DOI 10.51558/2303-5161.2025.13.13.30 Professional paper

THE POSSIBILITY OF FINDING NEW DEPOSITS OF CONSTRUCTION AGGREGATES IN TUZLA CANTON FOR THE NEEDS OF BUILDING ROAD INFRASTRUCTURE

Ismir Hajdarević[1], Ekrem Bektašević[2], Alen Baraković[3], Kemal Gutić[4]

[1] *MSc, B.Sc. Eng. geology Geological survey of Federation of Bosnia and Herzegovina, Sarajevo, BA, ismirhajdarevic@yahoo.com*
[2] *PhD, B.Sc. Eng. Mining, PPG d.o.o. Sarajevo, bektasevic.ekrem@gmail.com*
[3] *B.Sc. Eng Mining, JP Autoceste Federacije BiH, Mostar*
[4] *PhD, Faculty of Mining, Geology and Civil Engineering - University of Tuzla, kemal.gutic@untz.ba*

Summary

Construction aggregates (crushed stone) is a mineral raw material that is practically irreplaceable in construction, both in low-rise construction and in high-rise construction [9]. Although in recent times more and more stone aggregates are obtained by recycling construction waste, still by far the largest part of these useful raw materials is obtained by exploitation from quarries and gravel pits [14]. Tuzla Canton has significant resources of this valuable mineral raw material. Currently, ten construction aggregates quarries have been opened in this canton, of which one is a diabase quarry, and the rest are limestone quarries.
The construction of several highways and expressways is planned in the area of Tuzla Canton, with the aim of better traffic connections with the rest of the country and with the world. In the near future, the construction of two highways is planned: "Border with the Republic of Croatia-Orašje-Brčko-Tuzla" and the so-called y arm of the highway that will connect Corridor Vc with Tuzla [8]. In order to meet the increased needs of the Tuzla Canton for construction aggregates during the period of intensive road infrastructure construction that follows, it will be necessary to open new quarries. In particular, an increase in demand for construction aggregates with a carbonate composition is expected. The authors of this paper, based on previous experiences, as well as their own knowledge, proposed several locations where geological formations of different ages and with high-quality limestone masses suitable for finding economically profitable deposits of Construction aggregates in the relative proximity of the route of the future highway in the territory of Tuzla Canton have been identified.
Key words: construction aggregates, Tuzla Canton, geological exploration, exploitation, quarry, limestone, diabase.

1. INTRODUCTION

Rocks are natural formations consisting of one or more minerals of a certain chemical composition and structure. Building stone is obtained from rocks. Stone is a non-metallic mineral raw material that is extremely important in construction. It is practically irreplaceable, both in low-rise construction and in high-rise construction. The largest part of its production falls on crushed stone, or as they call it construction aggregates, the production of which at the world level is growing

year by year. Although not all countries keep accurate statistics regarding the production of stone aggregates [12], it is assumed that the annual production of these materials in the world is close to 20 billion cubic meters. Although in recent times more and more stone aggregates are obtained by recycling construction waste, still by far the largest part of these useful raw materials is obtained by exploitation from quarries and gravel pits.

The communication connectivity of an area is a basic prerequisite for its further development. At hree Pan-European transport conferences held in Prague in 1991, in Crete in 1994 and in Helsinki in 1997, Europe defined a total of ten new transport corridors in Central and Eastern Europe. It is planned to build roads and railways on these corridors. Corridor Vc, which connects Eastern and Central Europe with the Mediterranean coast, as part of this European project, passes through our country. A part of the international highway is under construction on it, which represents the largest post-war infrastructure project in Bosnia and Herzegovina.

In addition to the highway on Corridor Vc, several more highways and expressways are planned to be built in Bosnia and Herzegovina. It is planned that some of them will pass through the Tuzla Canton, which will greatly contribute to the better traffic connection of this industrial region with the rest of the country (Fig. 1.). First, the plan is to build the highway "The border with the Republic of Croatia-Orašje-Brčko-Tuzla", the total length of which is 61 kilometers. This highway is divided into two parts. The first unit is the section "Orašje-Brčko-Maoča" with a length of approximately 30 kilometers, while the second unit is the section "Maoča-Tuzla" with a length of approximately 31 kilometers. The implementation of this project should begin with the construction of the Čanići-Tuzla subdivision (Šićki Brod), which is included in the FBiH Public Investment Program 2022 - 2024. The connection of the Tuzla Canton with the highway on Corridor Vc was also planned. The so-called y branch will depart from Corridor Vc in the region of Žepča and Zavidovići, and will continue along the Krivaja valley, then turn towards Seona in the municipality of Banovići and further towards the municipality of Lukavac. It will bypass Modračko Lake on its western side, and south of the town of Lukavac will turn east towards Šićki Brod, where it will join the Tuzla-Orašje highway [8]. The construction of the Tuzla-Zvornik expressway is also planned.

The planned works on the road infrastructure will require an increased demand for stone aggregates, above all for those of carbonate origin. This work is, among other things, a modest attempt by the authors to point out the existence of promising locations for finding deposits of technical and construction stone, primarily limestone, near the route of the future highway that will be built in the coming years in the Tuzla Canton.

2. INCREASING NEEDS FOR CONSTRUCTION AGGREGATES IN TUZLA CANTON DUE TO THE CONSTRUCTION OF NEW ROAD INFRASTRUCTURE

The question arises, how to supply the Tuzla Canton market with the necessary quantities of stone aggregates in the coming period when the plan is to significantly increase the construction of road infrastructure, primarily highways? Due to the cost of transportation, construction aggregates quarries should not be more than 30 kilometers away from the route being built [14]. This narrows the choice of existing quarries from which stone could be used for these needs, as well as the selection of new locations for opening quarries. Currently, there are ten limestone quarries in continuous exploitation in the Tuzla Canton, seven of which are located in a zone closer than 30

kilometers from the planned highway route. At several other locations, the process of obtaining permits for the opening of quarries is underway.

It should be noted that the existing construction aggregates quarries currently manage to meet the needs of the market for crushed stone. It is expected that in the coming period, with the beginning of the construction of certain sections of the highway, if no new quarries are opened, there will be a shortage of aggregates of carbonate origin. This is because the existing quarries do not have enough capacity to meet the growing needs of the market. In addition, it should be noted that some of the largest quarries produce almost exclusively for the needs of the industry for which they were opened. Primarily the Vijenac limestone quarry, which markets almost 90% of its production for industrial needs. Also, the Duboki Potok-Bijela Rijeka and Drenik limestone quarries use a significant part of their production to meet the needs of their own lime factory and concrete element factory.

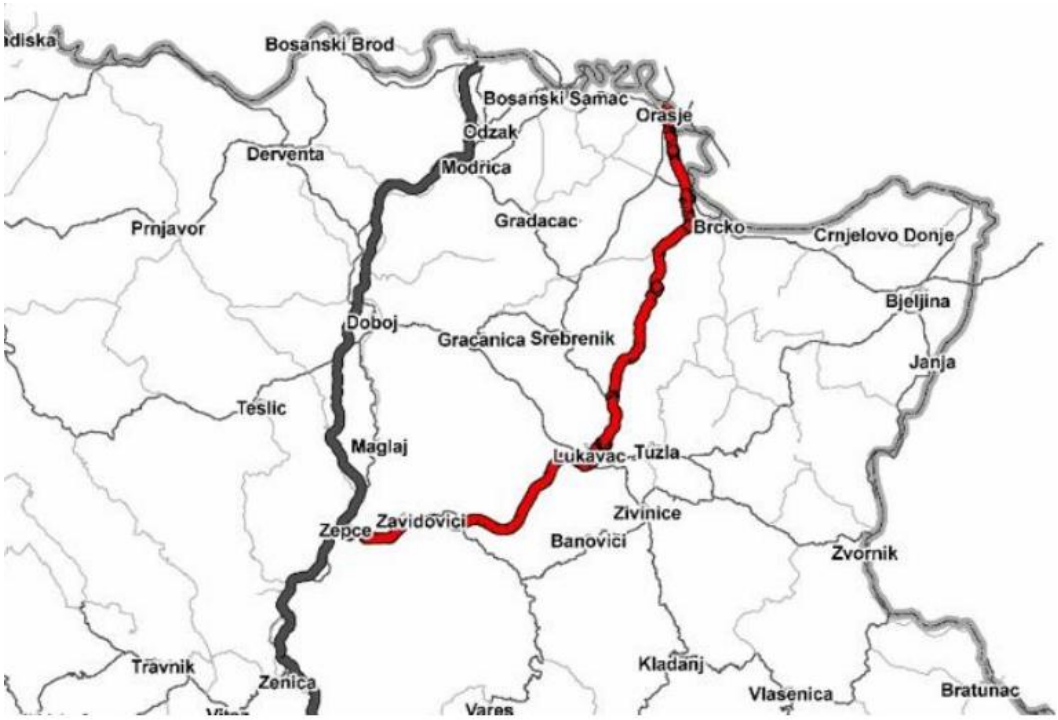

Figure 1. Highway Border with the Republic of Croatia-Orašje-Brčko-Tuzla and Highway Žepče-Tuzla (source - Public Company Autoceste FBiH d.o.o. Mostar)

3. OVERVIEW OF THE EXPLOITATION OF CONSTRUCTION AGGREGATES IN THE AREA OF TUZLA CANTON

Seven limestone quarries and one diabase quarry in the Tuzla Canton are located in a zone closer than thirty kilometers from the route of the future highway [1]. We give a brief overview of these construction aggregates quarries, as well as the basic physical and mechanical characteristics of the stone exploited in them.

Vijenac limestone quarry

The Vijenac limestone quarry is located on the hill of the same name, about 8 kilometers northeast of Banovići (Fig. 2.). An asphalt road leads to the quarry via Prokosovići and Poljica. It is

connected by an asphalt road to Banovići via the villages of Čubrić and Treštenica. A quarry was opened at this location as early as 1957. These are Tithonian-Valendian (Jurassic-Cretaceous) coral-reef limestones. The open profile shows stratification, and the thickness of the layers is from 1.5 to about 10 meters. The strata extend in the direction NE - SW, and fall in the direction southeast and east at an angle of 52 - 75°. At this quarry, three exploitation floors were opened at elevations of 500, 525 and 550 meters.

The Vijenac limestone quarry was opened for the needs of the industry in Lukavac and today it works for the needs of the Soda Factory and the Cement Factory. The total annual production of the quarry is about 580,000 m^3 of solid mass, of which about 515,000 m^3 is used for the aforementioned factories, and the rest is marketed. Limestone is transported from the quarry to the soda factory in Lukavac by cable car with a capacity of 150 t/h and a straight line length of 12 km. Since transportation by cable car cannot meet the needs of the industry in Lukavac, the rest is transported by trucks.

Figure 2. Vijenac limestone quarry (Photo „Rudnik krečnjaka Vijenac d.o.o. Lukavac“)

According to the results of the analysis (Tab. 1.), stone from the Vijenac limestone deposit can be used: for the production of calcined and caustic soda, for the production of nitrogen fertilizers, in the cement industry, for the production of filler flour for asphalt, for the lower part of roads and for most of the upper parts of roads in road construction, for the production of various types of concrete mixtures, as well as crushed stone for masonry in construction, etc. [1]

There is a possibility of increasing the production capacity of limestone from the Vijenac quarry, for the purposes of building future highways, but on a limited scale, due to the advantage of supplying industrial plants in Lukavac. The advantage of this quarry is its location near the route of the future highway (about 3 kilometers away from the nearest planned route). Considering the distance from the route, stone aggregates from this quarry could be used on almost the entire section of the future Žepče-Tuzla highway, as well as on the Šićki Brod-Čanići subsection of the Tuzla-Orašje highway.

Table 1. Physical and mechanical characteristics of limestone from the Vijenac quarry

No.	Type of determination	Value
1.1.	Compressive strength (dry specimens)	mean = 140,5 MPa
1.2.	Compressive strength (saturated specimens)	mean = 127,6 Mpa
1.3.	Compressive strength (sp. after 25 freeze-thaw cycles)	mean = 124,02 Mpa
2.	Absorption of water at atmospheric pressure	= 0,199%
3.	Bulk density	= 2674 kg/m^3
4.	Density	= 2715 kg/m^3
5.	Coefficient of Density	= 0,984
6.	Absolute porosity	= 1,56% (vol.)
7.	Frost resistance (after 5 cycles of immersion in Na_2SO_4)	= 0,113% - resistant
8.	Abrasion resistance (Böhme test)	mean =15,44 cm^3/50 cm^2
9.	Impact resistance	= 21,2%
10.	Abrasion according to the LA method: gradation "B"	= 25,9%
11.	Abrasion according to the LA method: gradetion "C"	= 21,0%

Stupari limestone quarry

The limestone quarry "Stupari" is located on the right bank of the river Gostelja, 2 km downstream from the settlement of Stupari (Fig. 3.). This deposit is made up of gray, bluish and greenish massive limestones of the Anisian ages [17], which, going upwards, pass into plate-like, marly limestones (thickness of the layers is 10-20 cm) of yellow, gray and reddish colors. The main mass of the rock is composed of microcrystalline calcite mud. Its structure is microcrystalline, and its texture is homogeneous. It is limestone (biomicrite), without the presence of organic matter in it. In the middle part of the deposit, a lens of reddish breccia limestone occurs, 12 - 15 m wide. The quarry is divided by height into four levels: 365, 390, 405 and 425 m. The main plateau is located at an altitude of 345 [1] .

Figure 3. Orthophoto shot of Stupari Limestone Quarry

The main road Tuzla - Sarajevo passes right next to the quarry, through which there is a connection with the road network of the wider region and the country. Products from this deposit can also be transported by rail via the Đurđevik Coal Mine terminal, located about 8

km from the quarry. Therefore, we can say that from the aspect of communications, this quarry has a very good position.

Table 2. Physical and mechanical characteristics of limestone from the Stupari quarry

Broj	Type of determination	Value
1.1.	Compressive strength (Dry specimens)	mean = 124,0 MPa
1.2.	Compressive strength (saturated specimens)	mean = 106,2 Mpa
1.3.	Compressive strength (sp. after 25 freeze-thaw cycles)	mean = 96,8 Mpa
2.	Absorption of water at atmospheric pressure	= 0,104%
3.	Bulk density	= 2690 kg/m^3
4.	Density	= 2780 kg/m^3
5.	Coefficient of Density	= 0,968
6.	Absolute porosity	= 3,24% (vol.)
7.	Frost resistance (after 5 cycles of immersion in Na_2SO_4)	= 0,11% - resistant
8.	Abrasion resistance (Böhme test)	mean =24,76 cm^3/50 cm^2
9.	Impact resistance of edges (Deval coefficient (k_D))	= 1,10
10.	Abrasion according to the LA method: gradation "B"	= 28,16

According to certificates, it can be used for the production of load-bearing bases (pads) in road construction, then for the production of crushed aggregates for concrete, as crushed stone in civil engineering, as processed and untreated stone for masonry, etc.(Tab. 2.) [1]
Regarding the possibility of using stone from this quarry for the construction of the planned highways Tuzla-Orašje, that is, Žepče-Tuzla, we can state that the quarry is about 29 kilometers away from the nearest part of the route, which is Šićki Brod. That is approximately the ultimate limit of economic profitability from the aspect of distance.

Oštro Brdo limestone quarry

The Oštro Brdo limestone deposit is located in the far north-eastern part of the municipality of Kladanj, near the border with the municipality of Živinice. The quarry is located about 3.5 km south of the village of Gračanica, on the left bank of the Zaboj stream, which flows into the river Suvaja. The deposit is represented by gray, layered, banked and massive limestones, which are breccia and tectonized, especially in its northern parts. The tectonized limestones are partially recrystallized and intersected by millimeter calcite veins. The thickness of the layers ranges from 20 to 60 cm, and banks up to 1 m thick are also encountered. The general dip of the layers is in the NE direction with relatively steep dip angles of 40 - 65^0.

Figure 4. Oštro Brdo limestone quarry (Photo Hajdarević I.)

Limestone from the Oštro Brdo quarry can be used: for the lower part of road constructions, and for most of the upper part of road constructions, for the production of various types of concrete mixes, as well as crushed stone for masonry in construction, etc. (tab. 3.) [1]
The Oštro Brdo quarry (Fig. 4.) from Šićki Brod, as the closest point on the future highway, is about 30 kilometers away, which represents the limit of the economic viability of using fractions from this quarry in road construction.

Table 3. Physical and mechanical characteristics of limestone from the Oštro Brdo quarry

Broj	Type of determination	Value
1.1.	Compressive strength (Dry specimens)	mean = 124,3 MPa
1.2.	Compressive strength (saturated specimens)	mean = 119,0 Mpa
1.3.	Compressive strength (sp. after 25 freeze-thaw cycles)	mean = 105,04 Mpa
2.	Absorption of water at atmospheric pressure	= 0,11%
3.	Bulk density	= 2672 kg/m^3
4.	Density	= 2778 kg/m^3
5.	Coefficient of Density	= 0,96
6.	Absolute porosity	= 0,78% (vol.)
7.	Frost resistance	- resistant
8.	Abrasion resistance (Böhme test)	mean =23,21 cm^3/50 cm^2

Duboki Potok-Bijela Rijeka limestone quarry

The Duboki Potok-Bijela Rijeka limestone quarry (Fig. 5.) is located about 6.5 km southeast of Srebrenik. The river Tinja limits the deposit from the north, the river Bijela from the west, and the nameless stream from the east side of the deposit. The deposit is located along the asphalt road Tuzla-Srebrenik-Orašje, which connects the deposit with all important centers. There is a railway station in Duboki Potok settlement, and the stone can be transported by railway for the needs of customers in the country and abroad.

Figure 5. Duboki Potok-Bijela Rijeka limestone quarry (Photo INGRAM d.o.o. Srebrenik)

The layers of lithotamnian limestones in the Duboki Potok-Bijela Rijeka quarry have a NW-SE direction, and lie about 250 to the north. In the lower parts, light gray limestones with foraminifera prevail. In the higher levels, there are banked and massive limestones with large nummulites [3]. On the deposit itself, all the wells were completed in limestone, which means that the power of the productive series, i.e. its floor, has not been defined. The basic plateau at the quarry is at 260 m.a.s.l. The height of each floor is 20 m and there are five of them (at elevations of 280, 320, 360 m), and the tailings floor is designed at an elevation of 380 m [1]. The annual production of limestone of different fractions amounts to about 300,000 m3 of solid mass. Part of the production of over 50,000 m3 is currently used in our own factories (a factory for the production of hydrated lime and a factory of concrete elements), while the rest is sold on the domestic and Croatian markets.

Table 4. Physical and mech. characteristics of limestone from the Duboki P.-Bijela R. quarry

Broj	Type of determination	Value
1.1.	Compressive strength (dry specimens)	mean = 137,4 MPa
1.2.	Compressive strength (saturated specimens)	mean = 125,6 Mpa
1.3.	Compressive strength (sp. after 25 freeze-thaw cycles)	mean = 115,6 Mpa
2.	Absorption of water at atmospheric pressure	= 0,52%
3.	Bulk density	= 2660 kg/m^3
4.	Density	= 2730 kg/m^3
5.	Coefficient of Density	= 0,974
6.	Absolute porosity	= 2,76% (vol.)
7.	Frost resistance (after 5 cycles of immersion in Na_2SO_4)	= 0,116% - resistant
8.	Abrasion resistance (Böhme test)	mean = 18,1 cm^3/50 cm^2
9.	Impact resistance (Trenton)	= 8,32%

Since the maximum planned capacity of the quarry is over 350,000 m3 of solid mass, it is evident that this quarry, in addition to the current market, could market over 50,000 m^3 of solid limestone annually for the construction of the future highway (Tab. 4.) [1]. With an additional increase in capacity and significantly more.

Drenik limestone quarry

The Drenik limestone quarry (Fig. 6.) is located about 1.5 km southeast of Srebrenik, on the left bank of the Tinja River. The deposit is located next to the asphalt road Tuzla-Srebrenik-Orašje, which connects the deposit with all important centers. The Drenik quarry was opened in lithotamnian bank-like and massive limestones of Paleocene-Eocene age [2].

After a break of several years, production in the Drenik quarry has been reactivated and currently amounts to about 70,000 m^3 of solid mass per year. The production is marketed on the domestic market and the market of the Republic of Croatia. The maximum projected capacity of the quarry is about 185,000 m^3 of solid mass, so it is evident that this quarry can produce significant quantities of different stone fractions (Tab. 5.) [1], as well as ready-made concrete for the construction of future highways in the area of Tuzla Canton.

Figure 6. Drenik limestone quarry (Photo Hajdarević I.)

Table 5. Physical and mechanical characteristics of limestone from the Drenik quarry

Broj	Type of determination	Value
1.1.	Compressive strength (dry specimens)	mean = 178,0 MPa
1.2.	Compressive strength (saturated specimens)	mean = 142,6 Mpa
2.	Absorption of water at atmospheric pressure	= 0,403%
3.	Bulk density	= 2670 kg/m^3
4.	Frost resistance (after 5 cycles of immersion in Na_2SO_4)	= 0,116% - resistant
5.	Abrasion resistance (Böhme test)	mean = 18,1 $cm^3/50\ cm^2$
6.	Sulfur content (as SO_3)	= 0,05%
7.	Chloride content	= 0,01%

Orlova Klisura limestone quarry

Orlova Klisura limestone quarry is located on the right bank of the Tinja in the gorge of the same name, between the villages of Gornji Potpeć and Lisovići, about 10 kilometers southeast of Srebrenik and about 20 kilometers northwest of Tuzla. Towards the Tinja river, it is characterized by steep sections up to 60 m high (Fig. 7.).

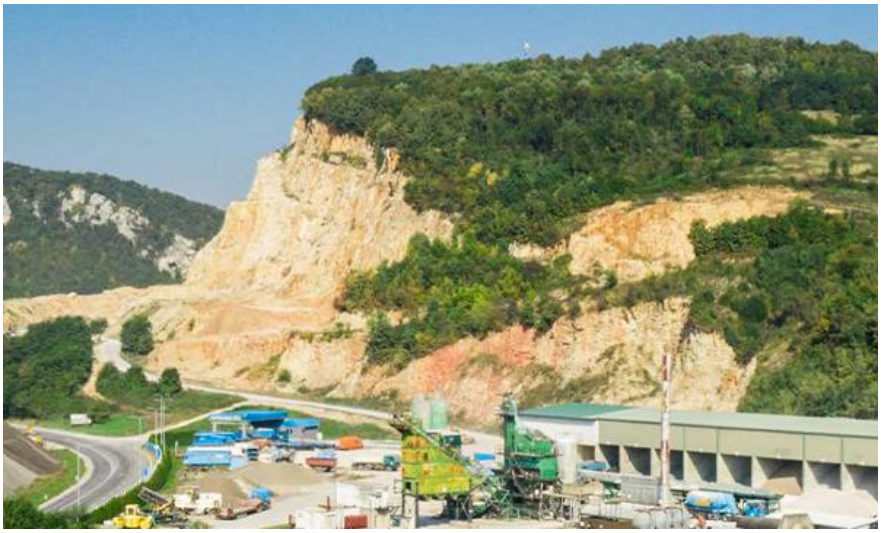

Figure 7. Orlova Klisura limestone quarry (Photo Jata Group)

Table 6. Physical and mechanical characteristics of limestone from the Orlova Klisura quarry

Broj	Type of determination	Value
1.1.	Compressive strength (dry specimens)	mean = 109,9 MPa
1.2.	Compressive strength (saturated specimens)	mean = 105,5 Mpa
1.3.	Compressive strength (sp. after 25 freeze-thaw cycles)	mean. = 92,7 Mpa
2.	Absorption of water at atmospheric pressure	= 0,20%
3.	Bulk density	= 2794 kg/m^3
4.	Density	= 2845 kg/m^3
5.	Resistance to crushing (LA method)	= 22,4
6.	Absolute porosity	= % (vol.)
7.	Frost resistance (after 5 cycles of immersion in Na_2SO_4)	= 0,24% - resistant
8.	Abrasion resistance (Böhme test)	mean = 15,2 cm^3/50 cm^2

Flysch sediments of Upper Cretaceous age and limestones of Paleocene-Eocene age are present in this deposit. The Upper Cretaceous flysch was developed from the basic plateau (290 m.a.s.l.) to an elevation of 340 m.a.s.l. and is represented by limestones (calcarenites) and, to a lesser extent, marls. Further, above the elevation of 340 m.a.s.l., all the way to the end of the outcrop, Paleocene-Eocene bank limestones lie discordantly over the flysch.The main road Tuzla-Srebrenik-Orašje passes right next to the quarry, as well as the Brčko-Banovići railway, so it can be said that from the point of view of communications, this deposit has a very favorable position.

According to certificates (Tab. 6.) [1], it can be used as a technical-building stone for obtaining fractions of stone aggregate intended for concrete mixtures, then for the production of the lower load-bearing layers of road constructions - buffers, as a material for the production of asphalt concrete for class III and IV traffic loads, for the production of bituminous and tar macadam, and as building stone for masonry and other similar purposes.

Due to the proximity of the route of the future Tuzla-Orašje highway (about 8 km in the closest part) and due to the increase in reserves by taking under concession the additional exploration space located in the existing quarry, this limestone deposit will be able to significantly contribute to the construction of this important infrastructure project.

Gradina-Potpeć limestone quarry

Construction aggregate quarry Gradina-Potpeć was opened in Paleocene-Eocene banked and massive limestones (Fig. 8.). It is located on the right bank of the Tinja River, about 5 kilometers southeast of Srebrenik. The deposit is located in the immediate vicinity of the Tuzla-Srebrenik-Orašje asphalt road, which is connected to the domestic and foreign markets. The railway station located in Srebrenik also increases the possibilities of placing stone fractions from this quarry on the market.

Figure 8. Gradina-Potpeć limestone quarry (Photo Hajdarević I.)

Table 7. Physical and mechan. characteristics of limestone from the Gradina-Potpeć quarry

Broj	Type of determination	Value
1.1.	Compressive strength (dry specimens)	mean. = 91,0 MPa
1.2.	Compressive strength (saturated specimens)	mean = 90,0 Mpa
1.3.	Compressive strength (sp. after 25 freeze-thaw cycles)	mean = 86,0 MPa
2.	Absorption of water at atmospheric pressure	= 0,30%
3.	Bulk density	= 2750 kg/m^3
4.	Density	= 2666 kg/m^3
5.	Absolute porosity	= 0,2% (vol.)
6.	Frost resistance (after 5 cycles of immersion in Na_2SO_4)	= % - resistant
7.	Abrasion resistance (Böhme test)	mean = 11,0 cm^3/50 cm^2
8.	Edge resistance to impact (drum)	A_u = 12,0 (L.A)

The Gradina-Potpeć quarry with satisfactory stone quality (Tab. 7.) [1], less than 10 kilometers from the route of the future Tuzla-Orašje highway, represents a potentially serious supplier of stone fractions of various assortments.

Ribnica diabase quarry

The "Ribnica" diabase deposit is located about 10 kilometers southwest of Banovići, near the town of Ribnica (Fig. 9.). It is located next to the Banovići-Zavidovići asphalt road (it is 12 km from Banovići and 20 km from Zavidovići), so it can be said that its position in terms of communication is the Dijabaz-dolerite massif. Ribnica has an area of about 20 km^2 and is located on the northern edge of the Krivajsko-Konjuška ultramafic massif, which is an integral part of the Dinaric ophiolitic zone [18]. Masses of diabases are found as smaller, broken fragments, like this one in the Ribnica locality, where geological research has determined

economically significant reserves of stone with satisfactory physical and mechanical properties (tab. 8.) [1]. Here, diabases are in contact with dolerites, which are more subordinate. They have the same mineral composition as diabases, the same ophitic structure, but they are somewhat coarser-grained than them. In addition to the fault zones, there are metadiabases that do not exceed the amount of 10% in the deposit.

Figure 9. Ribnica diabase quarry (Photo Hajdarević I.)

Table 8. Physical and mechanical characteristics of diabase from the Ribnica quarry

Broj	Type of determination	Value
1.1.	Compressive strength (dry specimens)	mean = 141,62 MPa
1.2.	Compressive strength (saturated specimens)	mean = 124,37 Mpa
1.3.	Compressive strength (sp. after 25 freeze-thaw cycles)	mean = 108,94 Mpa
2.	Absorption of water at atmospheric pressure	= 0,28186%
3.	Bulk density	= 2890,7 kg/m^3
4.	Density	= 2923,3 kg/m^3
5.	Coefficient of Density	= 0,98892
6.	Absolute porosity	= 1,1258% (vol.)
7.	Frost resistance (after 5 cycles of immersion in Na_2SO_4)	= 0,14562% - resistant
8.	Abrasion resistance (Böhme test)	mean =14,84 cm^3/50 cm^2
9.	Impact resistance of edges (Deval coefficient (K_D)	= 3,9828%
10.	Abrasion according to the LA method: gradation "B"	= 15,7996%
11.	Sulfur content (as SO_3)	= 0,17733%

Diabase stone fractions from the Ribnica quarry could satisfy all, or almost all, material needs for the wear layers of the planned highways in the territory of the Tuzla Canton.

Due to the higher price of diabase fractions compared to carbonate fractions, the use of this material is not to such an extent conditioned by the immediate proximity of the quarry to the route of the road being built.

This allows a greater distance of the quarry from the installation site.

4. PERSPECTIVE GEOLOGICAL FORMATIONS FOR FINDING DEPOSITS OF CONSTRUCTION AGGREGATE IN THE TERRITORY OF TUZLA CANTON

The first geological surveys of the area of today's Tuzla Canton began during the time of the Austro-Hungarian Monarchy and are part of the regional surveys carried out by the Geological Survey from Vienna. At that time, these regions were explored by famous geologists: Hauer [5], Bittner [13], Tietze [13], Mojsisovitz [13], Grimer [4].

In the second half of the 20th century, the Basic Geological Map (OGK) was started on a scale of 1:100,000 for the purposes of creating maps: Zavidovići, Doboj, Vlasenica, Zvornik, Brčko and Tuzla. These Basic Geological Map sheets provided basic data on the geological structure of the terrain, structural-tectonic composition of the terrain, rock types, etc. They were made by the Geological Institute Sarajevo.

At the same time, in addition to the creation of OGK, research was carried out in several directions: research to prove reserves of hard and brown coal, lignite, oil and gas, research to find new deposits of rock salt, hydrogeological and hydrological research of waters for industrial purposes (lake Modrac), research underground water (drinking, mineral and thermal mineral), as well as for the christening of various deposits of non-metallic raw materials for the cement industry, production of gas concrete, and more recently, research to prove stocks of technical-building stone. Those investigations were carried out by geologists: M. Luković [11], I. Soklić [15], P. Stevanović [16], M. Eremija [16], Č. Jovanović [7] and numerous others.

From a geological point of view, the territory of Tuzla Canton is an interesting area for research into the existence of possible deposits of quality construction aggregate. From the research that was done during the creation of OGK, it is clearly visible which geological formations can contain quality masses of stone that can be used as aggregate in construction techniques.

As for the perspective of finding rock masses suitable for obtaining aggregates that can be used in pavement constructions, it should be pointed out that they must meet certain conditions. Primarily, they should have satisfactory physical and mechanical characteristics in accordance with technical regulations and applicable standards. Also, they should have favorable mineralogical-petrographic characteristics, as well as an appropriate chemical composition.

Geological factors that influence the evaluation of the value of a deposit of construction aggregate are: the size of the deposit, the type of mineral raw material, the quality of the mineral raw material, the possibility of exploitation, the geomorphological characteristics of the terrain, the degree of geological exploration of the deposit and the proximity of the market.

All rocks are not suitable for use as construction aggregate. We distinguish rocks of magmatic origin, which are often called by the not very precise name "eruptives", and rocks of carbonate origin, limestone and dolostone.

Rocks of magmatic origin, due to their favorable physical and mechanical properties and high resistance to the action of external factors, are mainly used to obtain aggregates that are used to make asphalt-concrete for wearing layers of roads. Of the igneous rocks in our region, basic rocks (diabases, spilites, dolerites) are mostly used, and neutral igneous rocks (andesites and dacites) are less common.

Rocks of carbonate origin are used in the largest percentage when making road constructions. They are used to build the lower part of the road (buffer including the bedding), and the largest part of

the upper part of the road, which includes the mechanically compacted bearing layer, a layer of stabilizing aggregate bound with bitumen or cement, as well as parts of the asphalt pavement (asphalt bearing and asphalt binding layer). Of course, rock aggregates used for these purposes must meet all prescribed standards.

Currently, the only quarry of construction aggregate of magmatic origin in the area of Tuzla Canton is the Ribnica diabase quarry. Considering the balance reserves of stone at this quarry, it could meet most of the aggregate needs for the wearing layer of the future highway.

In the Table 9. we provide an overview of balance reserves (A+B+C1 category) at existing quarries that could supply the routes of the future highways Tuzla-Brčko and Žepče-Tuzla with stone aggregates [1]:

Table 9. Overview of balance stone reserves by quarries

Quarries of stone of magmatic origin - diabase (for Asphalt wearing course)			
Red. br.	Quarry	Municipality	Balance reserves (A+B+C1 cat.) (m^3)
1.	Ribnica	Banovići	14 632 000
In total			**14 632 000**
Quarries of stone of carbonate origin - limestone			
1.	Vijenac[1]	Lukavac	20 297 000
2.	Stupari	Kladanj	707 000
3.	Oštro Brdo	Kladanj	4 632 000
4.	Duboki Potok-Bijela Rijeka[2]	Srebrenik	14 163 000
5.	Drenik	Srebrenik	3 842 000
6.	Orlova Klisura	Srebrenik	3 227 000
7.	Gradina-Potpeć	Srebrenik	1 650 000
In total			**48 518 000**

[1] - *by far the largest part of the reserves from the Vijenac quarry is intended for industrial use in cement and bicarbonate factories*

[2] - *part of the production from the Duboki Potok-Bijela Rijeka quarry is reserved for the production of lime and concrete elements in our own factories*

It should be emphasized that most of the current production capacities in these quarries are used to meet the current needs of the economy and the population of the Tuzla Canton and its surroundings, which means that in order to meet the demand for new quantities in the scale necessary for the smooth construction of the planned highways, a significant expansion of the production capacities in current quarries, as well as the opening of new quarries of construction aggregates.

From all areas with rock masses suitable for opening a quarry of construction aggregates in the area of Tuzla Canton, primarily intended for obtaining stone aggregates for the construction of future highways, we have singled out the following:

Area no. 1 (Vijenac-Jaruške Gornje-Oštrić)

Limestone masses that meet the criteria for opening a quarry of construction aggregates, and which are closest to the planned route of the future Žepče-Tuzla highway, are located in the territory of the municipality of Banovići, east of the town of Seona, and south and southeast of the village of Jaruška. It is a geological formation made of massive limestone beds of Jurassic-Cretaceous age. These rocks are very suitable for use as construction aggregates, which is

proven by the fact that in 1957 one of the largest limestone quarries was opened in them, not only in the area of Tuzla Canton, but also in the whole of Bosnia and Herzegovina. It is the Vijenac quarry, where exploitation is still carried out. This quarry is located on the northeastern edge of this limestone massif.

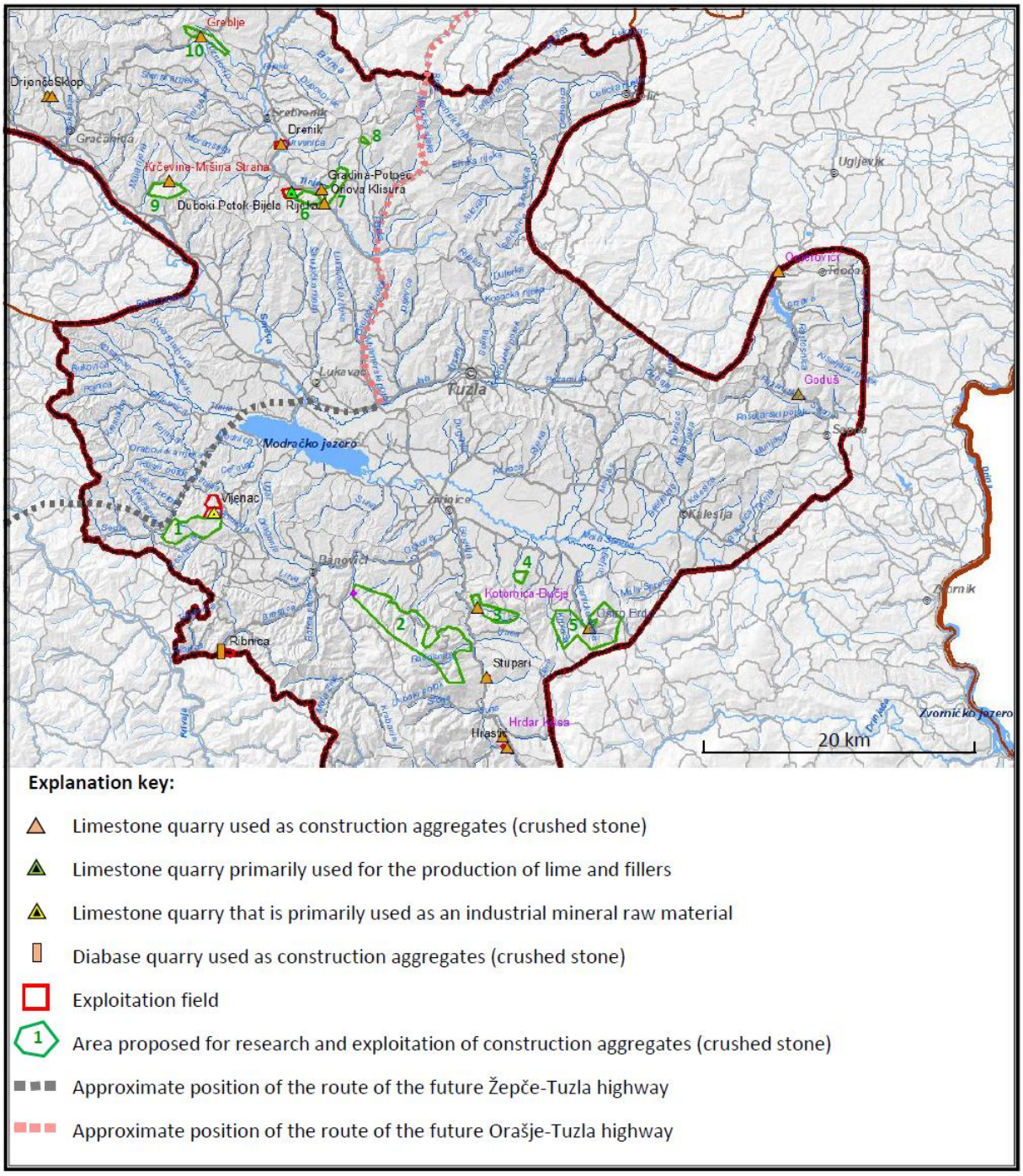

Figure 10. Map showing quarries and potential areas for exploration and exploitation of technical and construction aggregates (crushed stone) in the Tuzla Canton

The planned route of the Žepče-Tuzla highway passes right next to the border of these rock masses, so we can say that this is one of the most favorable terrains for finding deposits of quality construction aggregates for the construction of this road communication. This rock mass

is 25 to 28 kilometers from Šićki Brod, so the stone fractions from a future quarry that would be opened here could also be used in the construction of the route on the Šićki Brod-Čanići subsection of the Tuzla-Orašje highway. All of the above speaks in favor of the fact that this is a very promising area for accessing geological research on the selection of a suitable location for the opening of a limestone quarry as construction aggregate (Fig. 10.) [1].

Area no. 2 (Ravni Bor-Djedinska planina)

Another interesting area in the Tuzla Canton for geological research with the aim of finding suitable locations for the opening of quarries of construction aggregates in carbonate rock masses is located on the northern and northeastern slopes of Djedinska mountain (Fig. 10.). From the Oskova river in the west, over the entire Djedinska mountain, all the way to the Gostilje River in the east, there is a belt of massive and banked limestones of the Middle and Upper Triassic [6]. This terrain is located for the most part in the municipality of Živinice, and only the extreme southeastern part in the municipality of Kladanj. Due to the complex tectonic structure, these formations are not broken down on the Basic Geological Map, although in some localities they can be broken down based on the found micro and macro fauna, as well as lithological features and stratigraphic position. The lowest horizons are represented by gray and light gray limestones with lenses of reddish limestones in the upper part. Hanbulo fauna was found in these limestones, which proves their Anisian age. Layered limestones, rarely dolomites, lie over these limestones in some places. In some places, marly limestones with chert nodules and fauna of Daonel and Halobia occur. This indicates the Ladinian age of these deposits. This series does not have a continuous horizontal extension and passes laterally into coral-reef limestones, which pass upwards into the Upper Triassic. Upper Triassic sediments are represented by limestones similar to Anisian, and less often by dolostones. Their age is proven by findings of the Upper Triassic microfauna.

The northern and northeastern parts of these carbonate masses are interesting for geological research with the aim of finding locations for quarries from which stone fractions could be used in the construction of planned highways. The reason for this is primarily due to the acceptable distance of these terrains from the highway routes. This zone includes the locality Ravni bor in the northwest, and further extends through Gravić kosa and Borovac to Ruj, Igrište and the village of Lupoglavo in the far southeast. This entire zone is 25-30 kilometers from Šićki Brod, which represents a tolerable distance from the aspect of transport costs. Geological surveys have already been carried out at the Ravni bor site and limestone reserves as a construction aggregate of more than 3 million cubic meters of solid mass have been proven, but due to certain administrative difficulties, the quarry has not yet received all the necessary permits for work.

Area no. 3 (Kotornica-Jasik)

The third interesting area is located east of the river Gostilje in the area of Kotornica-Jasik in the municipality of Živinice (Fig. 10.). It is part of the carbonate, predominantly limestone rock masses that represent the continuation of those from the Djedinska mountain area. There was already a limestone quarry in the Kotornica-Bučje location, which was closed a few years ago. In the same locality, the reopening of the limestone quarry is in the process.

The area that is interesting includes the Jasik hill, as well as both banks of the Kotornica stream, where it would be worth starting geological research with the aim of finding more locations with quality stone suitable for opening a quarry of construction aggregates. In addition to high-quality

limestone masses, this area is also interesting due to its proximity to the Sarajevo-Tuzla main road, which greatly facilitates the possibility of transporting stone aggregates to the market. This area is about 25 kilometers from the route of the future highway near Šićki Brod, which is a satisfactory distance, given the good communication connections.

Area no. 4 (Berbenjak)

The mass of undecomposed limestones of the Middle and Upper Triassic, which is located about 5 to 6 kilometers northeast of the Jasik-Kotornica area in the Berbenjak hill area between Donja and Gornja Lukavica (Fig. 10.), on the southern edge of Sprečko polje, is also interesting in terms of the possibility of finding a suitable location for opening a quarry of construction aggregates. this limestone mass also belongs to a belt of carbonate deposits that can be followed from the Oskova river in the west, through Djedinska mountain Stupari and Kotornica to the Gračanica village on the southern edge of the Sprečko polje. It is located in the territory of the municipality of Živinice.

This area is about 26 kilometers away from Šićki Brod, as the closest point on the route of the future highway.

Area no. 5 (Obli vrh-Veliko brdo)

The next in the series of carbonate masses of Middle Triassic to Upper Triassic age, going from west to east, is in the area that includes the sites Obli vrh and Veliko brdo on the border of the municipalities of Živinice and Kladanj (Fig. 10.). A construction aggregates quarry has already been opened within this rock mass and has been operating for many years. It is the Oštro Brdo quarry. In the limestone masses within the proposed area, detailed geological research could undoubtedly find more suitable locations for the opening of quarries that would meet the necessary standards in terms of quality and quantity.

This area is from the nearest point on the future highway, which is Šićki Brod, about 30 kilometers away, which is approximately the ultimate limit of profitability from the point of view of transportation costs.

Area no. 6 (Drenovac-Orlova klisura)

The Paleocene-Eocene limestone massif in the Drenovac-Orlova Klisura region is located on the left bank of the Tinja River in the municipality of Srebrenik (Fig. 10.). These lithotamnian limestones occur in the form of lenses over 3 km long and 700-800 m wide. In the lower parts, light gray limestones with foraminifera prevail. In the higher levels, there are banked and massive limestones with large nummulites. Massive limestone is a rock of monomineralic composition, of organic origin, formed from zoogenic and phytosediments with a high $CaCO_3$ content. Layered gray marls are found in the limestone floor in the wider area of the deposit.

In the northwestern part of this limestone mass, there is already an old active quarry Duboki Potok-Bijela Rijeka. In the extreme southeastern part of this area, the necessary permits for the opening of another quarry are in the process of being obtained. Due to the proven quality of these limestones, as well as the proximity of the future Tuzla-Orašje highway (8 to 10 kilometers), this is a very attractive area for opening a construction aggregates quarry.

Area no. 7 (Kameničak-Kovačevo brdo)

Northeast of the Orlova Klisura and Gradina-Potpeć quarries in the Kameničak-Kovačevo brdo area continues the area with massive Paleocene-Eocene limestones (Fig. 10.). This area, excluding populated areas, is suitable for expanding the two mentioned quarries, as well as for possibly opening new quarries. Good road communications, as well as the proximity of the Tuzla-Orašje highway route, give importance to this area in terms of the possibility of conducting geological research with the aim of finding favorable locations for opening a quarry. The route of the future highway is about 7 to 8 kilometers from this area.

Area no. 8 (Grabovik-Zaketuša)

In the area of Grabovik-Zaketuša (Fig. 10), there are limestone rock masses, also of Paleocene-Eocene age [2]. It is located on the territory of the municipality of Srebrenik. The favorable position of this area is reflected in the fact that it is the closest of the existing quarries, as well as of all the rock masses proposed so far, to the Čanići-Maoča subsection of the Tuzla-Orašje highway. Such a position of the quarry that would be opened in this area would enable the lowest transport costs of stone aggregates for the part of the highway that leads further towards Maoča and Brčko.

Area no. 9 (Hotilj-Krčevine)

The area of Hotilj-Krčevina is located on the territory of the municipality of Gračanica, in the region of Orahovica Donje. It covers a large part of the Hotilj hill, as well as the area of Krčevina northeast of it (Fig. 10.). Limestones with rudites and globotruncas [10] that make up this terrain could be suitable for use as construction aggregates. One quarry within this area at the location of Krčevine-Mršina strana was already in the opening phase, but the process of obtaining permits has been suspended in the meantime.

Before the final decision to open a quarry in these limestones, it would be necessary to carry out a detailed geological prospecting of the terrain, in order to determine the most promising locations for geological research in order to open a quarry. This terrain is located between 22 and 30 kilometers from the Šićki Brod-Čanići subsection of the Tuzla-Orašje highway. From the route Žepče-Tuzla, the closest part in Lukavac is 22 kilometers away.

Area no. 10 (Krešnice-Ćerimovo)

Between Doborovci and Srnice Gornje, in the municipality of Gračanica, there is a belt of massive limestone beds that stretches from west to east. From the region of the Vranjevac hill, this belt stretches to the southeast in the direction of the localities of Krešnice and Ćerimovo (Fig. 10.). The length of the zone with massive limestone is about 3 kilometers, while its width varies from 200 to 800 meters. The Greblje quarry is located in that area. The company that opened the quarry was granted the right to explore, but did not obtain all the permits necessary to start legal exploitation. These limestones should be geologically investigated in more detail, because there is a real possibility that the quality and quantity of stone can meet the requirements for use in highway construction.

This area is particularly interesting because it is not too far from the Tuzla-Orašje highway route that leads through the territory of Brčko District. It is about 28 kilometers from Maoča, and about 30 kilometers from Brka.

5. CONCLUSION

If the Tuzla canton wants to use its raw material base, which it undoubtedly possesses, and thus reduce the costs of building the highway, which is so necessary for this canton, it is necessary to introduce changes and additions to the spatial plan, which would clearly indicate the additional areas intended for the exploration and exploitation of construction aggregates (crushed stone). We should take advantage of the increasing demand for construction aggregates as a natural material and enable businessmen who are engaged in the exploitation of these mineral raw materials to use at least part of the potential we have in this area. The Tuzla Canton has significant resources of this sought-after material that have not been used to a sufficient extent. It is necessary to attract potential concessionaires and stimulate them in appropriate ways, or at least enable them to obtain the necessary permits within the deadlines prescribed by law. All these activities require the joint work of competent municipal, cantonal and, if necessary, federal institutions. Of course, it should be insisted that concessionaires must comply with all prescribed environmental norms and standards.

In order to obtain a competitive economic branch that implies sustainable growth in the exploitation and processing of construction aggregates, it is necessary to pay special attention to geological research, both of the deposits known so far, as well as areas promising to find these useful mineral raw materials. Suitability for the exploitation of any mineral raw material, including construction aggregates, is defined above all by the existence of deposits with reserves for long-term exploitation, proximity to the market, as well as the possibility of profitable production. The authors of this paper, on the basis of previous experiences, as well as their own knowledge, proposed several locations where geological formations of different ages and with high-quality limestone masses were found, suitable for finding economically profitable deposits of construction aggregates in the relative proximity of the route of the future highway in the territory of the Tuzla Canton.

REFERENCE

[1] Brkić, E., Hajdarević, I., Bajrović, M.: Katastar ležišta i pojava nemetaličnih mineralnih sirovina FBiH. Federalni zavod za geologiju, Sarajevo.

[2] Buzaljko, R.,Vujnović, L., Olujić, J., Marković, S.: Osnovna geološka karta i Tumač za OGK list Brčko, M 1:100 000. Geoinžinjering – Institut za geologiju, Sarajevo, Geološki zavod, Zagreb, 1985.

[3] Čičić, S., Mojičević, M., Jovanović, Č., Tokić, S., Dimitrov, P.: Osnovna geološka karta i Tumač za OGK list Tuzla, M 1:100 000. Geoinžinjering – Institut za geologiju, Sarajevo, 1988.

[4] Grimmer, J.: Kohlenvorkomen von Bosniens und Herzeg. Wien, 1901.

[5] Hauer, F.: Über erze und Mineralien ans Bosnien. Jahrbuch, 1884.

[6] Hrvatović, H.: Geological guide-book through Bosnia and Herzegovina. Geological Survey, Sarajevo, 1999.

[7] Jovanović, Č., Jovanović, O.: Miocen Šibošničko-loparskog područja. Geološki glasnik br. 11, Sarajevo, 1966.

[8] JP Autoceste FBiH d.o.o. Mostar: Izvještaj o realizaciji projekta: Izgradnja brzih cesta i autocesta izvan Koridora Vc u Federaciji BiH zaključno sa 30.09.2023. godine. Sarajevo,

Oktobar 2023.
[9] Kurtović, A.: Kamen u graditeljstvu. Građevinski fakultet Univerziteta u Sarajevu, Sarajevo, 2014. god.
[10] Laušević, M., Jovanović, Č.: Osnovna geološka karta i Tumač za OGK list Doboj, M 1:100 000. Geoinžinjering – Institut za geologiju, Sarajevo, 1983.
[11] Luković, M.: Geološki sastav i petrolejske pojave planine Majevice. Rudarski i topioničarski vesnik, beograd, 1929. god.
[12] Miatto A, Schandl H, Fishman T, Tanikawa H (2017) Global patterns and trends for non-metallic minerals used for construction. J Ind Ecol 21(4): 924–937
[13] Mojsisovics, E., Tietze, E., Bittner, A.: Grundlinien der geologie von Bosnien und Herzegovina. Jahrbuch der Geologie R. A. Wien, 1880.
[14] Přikryl, R.: Geomaterials as construction aggregates: a state-of-the-art. Bulletin of Engineering Geology and the Environment (2021) 80:8831–8845. https://doi.org/10.1007/s10064-021-02488-9
[15] Soklić, I.: Postanak i struktura tuzlanskog basena. Geološki glasnik br. 10, Sarajevo, 1964.
[16] Stevanović, P., Eremija, M.: Miocen Donje Tuzle. 1960.
[17] Strajin, V., Mojičević, M., Pamić, J., Sunarić-Pamić, O., Olujić, J., Veljković, D., Đorđević D., Kubat, I.: Osnovna geološka karta i Tumač za OGK list Vlasenica, M 1:100 000. Institut za geološka istraživanja, Sarajevo, 1978.
[18] Sunarić-Pamić, O., Pamić, J., kapelar, I., Olujić, J., Zec, F.: Osnovna geološka karta i Tumač za OGK list Zavidovići, M 1:100 000. Institut za geološka istraživanja, Sarajevo, 1966.