



Rock Mining in Poland – Current Status and Conditions for Development

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Abstract

This work presents development of extraction of rock raw minerals in the period 1950 - 2017 with particular emphasis on the extraction and production of natural aggregates in the last

30 years. In that time, share of rock raw minerals in the extraction of solid minerals in Poland increased from 36.8% to 66.9%, while the share of extraction of natural aggregates also increased by 30%, from 23.9% to 53.9%. One threat for the production of gravel aggregates is gradual decrease of gravel fractions in deposits, which are in great demand in the construction sector. Dolnośląskie, świętokrzyskie and małopolskie Voyvodships are of primary importance for the extraction and production of crushed aggregates (42 %, 35% and 12% respectively).

In świętokrzyskie Voyvodship resources in developed deposits are at the stage of depletion. Development of rock mining, despite large and increasing demand for mineral materials, faces many difficulties, resulting, among others, from ecological (environmental), urban planning, social, economic conditionings.

Keywords: rock raw minerals, natural aggregates, opencast mining

Introduction

Rock raw minerals, also called non-metallic raw minerals, include a vast and diversified group of rocks, covering all solid minerals except for energy, metallic and chemical raw minerals. The group includes both very hard and hard minerals (including block minerals), crumbly minerals (sands, gravels) and argillaceous minerals (clays, etc.). Genetic and petrographic classification of rock minerals distinguishes over 50 lithological variants including various rocks of magma, sedimentary, metamorphic and hydrothermal origins. It is obvious that such a vast assortment of rocks has to be diversified in terms of structure, mineral and chemical composition, physical and mechanical properties, workability, application, etc. The basic common feature of those minerals is that they are located at small depths (in the subsurface layer) and they are commonly extracted in the way of opencast mining (underground mining methods are hardly ever applied). For the reasons of practicability very often a simplified division of mineral materials is applied, which consists of the six following main groups of minerals [5]:

1. Broken and block stones including rocks extracted for the production of crushed road and construction aggregates as well as block stone, dolomite, refractory quartzites, magnesites,
2. Natural sands and gravels,
3. Carbonate and sulphate raw materials (cement-lime minerals, natural gypsum, chalk, anhydrite),

4. Argillaceous minerals (ceramic and refractory clays, loams, kaolin, etc.)

5. Industrial sands (glass and molding sands, sands for cellular concrete and sand-lime bricks) and backfilling sands,

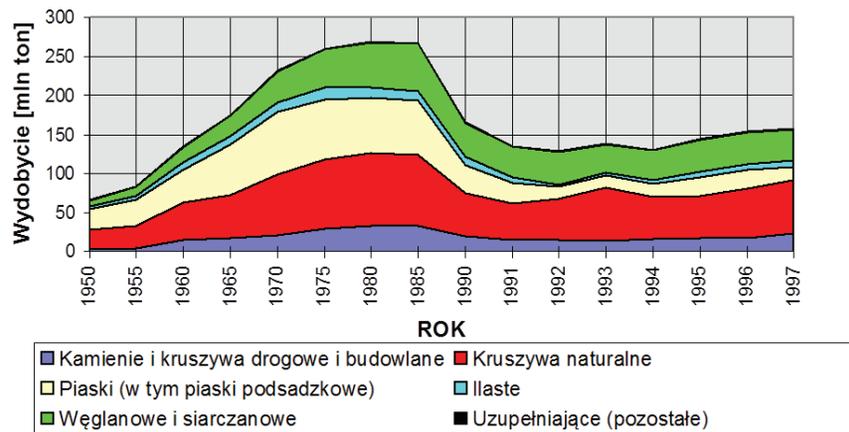
6. Other sands extracted in small quantities (amber, banded quartz, phyllite, quartz, mica shales, etc.).

Fig. 1 presents extraction of the above mentioned six groups of rock raw minerals in the years 1950–1997. After period of dynamic growth of extraction in the years 1960–75 (250–300 million Mg/year), in the years 1985–1992 there was a sharp decrease to about 130 million Mg, which means reduction of the total extraction by about 50%, including reduction of the extraction of backfilling sands by about 80%.

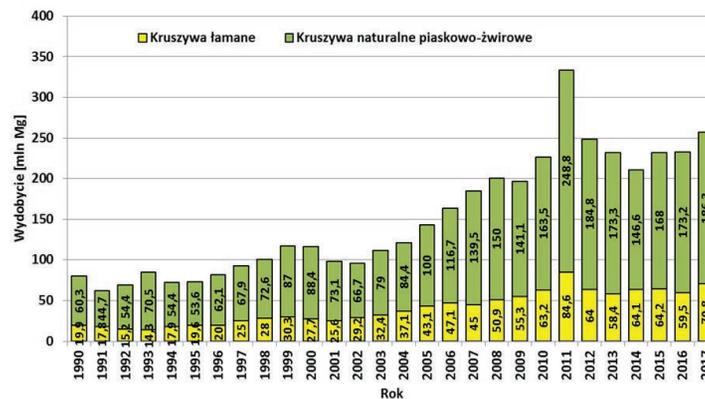
After that period the extraction increased to about 320 million Mg in 2017. In consequence, in the period of almost 30 years (1989–2017) the share of rock raw mineral extraction in the total extraction of solid minerals in Poland increased from about 36.8% to 66.9%; similarly, share of the extraction of natural aggregates increased from about 23.9% to 53.8% [4] (table 1).

Rock raw minerals play the key role in the construction industry, and they are also base materials for many other branches of economy. The most significant among the raw minerals are natural aggregates, which make up for 80% of extraction (table 1) and which are mainly discussed in the subsequent part of the article.

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Rys. 1. Wydobycie surowców skalnych w latach 1950–1997 [5]
Fig. 1. Extraction of rock raw minerals in the years 1950–1997 [5]



Rys. 2 Wydobycie kruszyw naturalnych w Polsce w latach 1990–2017 [4]
Fig. 2. Extraction of natural aggregates in Poland in the years 1990–2017 [4]

Extraction and production of natural aggregates

Extraction of gravels, sands and rocks for the production of crushed-stone aggregates in Poland in the years 1950–2017 are presented in Figure 2.

The adoption by the Polish government of the Highway Construction Program in Poland in 1993 (despite initial problems with its implementation) and increase in the GDP resulted in the increased demand and production of natural aggregates and other rock raw materials. The year 2003 and the following years after Polish accession to the EU proved to be years of economic boom, which resulted in the increased demand for construction materials, mainly aggregates. In the record-breaking year 2011 the extraction of aggregated (333 million Mg) increased by 350% as compared to the extraction in 2002. In the years 1992–2017 characteristic fluctuations (developmental cycles) are observed in the changes in the extraction and production of natural aggregates in Poland, featuring several years of growth (7–9 years) followed by a 3-year decrease in the extraction [2, 4, 6], (Fig. 3).

Lately, in the years 2012–2014 we experienced decrease in the extraction by 37%, from 333 to 211 million Mg, and after 2014 the extraction increased to 256

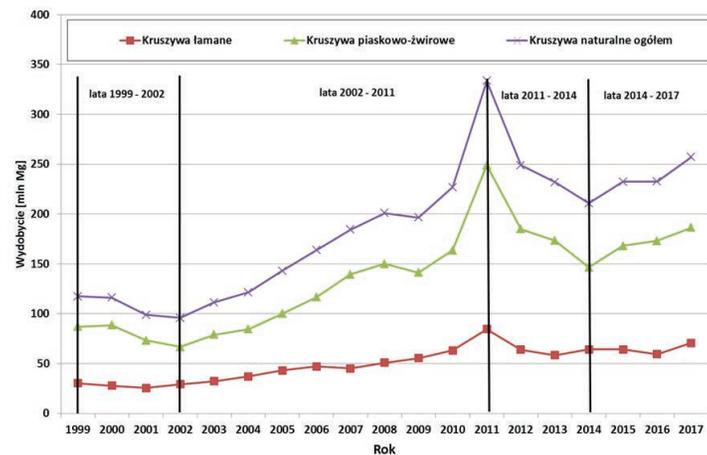
million Mg, that is by 21% in 2017. Assuming similar development of extraction to that of the previous cycle, it may be assumed that this period should end around 2020–2021, which is the end of co-financing of investments by the EU within current budget tranche. Afterwards, the demand for aggregates is most likely to decrease.

Almost 100% of the sector of natural aggregates in Poland is private. Both Polish capital, including numerous employee and family companies, and foreign capital representing renowned global construction companies are engaged in the extraction and production of aggregates. The sector constantly undergoes ownership, organizational and production changes. After 2000 many new small mining facilities emerged, which contributes to the increase in the fragmentation of the extraction and production of aggregates. This in particular applies to the extraction of sands and gravels.

Distribution of the number of mines depending on the volume of extraction shows that in 2015 the extraction of gravels and sands did not exceed 40 000 Mg/year in over 3/4 of the exploited deposits, which means that the extraction was carried out in the basis of licenses (max. 20 000 m³ from a deposit) and in-

Tab. 1. Wydobycie kopalin stałych w Polsce w latach 1989–2017 [1, 2]
 Tab. 1. Extraction of solid minerals in Poland in 1989–2017 [1, 2]

No.	Type of mineral	Extraction of solid minerals in Poland in the years							
		1989		1998		2008		2017	
		[million Mg]	[%]	[million Mg]	[%]	[million Mg]	[%]	[million Mg]	[%]
1	Coal	177.6	38.7	113.9	30.2	78	17.8	56.8	11.9
2	Lignite	72	15.7	62.9	16.7	59.5	13.6	63.1	13.2
3	Non-ferrous metal ores (Cu, Zn-Pb)	31.7	6.9	31	8.2	26.8	6.1	32.9	6.9
4	Chemical minerals	9	2.0	4.5	1.2	3.8	0.9	5.4	1.1
5	Rock minerals, including	169	36.8	164.8	43.7	269.6	61.6	319.8	66.9
6	Natural aggregates	110	23.9	100.6	26.7	200.9	45.9	257.1	53.8
7	Total	459.3	100.0	377.1	100.0	437.7	100.0	478.0	100.0



Rys. 3. Tendencje zmian wydobycia kruszyw naturalnych w Polsce w latach 1999–2017
 Fig. 3. Trends in changes in the extraction of natural aggregates in Poland in 1999–2017

creased by 10% since 2007. Only in 120 out of 2565 exploited deposits the extraction rate exceeds 300 000 Mg/year, however this extraction volume accounted for almost 50% of total extraction of gravels and sands [2, 4], (fig. 4). The average extraction from a deposit in 2015 amounted to 65 500 Mg/year and decreased by 1/4 (88.0 Mg/year) as compared to extraction in 2007 [2, 4].

The situation is different in case of crushed aggregates, which to large extent results from geological conditionings; deposits of solid rocks for the production of crushed aggregates are located mainly on the south of Poland. The production is concentrated in three Voyvodships: dolnośląskie, świętokrzyskie and małopolskie (approx. 90% of national extraction). Next are śląskie, podkarpackie and opolskie Voyvodships. There were less than 50 mines extracting up to 40 000 Mg/year in 2015, and since 2007 their number decreased by over 3%. There were 28.4% mines extracting over 300 000 Mg/year and their number increased by 2.6% since 2007. Joint extraction from those mines amounted to almost 85% of total extraction (fig. 5.) The average extraction from a deposit amounted to 272 000 Mg/year and increased by

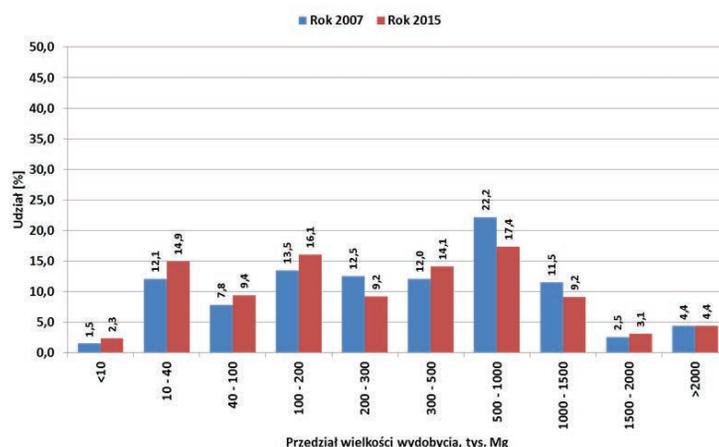
40 000 Mg/year as compared with the extraction from 2007.

Presented distributions of extraction refer to single deposits, while distributions of the volume of production of gravels and sands as well as crushed aggregates by particular producers are more concentrated, since large producers very often exploit several (and sometimes over 20) gravel and sand deposits, while middle-sized and small producers exploit only a couple of deposits. For example, large producers of crushed aggregates (about 20 entities) extracting over 1 million Mg/year, are responsible for the production of over 65% of the national production of crushed aggregates.

Trends in changes in the quality of gravel and sand deposits

One serious threat for the production of aggregates is deteriorating quality of gravels and sands deposits, which influences the volume of production of wanted gravel assortments and increase in the costs of their production. In the 'Bilans zasobów kopalin...' PIG - BIP [1] the following three subgroups of gravels and sands deposits are distinguished:

- gravels for which SP < 30%,



Rys. 4. Rozkład wielkości wydobywania ze złóż piasków i żwirów w latach 2007 i 2015 [1,4]
 Fig. 4. Distribution of production from sands and gravel deposits in 2007 and 2015 [1, 4]

Tab. 2. Udział procentowy poszczególnych podgrup złóż w łącznych zasobach żwirów i piasków w latach 2007 i 2016 [4]
 Tab. 2. Percentage contribution of individual subgroups of deposits in the total resources of gravel and sands in 2007 and 2016 [4]

Type of deposit	Balance resources		Industrial resources	
	2007	2016	2007	2016
Sand deposits	27.8	37	25.7	42.5
Gravel and sand deposits	65.5	58.1	65.5	55.4
Gravel deposits	6.7	4.9	8.8	2.1
Total	100	100	100	100

- sands with gravel (SP – 30 - 75%),
- sands – SP > 75%,

where: SP – average content of 0–2 mm fraction in the deposit.

The analysis of changes in the volume of deposits in a 10-year period (2007 - 2016) [1, 3, 4] shows that in spite of extraction we face fairly big increase, since total balance deposits of gravels and sands have increased by approx. 26.6%, and industrial deposits – by 75%, it is unfavorable that the increase mainly concerns sand deposits (SP > 75). Industrial sand deposits increased almost twice (by 190%), while gravel and sand deposits by approx. 50%, whereas gravel deposits decreased by almost 60%. Change in the structure of deposits results in the change of share of particular subgroups of gravels and sands in total balance and industrial deposits, which is presented in Table 2.

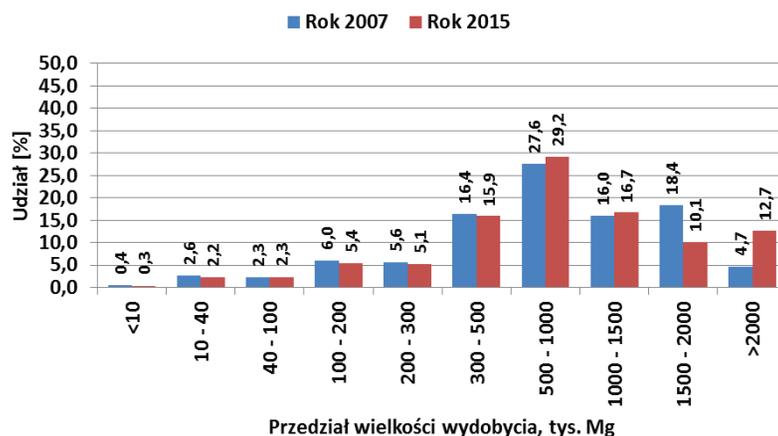
The share of sands in industrial resources increases particularly fast, from 25.7% to 42.5% (in 2017 there was a further increase to 49.2%) while the share of gravel and sand resources decreases. Assuming average sand point (SP) values in particular subgroups of sands and gravels, average SP may be calculated in total resources documented and exploited in a given year (fig. 6).

For state resources and in three regional zones (southern, middle and northern zones) the increases were distributed as follows [4]:

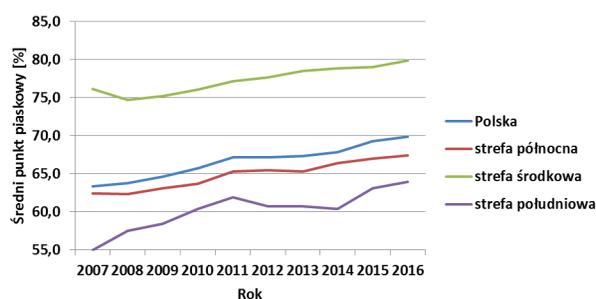
Balance resources:
 country – 4.5%, in the zones: 2.0 – 6.6%,
 Industrial resources:
 country – 10.4%, in the zones: 4.9 – 16.4%,
 Extracted resources:
 country – 4.8%, in the zones: 5.5 – 8.7%,

With SP values for exploited resources we may also determine possible probable volumes of production of thick (gravel) and fine (sand) assortments of gravel and sand aggregates. For the last year covered by the analysis (2016), in which 173 million Mg of gravels and sands of average SP – 69.9% were extracted, assuming recovery of sand fractions in the extraction process at the rate of 70% (with underwater extraction part of sand is recovered to the pit already during the extraction), the probable production on the national scale amounted to:

- gravel fractions (assortments) (> 2 mm) - approx. 52 million Mg,
- sand fractions (assortments) (> 2 mm) - approx. 85 million Mg.



Rys. 5. Rozkład wielkości wydobycia ze złóż kamieni łamanych w latach 2007 i 2015 [1,4]
 Fig. 5. Distribution of production from mined rock deposits in 2007 and 2015 [1, 4]



Rys. 6. Średnie punkty piaskowe zasobów przemysłowych żwirów i piasków w latach 2007–2016 [4]
 Fig. 6. Medium sand points for industrial gravel and sands in 2007–2016 [4]

The calculations show that total production of gravel and sand aggregated in 2016 most probably (due to the lack of official data) amounted to approx. 137 million Mg, which in comparison to licensed gravels and sands extraction accounted for 79.2%; the remaining part are mining losses. Various assortments of aggregates are used in the construction sector and other branches of economy, which is why, depending on the demand, gravel fractions are produced, as well as classified mixtures, sandy gravels, raw sands, including raw sands with gravel additions, classified sands. In practice, production of gravels was lower than the calculated volume (52 million Mg), since some of them is sold in the form of classified mixtures and sandy gravels, as well as raw sands with gravel additions.

The construction sector in the first place seeks thick aggregates (both gravel and crushed), while the demand for fine (sand) aggregates is variable and to large extent depends on the demand of the roads construction sector. In recent years that demand was significantly lower than the volume of sand production and the mines encountered problems with their sales (aggregates difficult to sale and non-saleable aggregates). The use of scrubbers and hydro cyclones for classification and enriching those fractions is too expensive for the majority of small facilities. Sand fraction aggregates

difficult to sell and non-saleable sand fraction aggregates are often used in mines to reclaim post-mining excavation pits. Deficit of natural aggregates in many countries and regions as well as limited resources of aggregates in Poland and increasing difficulties in obtaining extraction license imply the need to selectively store sand aggregates assortment instead of ‘drowning’ them in post-mining excavation pits. Presented trend of increase of fine sand fractions of aggregates in gravels and sands resources allows to make predictions about SP in the future years [4].

Territorial distribution of the production of crushed aggregates

Decrease in the production capacity of gravel aggregates signifies increase in demand for thicker fractions (grits) produced from crushed aggregates or applying technology of production of concrete with larger share of sands (fine-grained concretes, sand concretes, cement composites, etc.). Technologies of this kind are used in some western countries. One problem associated with the production of crushed aggregates is uneven distribution of rock minerals deposits (the south of Poland) and ever more difficult operating conditions (increased thickness of the cover, increased depth of extraction, the necessity of plunge dehydration, increased amount

Tab. 3. Rozkład terytorialny zasobów i wydobycia kamieni łamanych w latach 2007 i 2015, [1, 2]
 Tab. 3. Territorial distribution of resources and production of the broken stones in 2007 and 2015 [1, 2]

Voyvodship	Balance resources, in million Mg		Industrial resources, in million Mg		Extraction, in million Mg	
	2007	2015	2007	2015	2007	2015
dolnośląskie	52.2	53.1	78.6	70.9	49.7	42.2
świętokrzyskie	21.9	21.9	9.3	13.6	27.5	35.0
małopolskie	12.8	11.8	7.8	8.9	11.5	11.8
podkarpackie	5.3	5.2	0.5	1.6	1.4	2.7
śląskie	4.3	4.6	1.7	2.1	5.3	4.2
opolskie	1.1	1.4	1.4	1.8	3.1	2.5
łódzkie	1.1	1.0	0.5	0.9	1.3	1.7
Poland	8712.6	10 801	2801.1	3 382.1	45.0	64.2

of extractive waste, increased production costs). This in particular applies to, among others, świętokrzyskie Voyvodship, in which extraction increase by over 80 in 10 years, and as a result the share of this Voyvodship in the national extraction increased to approx. 35%, while its industrial resources constitute only approx. 13.6% of the national resources (Table 3).

Sufficiency index for industrial resources amounted to approx. 13 years by the end of 2017. Given vast difficulties associated with obtaining an extraction license both for undeveloped and exploited deposits, it may be assumed that in about 10 years the production based for crushed aggregates in the świętokrzyskie Voyvodship may rapidly decrease.

Summary, conditions for development

Rock mining in Poland occupies the first place in terms of the volume of extraction, as well as the number of deposits and volume of resources, it is very significant for the development of the country, including, in particular, implementation of construction projects. Over 30 years the share of extraction of rock raw minerals in the extraction of solid minerals increased from 36.8% to 66.9%, that is by over 30%.

Rock raw minerals of particular significance include natural aggregates (gravels, sands, crushed aggregates). Constantly increasing global demand for aggregates of the construction industry and other branches of economy makes aggregates already a deficit material in some countries and regions, where their prices are very high [8].

In Poland over 25 years (1992–2017) the extraction of aggregates (gravels, sands and broken stones) increased about 4 times, from 63 to 257 million Mg, which resulted in the increase of the share of their ex-

traction in the total extraction of solid minerals by 30% (from 23.9% to 53.9%).

Gravels and sands are extracted in the entire country (in all the Voyvodships and in the Baltic area). After 2000 many new small mining facilities (gravel pits) emerged, which contributed to the increase in the fragmentation of aggregate production. The extraction from $\frac{3}{4}$ of exploited deposits does not exceed 40 000 Mg/year. In over 120 mines the extraction rate exceeds 300 000 Mg/year (approx. 5% of exploited deposits), and that amounts to approx. 50% of total extraction of gravels and sands.

One threat to the production of gravel aggregates is deterioration in quality of the raw material base of the deposits. Gravel deposits of sand point (SP) below 30% are almost depleted, the share of resources of gravel and sand deposits (SP – 30–75%) is also decreasing, while the share of resources of sand deposits (SP > 75) increases; whereas the construction sector demands more thick granulation aggregates for the production of concrete and concrete precasts. This results in periodical difficulties in the sales of fine granulated (sand) fractions extracted along with gravels.

Limited production capacities of thicker assortments of aggregates (gravel, grit, mixed, etc. aggregates) and overproduction of sand fractions imply, among others, the need to change some technologies of concrete and concrete precasts' production with the use of technologies of fine aggregate (sand) concretes, cement composites, etc.

The production of crushed aggregates, due to geological conditionings, is focused in three Voyvodships: dolnośląskie, świętokrzyskie and małopolskie (approx. 90% of national extraction). Increase in the production of crushed aggregates in the świętokrzyskie Voyvod-

ship, limited industrial resources and large difficulties in obtaining new licenses causes gradual depletion of resources exploited in this Voyvodship.

The discovery of opencast mining of rock minerals, despite large demand for mineral materials and products and also potentially large resources capacities, increasing technical and technological as well as organizational standards, vast increase in quality and efficiency of production, still has to face significant difficulties and limitations. They result from, among others, ecological (environmental) conditionings of the exploitations (conditional and conflict deposits), and also those associated with urban planning (many areas designated for planned development) or of social, economic nature.

Perceiving mining exploitation, in particular opencast exploitation as remarkably negative and requiring liquidation (which is also approved in educational programs) and lack of awareness and appreciation for the effects of mining activity in the forms of providing necessary materials, as well as creating new, often very attractive natural and landscape formations after the exploitation is finished requires introducing chang-

es in some legal acts (mineral resources deposits are practically unprotected), as well as in information and education activities.

Financial means from the EU are to large extent responsible for dynamic development of the construction industry and increased demand for construction materials (cement, aggregates, etc.). Taking into account the end of current financial tranche from the EU in 2020, we should consider the threat of following the steps of some European countries (Spain, Portugal, Greece, Ireland, Italy) in which extraction and production of aggregates decreased by over 50% after 2008. Those countries were affected by economic and financial crisis caused, among others, by overinvestments in the construction sector. It seems that Poland should not be affected in a similar way since construction demands are still high, in transport, housing, service and industrial infrastructure. Many European countries, including Germany, France, Great Britain Austria, Sweden, etc. are also examples of stabilization of demand for aggregates or its gradual increase. Most probably, around 2020 the demand for aggregates will decrease, however not by as much as in the above mentioned countries.

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Górnictwo skalne w Polsce – aktualny stan i uwarunkowania rozwoju

Przedstawiono rozwój wydobycia surowców skalnych w okresie 1950 - 2017 ze szczególnym uwzględnieniem wydobycia i produkcji kruszyw naturalnych w ostatnim 30-leciu. W tym okresie udział wydobycia surowców skalnych w wydobyciu kopalin stałych w Polsce wzrósł z 36,8 do 66,9%, w tym udział wydobycia kruszyw naturalnych wzrósł również o 30% z 23,9 do 53,9%. Zagrożeniem dla produkcji kruszyw żwirowych jest stopniowe zmniejszanie się

w złożach zawartości frakcji żwirowych, na które jest duże zapotrzebowanie budownictwa.

W wydobyciu i produkcji kruszyw łamanych dominujące znaczenie mają województwa dolnośląskie (42%), świętokrzyskie (35%) i małopolskie (12%). W województwie świętokrzyskim następuje wyczerpywanie się zasobów w złożach zagospodarowanych. Rozwój górnictwa skalnego pomimo dużego, wzrastającego zapotrzebowania na surowce mineralne napotyka na wiele trudności wynikających między innymi z uwarunkowań ekologicznych(środowiskowych), urbanistycznych, społecznych, ekonomicznych i innych.

Słowa kluczowe: surowce skalne, kruszywa naturalne, górnictwo odkrywkowe