observe the presence of non-stable chemical minerals such as insoluble sulphates and non-stable sulfides which may effect on formation on sulphuric acid or creation of surface tension of exposed concrete structures in high temperatures during the application, or non stable volume minerals such as mica, smectite (known as Montmorillonite- -Saponite mineral group) or expanded clay.

Second:

Based on chemical analysis of samples it was necessary to prepare the sample for mineralogical observation of sulphate content. Relating to petrographic analyses results during transmitted polarized microscope observation there are noted points in range 20-40 microns of sulphur mineralization (Pyrite – FeS2).

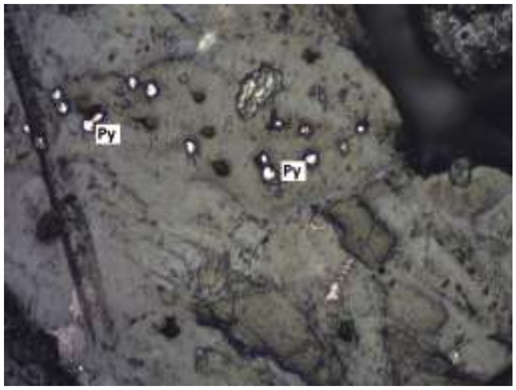


Fig. 6: Micrograph view of polished river sand sample surface observed on reflected light of mineralogical microscope. Bright grains represent sulphur spots with dimensions ranging from 20-40 μ and PY index shows pyrite- FeS_2.

Gravel 1 (416.8 gr.), 1-4-6 mm.

During the observation with stereomicroscope apparatus it is concluded that this sample, composed from micro-aggregate grains with partially regular shaped size in range of 1mm, made 30% of total sample mass, while dimensions 2-4 mm occupied 40% of total mass. Grains with dimension ranging from 4-6 mm made up to 30% of the total mass of the sample (Fig. 7 & 8).

Fig. 7: Gravel 1, 1-4-6 mm, Natural view. Pieces of aggregate-grains with dimensions 1-4-6 mm, consist mainly from sandy material pieces of darkness color, those with green to black color represent basalt material while those colored with white to grey are calcareous aggregates (carbonate $CaCO_3$).

Fig. 8: Gravel 1, observed with stereomicroscope apparatus with magnification scale 8x.
Carbonate aggregates, sandy material pieces with dimensions 2-4mm.

Up to 50% of those aggregate-pieces are represented by sandy material, 25-30% from basalt material having dark green to black color, while carbonate material – calcareous material ($CaCO_3$) make 10-15% of total mass represent by white – grey color.

Gravel 1 (50 pieces, 73.5 gr.) (8-14 mm)

During the observation with stereomicroscope is noted that this sample represent aggregate pieces with non uniform shape and dimensions ranging from 8-14mm. Pieces are mostly sandy material making 65-75% of the total mass, while basalt is up to 10-15% and calcareous pieces represent 15% of the total mass. (See Fig. 9).

Gravel 2 (30 pieces, 235.8 gr.) (1-2 cm.)

Made from fractioned aggregates with dimensions ranging from 1-2 cm (Fig. 10), which represent 65% of sandy quartz micro grains, 20-25% is calcareous-carbonate which is represented by white-grey color while basalt pieces and volcanic rocks (siliceous – chloride base) made up 10% of the total mass.

Fig. 9: Gravel 1, 8-14 mm, natural view. Sandy material made of fractioned aggregates. Basalt is represented by darkness pieces and calcareous material is represented by white-grey pieces.

Fig. 10: Gravel 2 (1-2 cm), natural view. Fractioned sandy material represented with beige-darkness color, while calcareous material is represented with white-grey color., Siliceous-chloride base volcanic rocks represented with green to darkness color.

Gravel 2 (51 pieces, 263.3 gr.) (12.5-20 mm)

The sample is represented by fractioned aggregates with non-uniform shape (Fig. 11).

Sandy piece materials made 60-65% of the total mass while volcanic rocks (green color) with chloride content, represent 10-15% of the total mass. Calcite pieces ($CaCO_3$) with beige – yellow color represent 5-10% of the total mass. Few pieces of red siliceous material (SiO_2 with insertion of ferrous material) are represented with reddish color.

Gravel 2 sample, was polished and prepared in thin section for examination with a transmitted or either reflected light microscope to determine types of mineral rocks taken in this study.

Fig. 11: Gravel 2, natural view (12.5-20 mm). Sandy aggregate pieces, chloride volcanic rocks, calcites, while red siliceous pieces are very rare (mainly formed by iron hydroxides).

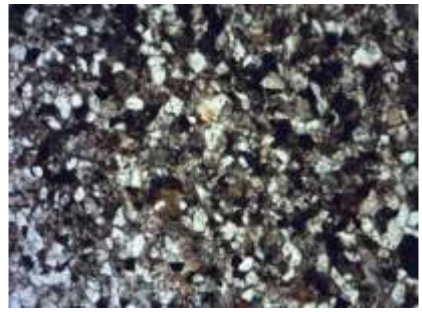


Fig. 12: Gravel 2 sample, textured microstructure of sandy material observed on polarized light petrographic microscope with magnification scale 40 x (Quartz grain size ranging from 0.1 - 0.2 mm).

a. 

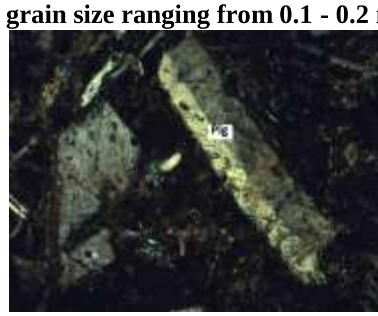
b. 

Fig. 13: Gravel 2 crystalline Plagioclase with grain size 0.1-0.2 mm. Polarized light microscope:
a. Magnification scale 40x b. Magnification scale 100x

Sand material is composed mainly from quartz (Fig. 12) with dimensions ranging from 0.1 - 0.2 mm making 60 % of the total mass of tested sample; plagioclase-anorthite 7-10 % (Fig. 13); mica grains (muscovite) up to 2-3 % (Fig. 14), inserted in cement of sand where chloride cement represent 15-20%, while opac minerals (magnetite, pyrite etc.) 2-4% of the mass.

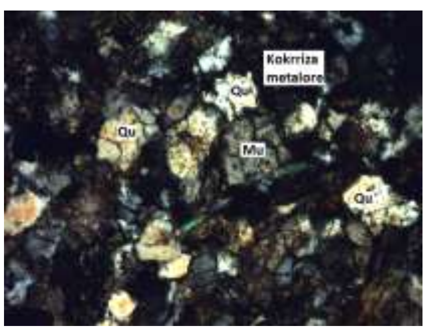


Fig. 14: Gravel 2, Sandy material containing mica grains (muscovite) in cement between quartz and plagioclase –feldspar quantity with grain dimensions ranging from 0.1-0.2 mm. Polarized light microscope with magnification scale 100x.

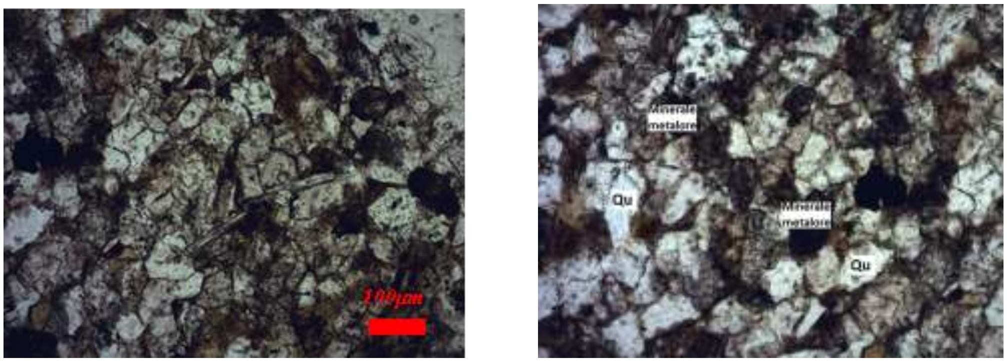


Fig.15: Gravel 2

- **a.** **Sandy material with chloride cement content observed in polarized light microscope. Magnifications scale 40x.**
- **b.** **Black spots represent opac minerals (magnetite, pyrite, etj.)**
  Polarized light microscope. Magnifications scale 40 x.

Gravel 2 (12 pieces, 518.4 gr.) (32.5- 45 mm)

Sample composed from sandy pieces, basalt represented from green-black color pieces, calcite and chlorite volcanic rocks are mainly fractioned aggregates with non-uniform shape, with dimensions ranging from 32.5 up to 45mm. Basalt pieces meet rare and contains secondary calcite ($CaCO_3$) seam traces represented by white color. The width of seam traces range from 2-5 mm making non-uniform shape of texture (Fig. 16).

Fig.16: Gravel 2: Natural view (32.5-45 mm) grain size. Basalt pieces with green black color, sandy pieces with yellow-darkness color, alkaline volcanic rocks pieceswith green color, small microcrystalline of calcite secondary ($CaCO_3$) with white color and dimensions 2-5mm.

Basalt mineral observation made with petrographic microscope (Fig. 17). Microstructure made by plagioclase, cemented from chlorite. Basalt pieces are almost cracked and filled mostly with calcite secondary (Fig. 18), while volcanic alkaline rocks have high content of chlorides (Fig. 19).

Fig. 17: Gravel 2, pieces, basaltic texture with darkness to black color composed from plagioclase rods with size up to 0.2mm, chlorite cement with opac minerals (metallic, such as magnetite, pyrite etc.) observed with polarized light microscope with magnification 40x.

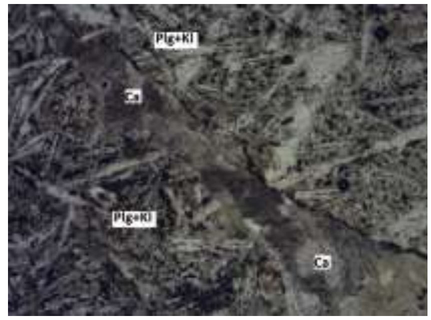


Fig. 18: Gravel 2 sample observed with polarized light microscope. View of micro-cracks filled with calcite second ($CaCO_3$). Magnification scale up to 40x.

a 

b 

Fig. 19: Gravel 2,

- **a. High chloride content volcanic rocks composed from iron hydroxides in the center, observed with polarized light microscope, magnification scale 100x.**
- b. **Volcanic rocks with high chlorides and silica content, observed on polarized-light microscope with magnification scale 100x.**

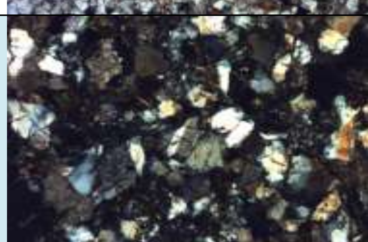
Sample 32.5-40 mm grain size

Meet mostly fractioned sandy rock particles almost shaped plate (Fig. 20), with beige to darkness color, with chloride, silica and carbonate cement content and few pieces of volcanic basaltic rocks with chlorides content.

Fig. 20: Natural view of sample 32.5-40 mm grain size,. Fractioned sand pieces, shaped plate with gray to dark beige color.

III CONCLUSIONS

According to mineralogical-stereoscopic test results, the conclusions for this study are:

Sample/Mineral	Microscopic examination	%	Grain size	Description
Limestone		100%	0-3 mm	This limestone sample consists entirely of calcite. Where replacement of the original calcite is apparent, the newly formed carbonate contains a minor amount of MgO (ca. 0.21 wt %).
Natural river sand		SiO_2= 35% Olivine and pyroxene = 12% (in form of silicates of Ca, Fe and Mg) Carbonate ($CaCO_3$) = 13% Metallic minerals(magnetite micro grains & pyrite) = 3-5% Aluminum silicates of Iron = 34%	0-4 mm	The microscopic examination of natural river sand shows the presence of quartz and aluminum silicates of iron as main components. A few grains of additional minerals were optically observed include carbonate, olivine, pyroxene, and metallic minerals.
Gravel 1		SiO_2= 50% Basalt = 25-30% Carbonate ($CaCO_3$) = 10-15%	1-4-6 mm	River gravel 1 with grain size 1-4-6 mm. Sandy material made of 50% SiO_2, some black to dark green basalt pieces up to percentage as identified in related section. It is found carbonate content too.
Gravel 1		SiO2= 65-75% Basalt = 10-15% Carbonate (CaCO3) = 15%	8-14 mm	Sandy material made of 75% SiO_2, and some black to dark green basalt pieces up to percentage as identified in related section. It is found carbonate content too.
Gravel 2		SiO2= 65% Basalt = 10% Carbonate (CaCO3) = 20-25%	10-20 mm	Sandy material made of 65% SiO_2, and some black to dark green basalt pieces up to percentage as identified in related section. It is found carbonate content too.
Gravel 2		SiO2= 60% (0.1-0.2 mm) Feldspar (plagioklazianorit group)= 7-10% Muscovite = 2-3% Iron aluminum silicates = 15-20% Magnetite & pyrite = 2-4%	12.5-20 mm	Sandy material made of 60% SiO_2. Feldspar and muscovite trace are founded in mineral microstructure under the microscope examination. Opac mineral such as magnetite and pyrite are founded too during the examination.

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