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THE NATURAL STONE MARKET IN THE CONTEXT OF RAPID CONSTRUCTION DEVELOPMENT AND PROTECTION AREAS OF MAJOR GROUNDWATER RESERVOIRS (GZWP)

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A b s t r a c t

Over the last few years, the demand for stone raw materials has increased significantly. The stone industry is an unusual sector that combines domestic stone extraction with the global market. The stone market supported by the achievements of new technologies provides a processed product, which in consequence create great potential for development of this sector. What is more an intensification of the demand effect on raw stones can be initiated by the construction industry, which is one of the basic drivers of the country's economy. In this paper there are presented conclusions from an analysis of the local and global stone market. What is more, authors present the results of analysis the mining potential of dimension and crushed stones deposits occurring in Poland in the context of limited exploitation possibilities due to selected protection areas such as areas of Major Groundwater Reservoirs (hereinafter: GZWP).

Keywords: dimension and crushed stones, building stone market, environmental conditions, protection areas of Major Groundwater Reservoirs, GZWP

1. INTRODUCTION

Rock mining is one of the most important pillars of the mining industry in Poland. The extracted rocks are used for many fields, including construction, road building, building materials industry or agriculture. A distinctive group of hard rock raw materials is the group of dimension and crushed stones. The mining of the aforementioned minerals is based on the extraction of natural broken aggregate, which represents a production of high weight but low unit value. Due to the volume of extraction, the group of block stones seems to be less important. This group affects a specific type of industry, namely the natural

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stone industry. This kind of industry is linked to the domestic extraction of block stone but is also dependent on the world market. The raw material from which stone elements are made is mined domestically as well as imported from abroad. The varying physical and chemical parameters, as well as the variety of colours and textures of the rocks (decorativeness), cause that they are used in a variety of industries. Roads, architecture, construction, decorative elements are just some of the applications of stone. The technology of extraction and processing, together with modern machinery, results in usage of the deposits located in Poland as source to provide raw material for: road construction, architectural elements, building and monumental stone elements, etc. Small architecture and construction are a wide range of possibilities for the use of block stones [1, 2, 3].

The level of extraction the raw stone materials which are include in the group of crushed and block stones, influences the socio-economic development of the country, as the use of stone is directly related to the development of construction. The paper presents the state of residential construction, which serves to confirm the relationship between the size of the market for stone elements and the construction industry. In addition, the main directions of imports and exports of block stone are indicated. Also, analysis of the number of unexploited deposits of crushed and block stones in Poland was done. The research was carried out in the context of limited exploitation possibilities due to selected protection areas, such as areas of the Main Groundwater Reservoirs (hereinafter: GZWP).

2. LOCATION OF FRACTURED AND BLOCK STONE DEPOSITS IN POLAND

The crushed and block stone deposits are mainly located in southern and south-western Poland. The deposit balance report, prepared at the end of 2022, shows that in Poland are registered 561 crushed and block stone deposits, of which 312 are in exploitation. In this paper, authors analysed a location of unexploited deposits in the context of their position in areas of protection of major groundwater reservoirs.

According to the definition on the PSH website, Major Groundwater Reservoirs are hydrogeological units, where water resources are subject of quantitative and qualitative protection. In Poland, the total area covered by groundwater reservoirs is 174,284 km^2. There are 160 documented groundwater reservoirs, including 140 main and 20 local reservoirs, as well as 3 undocumented reservoirs. Article 59 of the Water Law Act (20 July 2017) states that, in relation to groundwater, the environmental goals are [4, 17]:

- to prevent or limit the input of pollutants into them,
- to prevent deterioration and improve their condition,
- to protect them and take corrective measures as well as to ensure a balance between the abstraction and recharge of these waters and achieve their good status.

The concept developed in Poland of documenting and protecting the most valuable resources of these waters is one of the ways of broadly protecting groundwater to achieve environmental goals. According to Article 120 of Water Law, protection of water resources is supported by the establishment of protection areas for inland water bodies, which include Major Groundwater Reservoirs (GZWP). In the

protection areas, accordance with the Water Law, it is prohibited to carry out any activity that could affect water resources, including mining activities other than those related to water intake [4, 17].

The analysis conducted based on data obtained from the Central Geological Database shows that approx. 30% of the undeveloped deposits of crushed and blocky stones are in protection areas of GZWP. Such localisation, in the context of the current law, practically exclude the possibility of their mining. In view of this, deposits located in GZWP's protection areas should be treated as strategic reserves. Fig. 1 shows the location of unexploited at the end of 2022 deposits of crushed and block stones. Deposits marked with an orange triangle are those located in GZWP areas. Table 1 contains a summary of the number of deposits depending on the type of development by voivodeships.

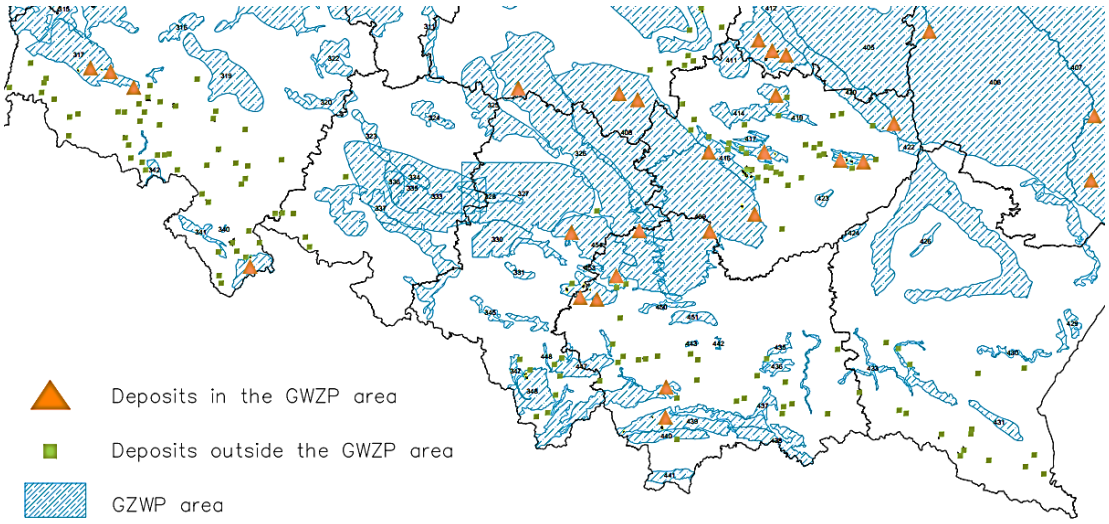

Fig. 1. Localisation of unexploited dimension and crushed stones deposits occurring in Poland, own study on the base of [6, 8]

Table 1. Number of deposits located in the voivodeships, own study on the base of [8]

Voivodeship	Exploited deposits	Deposit with preliminary identified resources	Deposit with resources identified in detail	Developed deposit exploited periodically	SUM
dolnośląskie	57	12	58	28	**156**
kujawsko-pomorskie			1		**1**
lubelskie	34		13	8	**55**
łódzkie	16	1	13	13	**43**
małopolskie	37	7	27	4	**75**
mazowieckie	11	1	10	11	**33**
opolskie	7		6	1	**14**
podkarpackie	13	10	16	1	**41**
podlaskie		1			**1**
śląskie	14	3	9	6	**32**
świętokrzyskie	44	12	47	7	**110**
SUM	**233**	**47**	**200**	**79**	**561**

3. ANALYSIS OF THE CONSTRUCTION MARKET

The construction industry needs processed stone products, so that the market for stone elements has ample room for growth. In this case, construction industry is the driving force of the economy and can initiate or contribute to strengthening the multiplier effect. Together with "tombstone industry" they have impact on develop the quarrying, processing plants, wholesalers supplying companies and individual customers with stone materials and a whole group of companies involved in the installation of stone elements. This paper therefore undertakes an analysis of the construction of residential infrastructure in the individual provinces.

Fig's 2-4 and Tables 2-3 present data on housing construction by province from 2015 to 2022. Table 5 as well as Fig's 5-6 show the structure of infrastructure relating to residential buildings between 2015 and 2022.

Analyzing the various tables and Fig's presented, one can conclude that the number of apartments and buildings put into use influences on development of particular regions. From above conclusion can be stand that demand for stone raw materials, including crushed stone aggregates as well as building stone elements growth in parallel with development of regions. The provinces with the highest number of completed buildings also have the highest number of stone factories and companies involved in the wholesale and retail sale of stone materials [2].

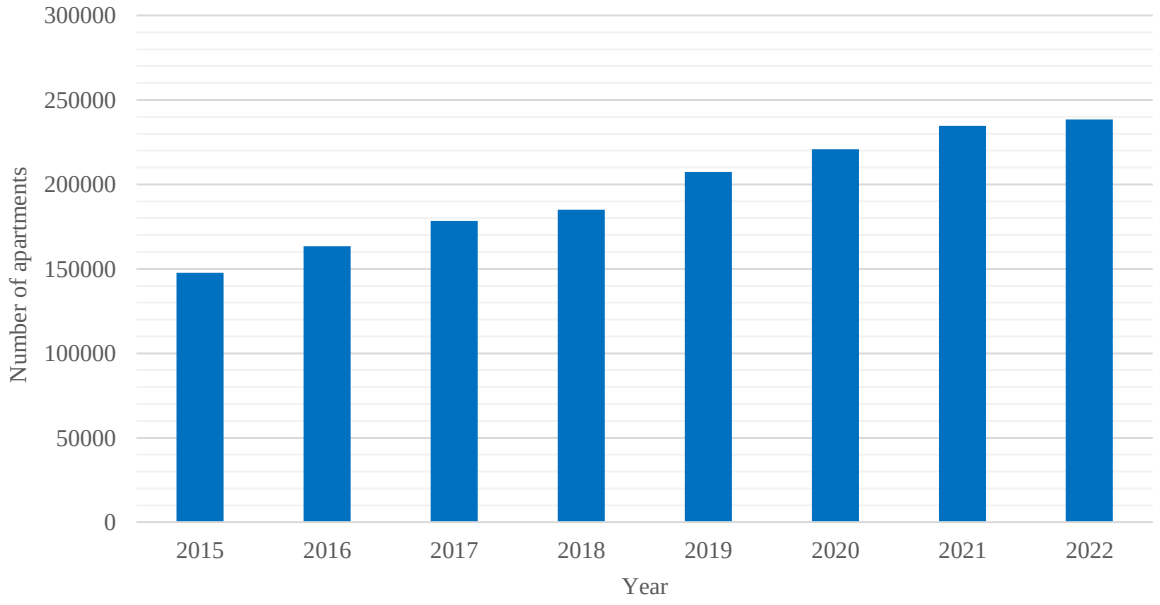

Fig. 2. Number of completed apartments in the period 2015- 2022, own study on the base of [7]

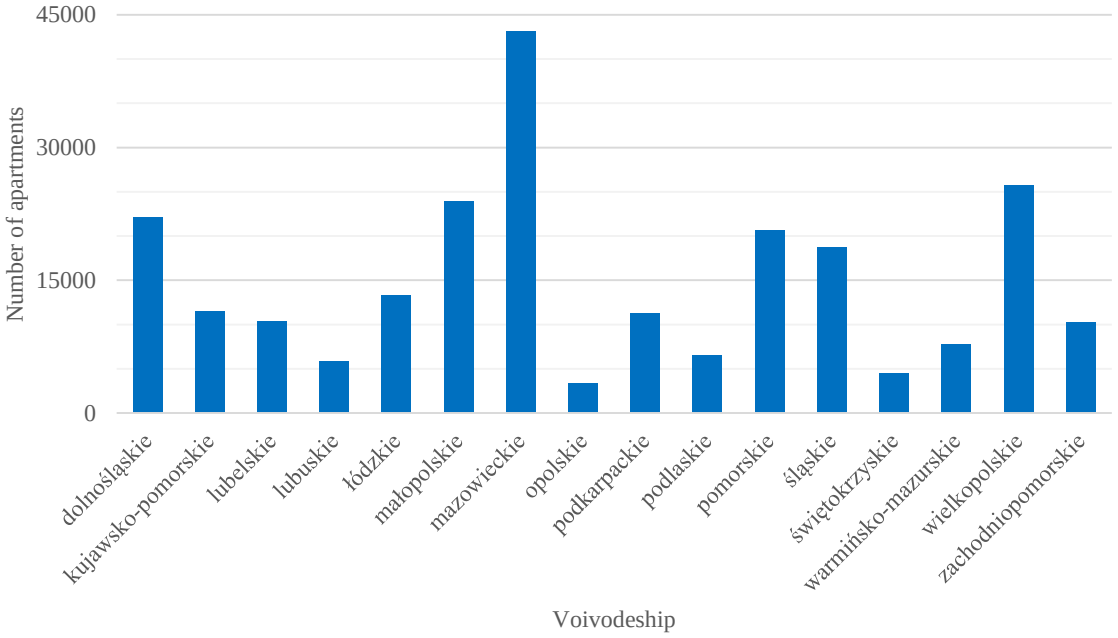

Fig. 3. Number of completed apartments in each voivodeship in 2022, own compilation based on [7]

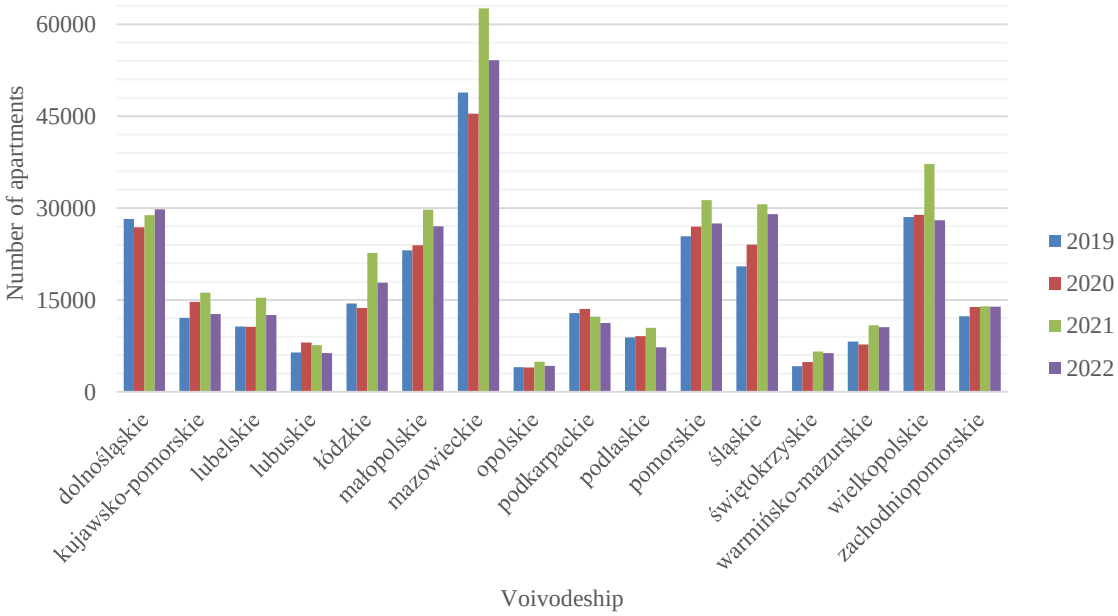

Fig. 4. Number of apartments for which a planning permission has been granted in each voivodeship in the period 2019 - 2022, own study on the base of [7]

Table 2. Number of apartments completed between 2015 and 2022, own study on the base of [7]

Voivodeship	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
	[psc]							
dolnośląskie	14 035	16 506	17 065	18 518	22 066	21 861	24 975	22 130
kujawsko-pomorskie	6 714	6 262	7 743	7 092	8 090	9 690	9 798	11 484
lubelskie	6 229	7 020	7 361	7 518	7 309	8 449	9 070	10 328
lubuskie	3 233	3 583	4 000	4 257	4 134	5 162	5 079	5 850
łódzkie	7 150	7 065	7 473	8 046	9 730	11 283	12 052	13 283
małopolskie	14 600	17 379	19 963	18 220	21 751	19 843	21 923	23 864
mazowieckie	29 227	36 049	37 274	41 078	43 159	46 638	44 385	43 137
opolskie	1 723	1 768	2 001	2 388	2 726	2 616	3 410	3 296
podkarpackie	7 640	7 875	8 131	7 773	9 213	10 043	9 904	11 215
podlaskie	4 762	4 699	5 023	4 952	6 089	6 424	7 733	6 536
pomorskie	13 182	13 155	15 815	16 664	18 363	19 088	21 765	20 614
śląskie	10 152	11 020	12 227	12 480	13 987	18 275	16 972	18 746
świętokrzyskie	3 409	3 020	3 151	3 257	3 888	3 974	4 525	4 407
warminsko-mazurskie	4 310	4 571	4 783	5 202	5 806	6 460	5 884	7 726
wielkopolskie	16 068	16 412	18 859	19 883	22 164	22 031	27 095	25 684
zachodnio-pomorskie	5 277	6 941	7 473	7 735	8 950	8 994	10 110	10 190
SUM	**147 711**	**163 325**	**178 342**	**185 063**	**207 425**	**220 831**	**234 680**	**238 490**

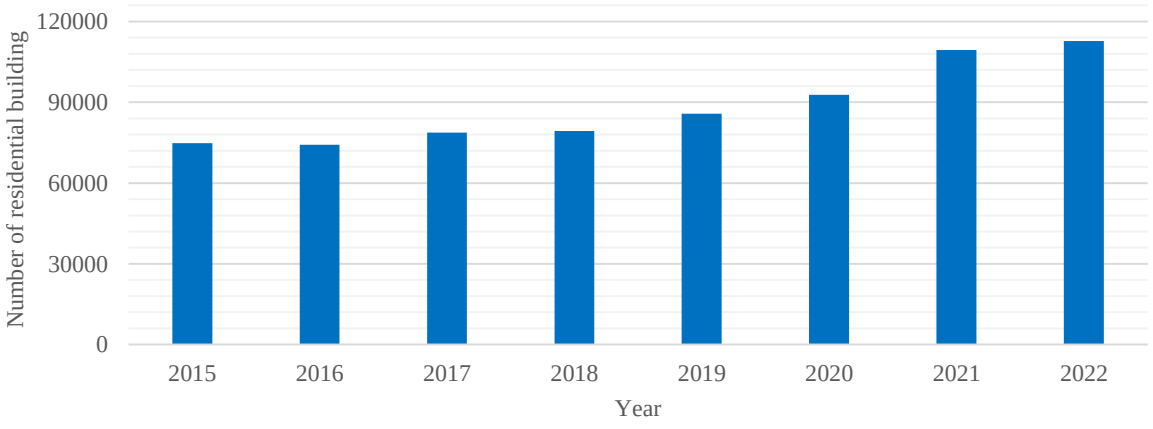

Fig. 5. Number of residential buildings delivered between 2015 and 2022, own study on the base of [7]

Table 3. Number of permits issued for construction and building notifications with building design – flats in the period 2019-2022, own study on the base of [7]

Voivodeship	New apartments				Extension of buildings				Conversion (adaptation) of buildings			
	[pcs]				[pcs]				[pcs]			
	2019	2020	2021	2022	2019	2020	2021	2022	2019	2020	2021	2022
dolnośląskie	27 520	26 187	28 257	29 430	31	118	229	37	570	386	373	325
kujawsko-pomorskie	11 834	14 124	15 895	12 367	56	54	90	59	198	514	235	289
lubelskie	10 414	10 376	15 200	12 314	161	87	130	144	77	121	35	90
lubuskie	6 145	7 802	7 263	5 984	42	46	103	37	244	180	250	297
łódzkie	13 911	13 340	22 242	17 518	299	227	351	262	187	95	92	60
małopolskie	22 575	23 613	29 524	26 742	345	191	117	153	173	120	92	103
mazowieckie	48 155	44 880	61 985	53 434	487	390	335	483	208	129	246	187
opolskie	3 908	3 885	4 753	4 074	42	27	75	13	83	63	67	160
podkarpackie	12 494	13 314	11 948	11 039	221	166	109	94	139	47	199	76
podlaskie	8 803	9 049	10 380	7 197	64	44	42	31	33	11	21	32
pomorskie	25 109	26 769	30 856	27 052	94	74	230	220	114	55	196	188
śląskie	19 822	23 233	29 948	28 363	201	288	213	170	448	420	461	472
świętokrzyskie	4 143	4 780	6 506	6 322	27	21	39	10	13	41	44	19
warminsko-mazurskie	7 967	7 594	10 696	10 331	32	31	32	59	215	104	133	145
wielkopolskie	27 747	28 270	36 504	27 355	386	290	324	221	413	352	362	425
zachodnio-pomorskie	11 863	13 544	13 620	13 481	71	55	49	65	395	228	268	354
SUM	**262 410**	**270 760**	**335 577**	**293 003**	**2 559**	**2 109**	**2 468**	**2 058**	**3 510**	**2 866**	**3 074**	**3 222**

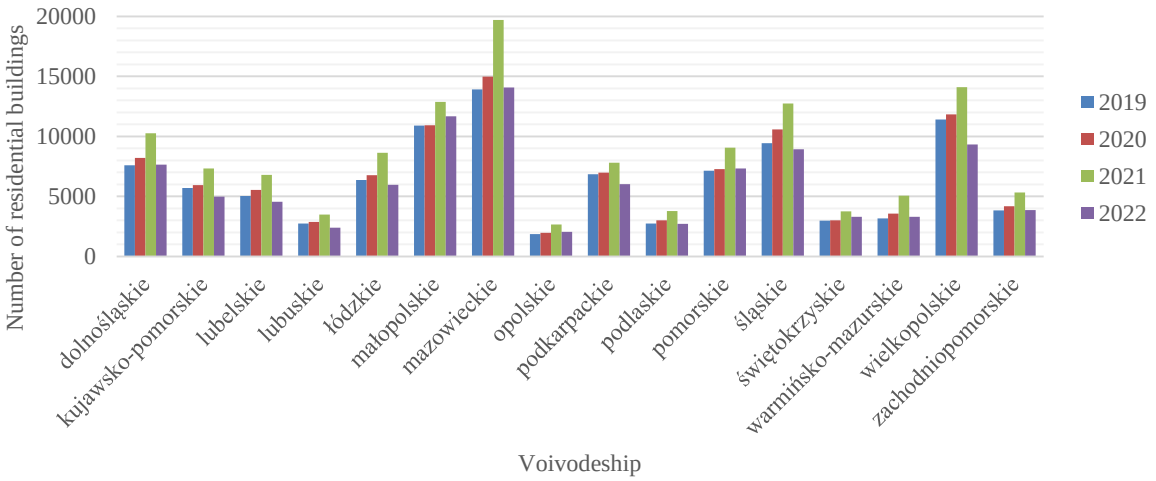

Fig. 6. Number of residential buildings for which planning permission has been granted in 2019- 2022, own study on the base of [7]

Table 4. Residential buildings completed between 2015 and 2022, own compilation based on [7]

Voivodeship	2015	2016	2017	2018	2019	2020	2021	2022
	[pcs.]							
dolnośląskie	5 513	5 419	5 824	6 370	7 059	7 814	9 719	9 447
kujawsko-pomorskie	3 680	3 790	3 829	4 001	4 410	4 853	5 394	6 015
lubelskie	3 651	3 831	3 715	3 628	3 937	4 220	4 819	5 410
lubuskie	1 704	1 675	1 777	1 967	2 197	2 475	2 640	2 882
łódzkie	4 502	4 405	4 756	4 600	4 843	5 148	6 262	6 362
małopolskie	8 078	7 735	8 529	8 183	8 419	8 497	10 662	11 436
mazowieckie	11 416	10 968	11 644	11 101	12 997	14 840	17 451	17 074
opolskie	1 264	1 197	1 286	1 358	1 486	1 702	1 928	1 948
podkarpackie	5 007	4 990	5 210	5 117	5 423	6 003	6 774	7 098
podlaskie	2 254	2 308	2 450	2 336	2 674	2 986	3 152	3 238
pomorskie	4 896	4 867	5 539	5 570	6 456	6 494	7 680	7 674
śląskie	7 146	7 311	7 840	8 315	8 342	9 141	10 709	10 840
świętokrzyskie	2 378	2 312	2 539	2 353	2 334	2 323	3 043	3 168
warminsko-mazurskie	1 985	1 850	1 819	1 926	1 919	2 312	2 595	3 041
wielkopolskie	8 713	8 937	9 264	9 836	10 467	10 879	12 858	13 267
zachodnio-pomorskie	2 579	2 632	2 741	2 630	2 745	3 012	3 702	3 878
SUM	**74 766**	**74 227**	**78 762**	**79 291**	**85 708**	**92 699**	**109 388**	**112 778**

4. IMPORT AND EXPORT OF BLOCK STONE

The natural crushed aggregates are balanced in Poland. Small number of crushed stones are exported and imported locally. The focus of the following work is on block stone. Granite, marble and sandstone deposits play the most important role in the world's building stone economy. On our continent, the best known are marbles from Italy, Greece and Spain, granites from Scandinavia, Ukraine, Poland and the Czech Republic. Asian countries such as India and China have enormous granite and marble resources, rich deposits are located also in Turkey, Thailand, Iran and South Korea. Other continents no longer have such a developed resource base, although Brazil, South Africa, the USA, Mexico, Egypt and Pakistan have significant ones [9].

In recent years, Europe, where mining was previously concentrated, has lost its leading position to Asia. China is the world's largest producer of stone materials, supplying mainly granite and marble

slabs and blocks. India, Iran and, above all, Turkey have also joined the ranks of major block stone producers. We will also note a slight increase in the importance of American countries especially Brazil, Mexico and the USA. The world's largest exporters of granite blocks include China, India, Brazil, Italy followed by Spain, South Africa, Belgium, Turkey, Portugal, Norway and Finland. In contrast, the largest importers are South Korea, the USA, China, Germany, Italy and Taiwan [4].

In the case of Poland, it is imported mainly marble and granite. Importing stone from other countries involves a number of processes, which need to be carried out to ensure that the products meet the client's quality and decorative (colour) requirements and expectations. From the point of view of legal aspects, international regulations on the production, transport and approval of natural stone products are important. For example, the European rules for the approval of natural stone products for marketing and use is regulated by Regulation (EU) No 305/2011 of the European Parliament and of the Council of 9 March 2011 laying down harmonised conditions for the marketing of construction products [11].

In Poland, more than 440 types of stones belonging to the group of "granites" (magma rocks) and more than 380 of others (carbonate rocks, sandstones, metamorphic rocks) are available in the offers of companies dealing in stone materials. Due to the marketing strategy of different companies, the same stones may have different names. They are sold as: blocks, cubes, slabs, tiles, kerbstones and more. They are not always available off-the-shelf often by order [2].

Poland has sizable resources of crushed and block stone - Fig.s for the end of 2022. - 11.73 billion tonnes. Table 5 and Fig. 7 show the volumes of crushed and block stone extraction and their disproportion at the turn of the year until 2021. Tables 6-8 show the volumes of imports and exports of block stone and the main directions of imports and their sales. The values summarized in the tables show that, in all the years analysed, the raw materials with the largest share in the value of imports and exports were treated building stone elements (excluding slate) and these were mainly products made from granite. On the Polish market, most block elements come from India (over 496 thousand tonnes), followed by China (over 467 thousand tonnes), with South Africa closing the lead (over 286 thousand tonnes). The remaining countries supply us with less than 100 thousand tonnes of block stone per year. As far as exports are concerned, these concern mainly granite rocks, with preference given to the nearest countries, primarily our neighbors: Germany (over 518,000 tonnes), the Czech Republic (over 419 tones) and Switzerland (over 303 tones).

The stone market is very affected by the production of gravestones - cemetery architecture. It should be remembered that here, too, there are certain hazards. Firstly - the increasing popularity of cremation is a competition for the stone craftsmanship and secondly - the competition for domestic stone companies are foreign-made tombstones and funeral parlours, which offer a comprehensive service including the construction of tombstones. Another problem for the stonemasonry industry is the large number of DIY stores that offer ready-made building stone products at attractive prices [2].

The Polish block stone industry consists of around 5,000 companies. They are mainly craftsmen - micro and small enterprises, engaged in stone processing with a small share of medium-sized companies (with more than 50 employees). Approx. 30% of them declare that they are mainly engaged in production and/or trade for the construction market. About 30% of the companies declare that they are mainly engaged in production and/or trade of tombstones, and the rest declare that they do not have a specification focus (production and/or trade for both markets) [2].

Table 5. Extraction of crushed and block stone in Poland in the period 2014-2021, own compilation based on [12, 13]

Type of stone	2014	2015	2016	2017	2018	2019	2020	2021
	[mln tonnes]							
Crushed stone	62,57	62,71	58,08	69,39	79,81	77,34	74,84	77,35
Block stone	1,51	1,47	1,47	1,40	1,44	1,37	1,72	1,78

Table 6. Main directions of block stones import to Poland in the period 2019-2022 own compilation based on [14, 15]

Form of stone / Country	Raw and pre-treated blocks				Block cut stones, slabs <25 cm thick				Stone building elements, other block stones and pavers, slabs and kerbs			
	2019	2020	2021	2022	2019	2020	2021	2022	2019	2020	2021	2022
	[tonnes]											
India	43538	45122	67415	77210	1509	1349	1187	285	62085	57634	76006	63310
China	136	356	302	93	67	86	0	2	189535	140119	74663	62169
South Africa	76330	65779	62075	65064	0	0	45	45	2064	1207	5092	8649
Ukraine	7606	6790	6527	6276	118	84	29	627	7831	7470	13880	19172
Slovakia	0	62	25	0	10	13	5	14	543	8415	23098	40406
Germany	222	260	311	129	157	174	104	77	16170	17675	17707	13119
Czech Republic	48	3729	19	0	17	15	6	17	6796	12114	13345	13323
Portugal	0	466	51	1060	0	0	0	0	8633	9003	17395	9147
Brazil	5063	5111	4941	3269	1341	1082	2353	1759	2369	2949	2868	3127
Italy	8	30	19	150	245	9	1	0	7203	7410	8264	9941
Zimbabwe	4351	6178	6551	6537	0	0	23	940	0	0	0	0
Sweden	3918	4154	3620	10000	0	0	2	49	576	260	741	417
Turkey	208	210	428	414	109	123	54	112	4846	5596	4173	3868
Spain	275	170	1237	3337	2	0	2869	45	2079	2156	3140	2332
Angola	0	0	0	16326	0	0	0	80	0	0	0	0
Norway	2565	3403	4014	1985	0	0	0	49	5	200	88	22
Finland	1029	1310	913	913	0	3	1	1	0	0	0	0
United Kingdom	1	2	2	0	0	0	0	0	114	44	105	1

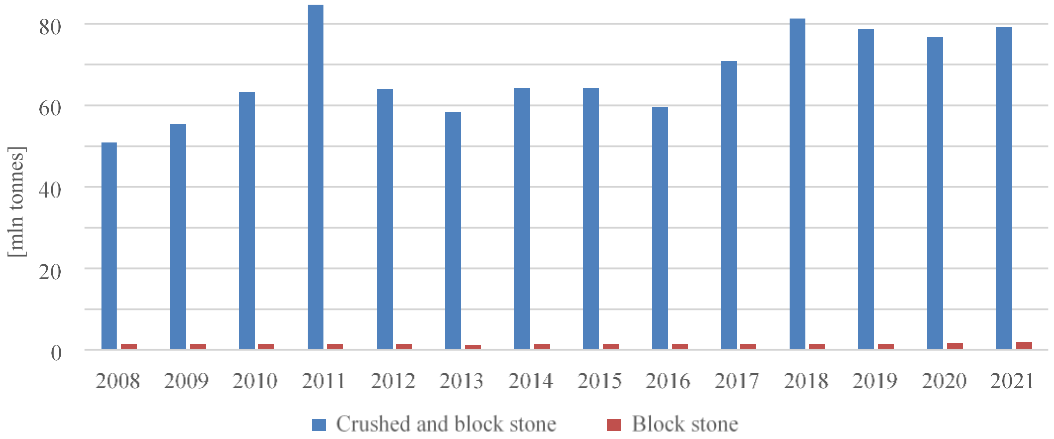

Fig. 7. Structure of the extraction of crushed and block stones in 2008- 2021, own compilation based on [12, 13]

Table 7. Main directions of block stone exports from Poland in 2019-2022, own compilation based on [14, 15]

Form of stone / Country	Raw and pre-treated blocks				Block cut stones, slabs <25 cm thick				Stone building elements, other block stones and pavers, slabs and kerbs			
	2019	2019	2020	2021	2022	2019	2020	2021	2022	2020	2021	2022
	[tones]											
Germany	52521	75	1	54	929	61671	79326	90071	91200	56774	44622	40951
Czech Republic	11347	528	335	419	359	29612	18532	24746	39380	16101	57119	220956
Switzerland	69529	3160	2979	2934	1951	2492	5326	7446	6547	74388	66558	60493
Slovakia	27	991	1094	1218	1520	565	426	913	3529	69	93	132
Ukraine	22	108	9	21	0	631	977	1132	313	66	67	1906
United Kingdom	0	0	4	1	4	23	50	765	752	0	116	216

Table 8. Block stone imports and exports in Poland in 2019-2021, own compilation based on [16]

		2019	2020	2021
		[mln tonnes/year]		
Raw and pretreated blocks	Import	0,2	0,2	0,2
	Export	0,1	0,1	0,2
Paving blocks, kerbs and other road stones	Import	0,1	0,1	0
	Export	0,1	0,1	0,1

5. SUMMARY

The construction industry is undoubtedly linked to the demand for raw rock. It is its main customer, and it not only uses aggregates, but also block stone. The market for aggregates from compact rocks in Poland is practically balanced, only locally at the border is their import and export noticeable. In Poland is relatively few side rock deposits, and stone is imported in the form of raw blocks, pre-processed blocks and building stone elements from various parts of the world, including India, China, and South Africa. Polish stone industry is linked to the extraction of side stone (less than 2 million tonnes per year), but also to the world market (import of block stone).

Companies trading in stone materials in Poland offer more than 440 types of stones classified as "granites" (magmatic rocks) and others (carbonate rocks, sandstones, metamorphic rocks). The same stones have different names in different companies due to their marketing strategy and the locations where they are sourced. They are sold in the form of blocks, slabs, and tiles. They are not always available off-the-shelf and are often made to order.

The number of housing and building completions, influences the development of the regions/provinces concerned (locally), but also has an impact on the demand for crushed and block stone. The provinces with the highest number of building completions have seen the highest number of stone companies and companies involved in the wholesale and retail sale of stone materials.

The stone market is still largely influenced by the production of tombstones - cemetery architecture, but changes are taking place here as well. There is a greater popularity of cremation, the import of ready-made tombstones made abroad at competitive prices, and the activity of construction stores offering ready-made stone building elements at attractive prices. These changes already have an impact on this market and will probably deepen in the near future.

According to Article 120 of Water Law, protection of water resources is supported by the establishment of protection areas for inland water bodies. Total area which the protected by law groundwater reservoirs are located cover ca 56% of Poland. In this area 163 separate groundwater reservoirs were established, of which 140 are GZWP. Accordance with the Water Law, in those areas it is prohibited to carry out any activity that could affect water resources [4, 17]. Considering the above, the demand for stone due to the increase in housing development, and the high cost of transportation, the unexploited deposits in the protected areas of the main groundwater reservoirs can't be mined now but can be treated as a strategic reserve.

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