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Research paper

Dependence of extraction and production of construction aggregates on selected indicators of economic development in Poland

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Abstract: The document presents current methods of forecasting aggregate production, mainly depending on the size and dynamics of changes in GDP. With a view to developing more accurate forecasts, this article presents the dependence of extraction and consumption of mineral aggregates used in construction on two indicators: the general business climate indicator in the construction industry and the cement consumption volume. The results obtained from regression and correlation analysis turned out more favourable for the dependence of aggregates production on cement consumption. This particularly applies to the dependence of sand and gravel aggregate production and total natural aggregate production on cement consumption. Good dependence has also been confirmed for other European countries as well as for the USA. For Poland, the indicator of sand and gravel aggregates production for cement production in recent years was between 9.5 and 12 Mg/Mg. The values of this indicator vary from country to country, mainly depending on the share of different types of aggregates in total production of aggregates in construction industry. Although the indicator values vary considerably, its advantage is that cement production is identified and included in the industrial production balance sheets of most countries, which is not the case when it comes to the identification or accurate record for the production of construction aggregates. The adoption of this indicator makes it possible to monitor the extraction of natural construction aggregates for individual countries and regions more accurately, as called for – among other things – by UN resolutions.

Keywords: mineral construction aggregates, mining and production, forecasts, cement production, general business climate indicator in the construction industry

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1. Introduction

Natural mineral aggregates constitute the basic raw material used in construction as well as in some other sectors of industry. In many applications they are a basic raw material, making up more than 90% of the construction materials in use (e.g. for road construction). Quantitatively, aggregates are most commonly used in the production of concrete, precast concrete products, roads, motorways, flats, houses, and many other building structures[6]. For example, the UEPG Review [13] states that the construction of 1 km of motorway uses up to 30 000 tonnes of aggregates, while the construction of 1 meter of railway for a High Speed train (TGV) uses up to 9 tonnes of aggregates, a typical home uses up to 400 tonnes, a school building consumes up to 3 000 tonnes, and for a sports stadium, up to 300 000 tonnes are needed, etc. Without natural aggregates, it would be impossible to produce asphalt, iron (fluxes) or steel, energy in conventional power plants (flue gas desulphurisation), construction chemicals (adhesives, mortars) or agricultural products (fertilisers), certain foodstuffs (e.g. sugar); neither would it be possible to carry out various earthworks (embankments, dikes, flood control dams, etc.), reclaim brownfield sites, build sports and leisure facilities (pitches, golf courses, and others), etc. Sands are used in the mining industry to extract hydrocarbons by means of fracking and stope filling as well as in water and sewage treatment plants. Therefore, it can be concluded that mineral aggregates, including sands, have both basic and vital applications in many sectors of human activity, from construction and industry to electronics and cosmetics, which we often forget about [1].

The growth of the world's population, urbanization as well as economic and industrial development contribute to the constant increase in demand for aggregates. Since 1950, the number of people living in cities has quadrupled to 4.2 billion, and the UN predicts that two and a half billion more people will have moved into urban centres over the next three decades. A large part of this increase is accounted for by Asian countries, whose dynamic development over the last two decades has clearly contributed to the depletion of deposits of aggregates, especially gravel and sand. Between 2011 and 2013, China alone consumed more concrete than the United States throughout the entire 20th century. By 2025, there will have been 220 cities with more than one million inhabitants and eight mega cities with more than 10 million inhabitants in the Middle Kingdom. In India, for example, aggregate consumption has doubled in the last two decades and is still growing [8]. In some countries, aggregates are used in large quantities to build coastlines or artificial islands. Singapore, which has added 130 square kilometres of land to its surface over the last half-century, is leading the way in this. Lagos, Nigeria's largest city, and China, which have formed hundreds of kilometres of coastline and built whole islands for luxurious resorts, have adopted similar practices. It is estimated that current consumption of mineral aggregates is about 50 billion Mg/year, which is about 6.5 Mg per statistical inhabitant. After water, aggregates are therefore the second most consumed product (raw material). China, India and other Asian countries together consume approx. 2/3 of global production of mineral aggregates [1, 3, 4]. Despite such a high volume of aggregate consumption in many countries and regions of the world, the extraction and production of aggregates are among the least regulated sectors of human activity. This is particularly the case in Asian, African and South American countries, where both resources and the extraction of aggregates, especially gravel and sand, are not monitored or recorded, and where they exist, records are very sketchy. This has a major negative impact on the environment on a large scale through the destruction of riverbeds and old riverbeds, erosion of sea coasts, lowering of water levels, drying up of cultivable areas, and so on. This has a major negative impact on the environment on a large scale, in the form of the destruction of riverbeds and old riverbeds, the erosion of seacoasts, the lowering of water levels, the drying up of cultivated areas, etc. These problems have been recognised by the UN and one of the assembly's agencies in Geneva in 2019 published a report on the impact of uncontrolled extraction of mineral aggregates, especially sands and gravel, in some countries and regions of the world on the natural and social environment [14]. The basic conclusion of this Report is that it is high time to stop believing in the unlimited resources of aggregate deposits and low awareness of the environmental and social consequences of exploitation, and that the scale of challenges associated with the extraction of sands and gravels in many regions of the world is one of the major challenges for sustainable development in the 21st century. The countries of South-East Asia and some countries in North Africa are given as examples of those where the exploitation of sand and gravel, often illegal, is devastating to the environment. In order to regulate the situation related to the management of natural aggregate resources, it is concluded that the planning and monitoring of their extraction process should be introduced on a general basis [14]. In Europe, including the EU, the situation is overall much better regulated, but here too, information on the extraction and production of aggregates is in many cases only approximate and imprecise. In Poland, the balance sheets for the extraction of, among others, gravel and sand as well as rock for the production of crushed aggregates are published every year by CUG PIB (the Central Geological Office of the National Research Institute) [2]; however, the volume of sand and gravel aggregates production reported by GUS (the Central Statistical Office) is approximately 50% lower than given in the extraction balances. This is mainly due to the fact that the statistics provided by GUS do not include data from companies with less than 10 employees. In Poland, more than 2/3 of sand and gravel mines are small and very small plants, the output of which does not exceed 40 thousand Mg/year (concessions issued by starosts); the production from these mines is not included in the GUS balance sheets [11]. An additional difficulty in analysing the production of aggregates consists in the fact that their production and consumption is often characterised by large fluctuations (both during the year, i.e. seasonal fluctuations, as well as between years, i.e. periodical cycles), which depends mainly on the periodic economic situation in construction and the dynamics of GDP changes. Fig. 1 presents changes in the extraction of natural aggregates in Poland in the years 1999 – 2019, where we notice characteristic periodic changes in the extraction of natural aggregates.

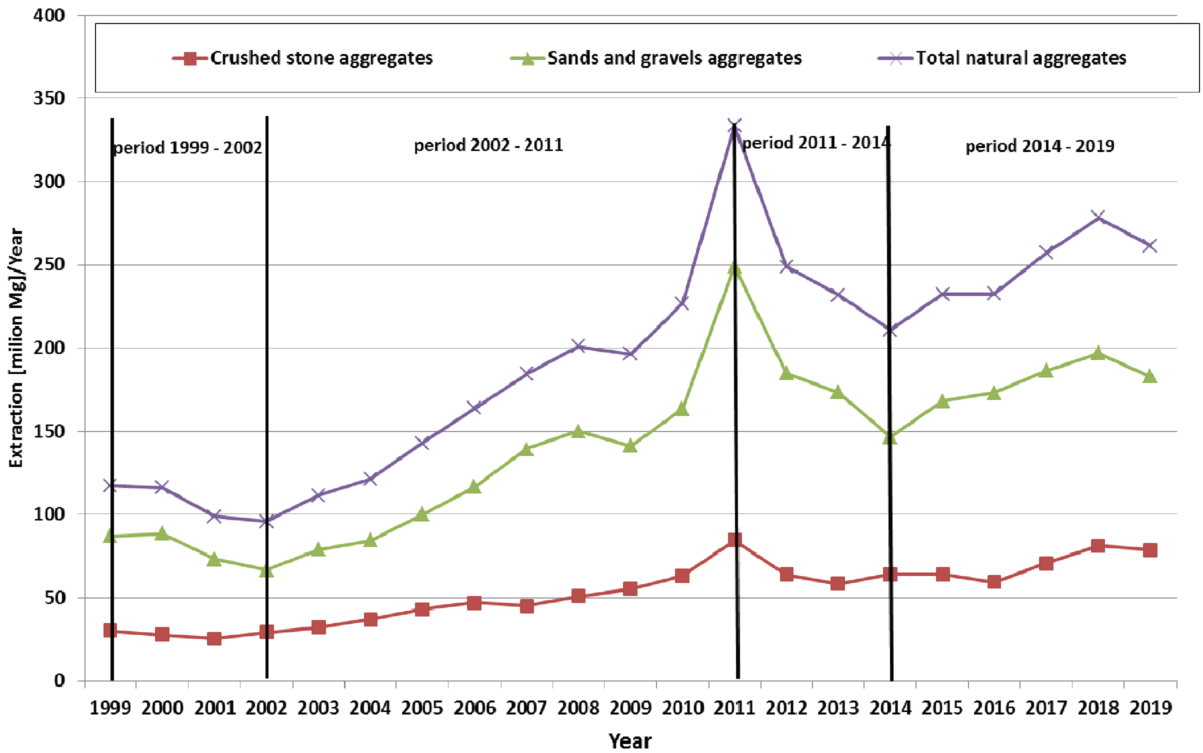

Fig. 1. Trends of changes in the extraction of natural aggregates in Poland, 1999 – 2019

2. Forecasts of production and consumption of mineral aggregates

The lack or incomplete records of the resources and volumes of aggregate extraction, especially sands and gravels, the large number of mining sites, often of an informal nature without proper permits, and fluctuations in demand make it difficult to draw up national and global balances of aggregate production and consumption. In many countries they include approximate (estimated) data. For these reasons, indirect statistical methods are being sought in order to establish forecasts of aggregate production and consumption in individual countries and regions of the world. The application of various forecasting methods to predict the production volume of mineral aggregates, including neural networks, has been presented, among others, in works [7, 10, 11]. Different classifications of economic forecasts are listed in the economic literature. Due to the forecast horizon, i.e. the length of time into the future for which the given forecast has been prepared, it is conventionally assumed that:

- a short-term forecast shall not exceed one year,
- a medium-length forecast concerns a 2–5 year period,
- a long-term forecast covers more than 5 years.

Moreover, forecasts are divided into: forward-looking, above-foresight, operational, strategic, etc. In a sense, this division is arbitrary, because it depends on the nature of the phenomenon under investigation[5]. It is clear that the longer the forecast horizon, the less likely it is that predictable conditions shall occur, and thus the certainty of the forecast decreases. There are, however, many possibilities for increasing forecasting certainty, which include:

- applying several forecasting methods and comparison of their results with one another,
- comparing the received forecast with other forecasts provided earlier,
- verifying the obtained results by deriving conclusions logically or mathematically from the already known forecasts,
- carrying out substantive verification.

Considering the type of forecast, its purpose and the nature of the phenomenon predicted, different forecasting methods are used, which include:
1) mathematical and statistical methods,
2) non-mathematical forecasting methods.

What can serve as an example of such studies are analysed trends in production and stochastic models of dependence in aggregate production on GDP development indicators or other economic development indicators. Fig. 2 shows the statistical dependence of natural aggregate production growth (DKN) on GDP dynamics (DPKB) in Poland between 1991 and 2012 [10, 11]. The model indicates that on a national scale, GDP growth constituted the barrier to the growth of demand and production of mineral aggregates in at least 2.7%. Later studies[9,12] indicate that this barrier to the growth of demand for aggregates is still valid. With less dynamic development, investment expenditure on infrastructure is generally limited in the first place.

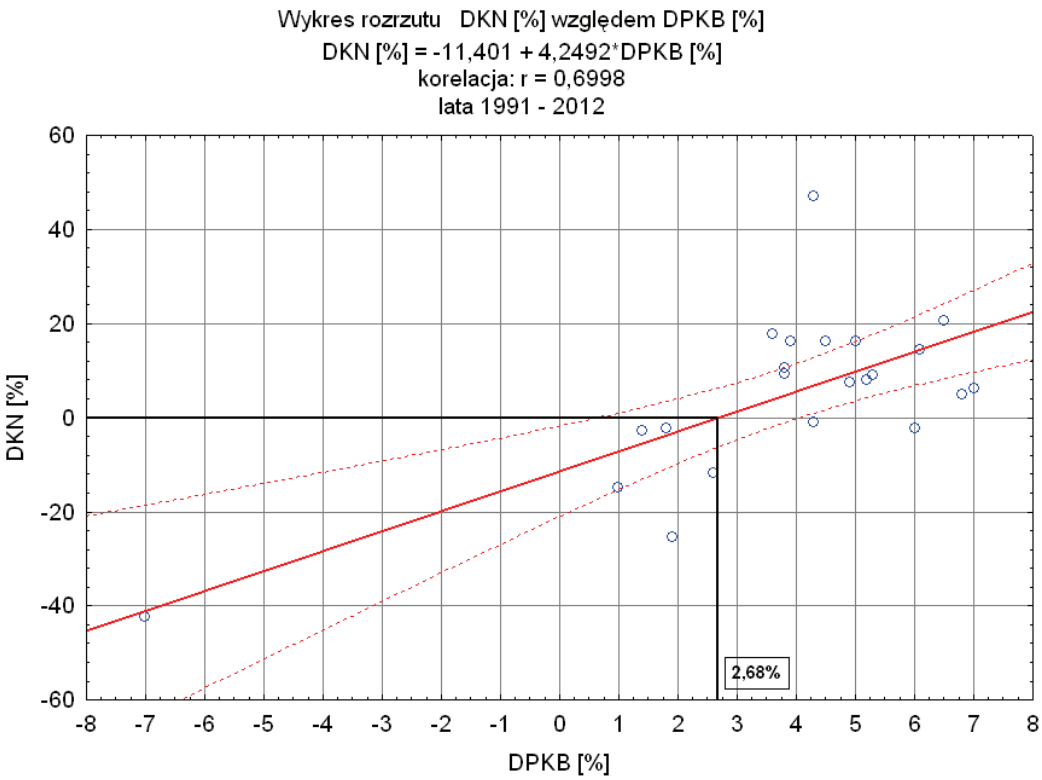

Fig. 2. Dependence of the dynamics of natural aggregate production (DKN) on the dynamics of GDP growth (DPKB) in Poland, 1991 – 2012 [11]

Table 1 presents the forecasts of construction aggregate production based on these dependencies, together with the comparison of their values with the extraction volume of sands and gravels as well as rocks used for production of crushed aggregates, according to the annual balance sheets published by PIG – PIB (Polish Geological Institute – Polish Research Institute) [2]. Of the three forecast variants (pessimistic, moderate, optimistic), depending on GDP growth forecasts, the forecast for the moderate variant turned out to be the most similar to the achieved extraction volumes, although in 2020, aggregate extraction shall be significantly lower than this forecast due to the impact of COVID19.

Table 1. Realization and forecasts of production of natural aggregates in Poland [11, 12, supplemented]

Details	Production of natural aggregates in years, million Mg										
	2010	2011	2012	2013[1]	2014[1]	2015[2]	2016[2]	2017[2]	2018[2]	2019[2]	2020[2]
Aggregates extracted	227	333	249	232	211	232	233	257	278	262	
Forecast – a pessimistic variant				229	222	218	220	222	224	226	228
Forecast – a moderate variant				231	228	220	230	240	251	262	273
Forecast – an optimistic variant				233	234	223	244	267	293	321	352

[1)] the 2013 forecast, [2)] the 2015 forecast.

In addition to the aforementioned trend model as well as the single and multiple regression and correlation models, an attempt was made to apply a new forecasting method using neural networks. Neural network models are among the adaptive methods, modified in the course of network learning process [7, 15]. Neural networks do not describe the phenomenon that is taking place, but only learn about it and allow to predict the behaviour of the dependent variable, for different independent variables. However, the networks make it possible to create response surfaces that allow us to recognise the essence of a phenomenon, obviously after having reduced the issue to three-dimensional space. For the models analysed, it is possible to show interdependencies, for example, between the size of population, GDP per capita, and production or consumption of aggregates per capita. Such a dependence for one of the networks is shown in Fig. 3. As it is apparent from the shape of the so-called response surface, in European countries, increasing GDP per capita results in an increase in aggregate production, but only to some extent, followed by a decrease and then an increase again. In Poland (population density is about 120 person/km^2), on the basis of the surface obtained, it was possible to predict (with a corresponding increase in GDP) an increase in aggregate production volume to about 8 – 9 Mg/person, followed by a decrease to 6 – 7 Mg/person.

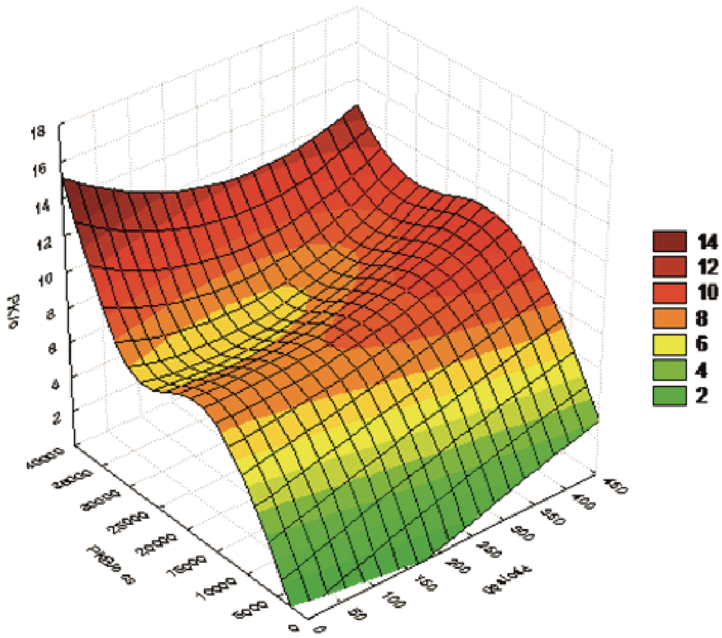

Fig. 3. Response surface for an exemplary neural network of natural aggregates production in Europe depending on GDP and population density [7]

In the year 2011, which was record-breaking in terms of extraction and consumption of aggregates (extraction of 333 million tonnes of natural construction aggregates), this ratio was about 8.8, while at present (2019) it has decreased to the level of about 6.9 and will decrease further in 2020.

3. An analysis of dependence of aggregate production on selected economic development indicators

The econometric analysis of the dependence of aggregate production on various indicators of economic development carried out to date has confirmed that the GDP indicator is relatively the best one, but the dependence models developed for both Poland and other countries are not accurate, and therefore the search for more accurate dependencies is still ongoing. The present paper will present dependencies for two indicators, namely:

- the general business climate indicator in the construction industry,
- the annual cement consumption volume.

3.1. An analysis of dependence of aggregate production on general business climate

GUS (The Central Statistical Office) [16] provides monthly and, more recently, quarterly business climate indicators in industrial processing, including, among others, construction. Business climate indicators for the construction industry are determined on the basis of questionnaire surveys of 5 000 enterprises with the number of employed persons: up to 9 (micro enterprises), 10 – 49 (small enterprises), 50 – 249 (medium-sized enterprises), 250 and more (large enterprises). The scope of the survey questions concern: construction and assembly activities, general economic situation of the company, barriers to operations, order portfolio, production capacity, guaranteed period of operation, production, financial situation of delays in payment for works performed, anticipated employment, anticipated prices [16]. On the basis of the collected responses, simple indicators – weighted by sales revenues – and composite indicators are calculated. These indicators are given at the total Polish and provincial levels. An example of such indicators is the indicator of the general economic climate in the construction industry in the years 2000 – 2020 (Fig. 4). The chart refers to the monthly data on the basis of which the annual averages were calculated, which were the basis for further studies. Values above zero are considered positive (indicating good economic situation), values below zero indicate "bad" economic situation. The chart of monthly data is cyclical, with increases in spring and summer and decreases in winter. A similar character of changes is observed in the extraction and production of construction aggregates. Recently, since the end of 2019, the business climate indicator has been at the negative value, with remarkably high values below zero recorded since April 2020 (–47.1%), i.e. since the occurrence of COVID 19 pandemic in Poland. Fig. 5 presents the dependence of the dynamics of changes in the production of natural aggregates (sand and gravel and crushed) for the average annual business climate indicator of construction companies. For this dependence, the Pearson's linear correlation coefficient r is 0.47, which indicates its significance at the level of 0.05. The analysis of linear regression equation shows that in the examined period 2000 – 2019, even with the business climate indicator at zero, it was possible to increase the aggregate production, on average annually by about 6.5%, i.e. relatively much.

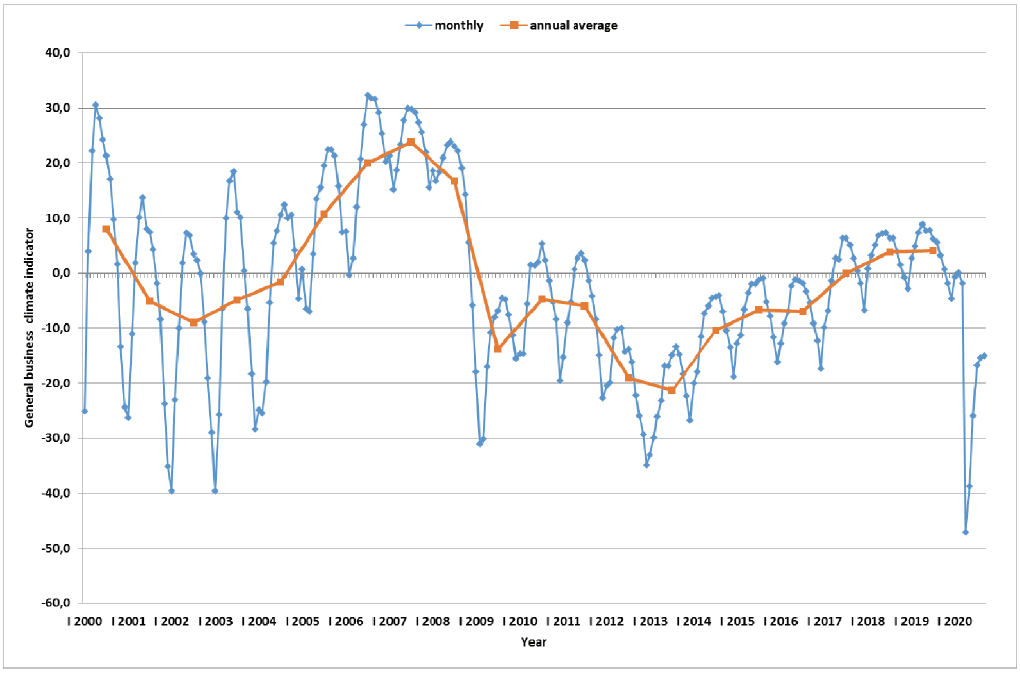

Fig. 4. Indicator for the general business climate in construction in 2000 – 2020 [16]

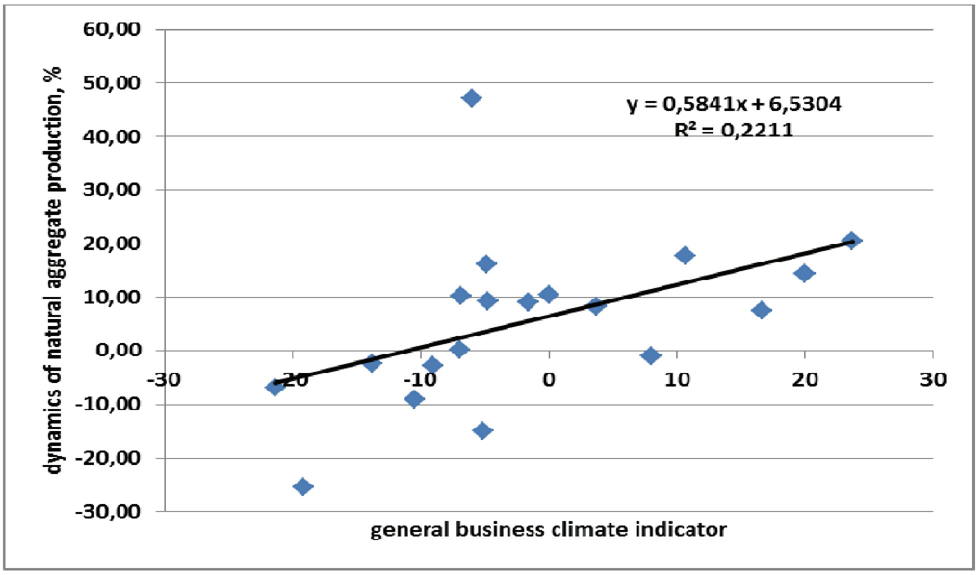

Fig. 5. Dependence of changes in the production of natural aggregates used in construction industry on the general business climate in the construction industry

3.2. An analysis of dependence of aggregate production (consumption) on cement consumption volume

One of the indicators on which the extraction and consumption of building aggregates depends is the consumption of cement, the production of which is generally quite accurately identified in the statistics of individual countries. The use of mineral aggregates for concrete and prefabricated products is estimated at between 28.7 to 32.8 billion Mg [14], i.e. about 2/3 of the aggregate production is used together with cement for the production of concrete, prefabricated concrete products, etc. Depending on the class of concrete, 5 – 7 Mg of aggregates per 1 Mg of cement are used for its production, including about 65% of coarse aggregate (gravel, grits) and 35% of sands. In most countries of the world the production and consumption of cement is growing rapidly; over the last two decades, it more than doubled and in 2017, it amounted to about 4.1 billion Mg. More than two thirds of the world's cement production takes place in Asian countries, i.e. in China (58.5%) and India (6.6%). In the EU, cement production is approximately 175 million Mg (4.3%) and in the USA 88.5 million Mg (2.2%). In Poland, cement production in 2018 – 2019 was approximately 19 million tonnes, and the consumption is approximately 19.5 million tonnes/year, due to the predominance of imports over exports. Examples of the development of aggregate production and cement consumption in Poland, Germany and Italy are shown in Figs. 6 – 8. For aggregate production, a division into sand and gravel, and crushed (stone) aggregates as well as the production of natural aggregates combined is included. For Germany and Italy, the production of artificial and recycled aggregates is also included.

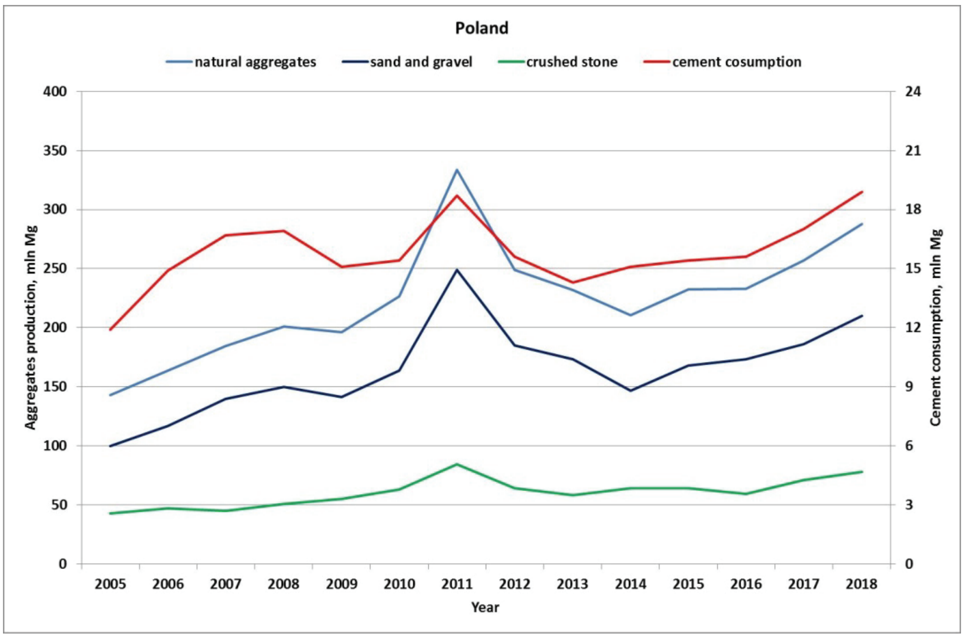

Fig. 6. The production of natural aggregates and the consumption of cement in Poland in the years 2005 – 2018

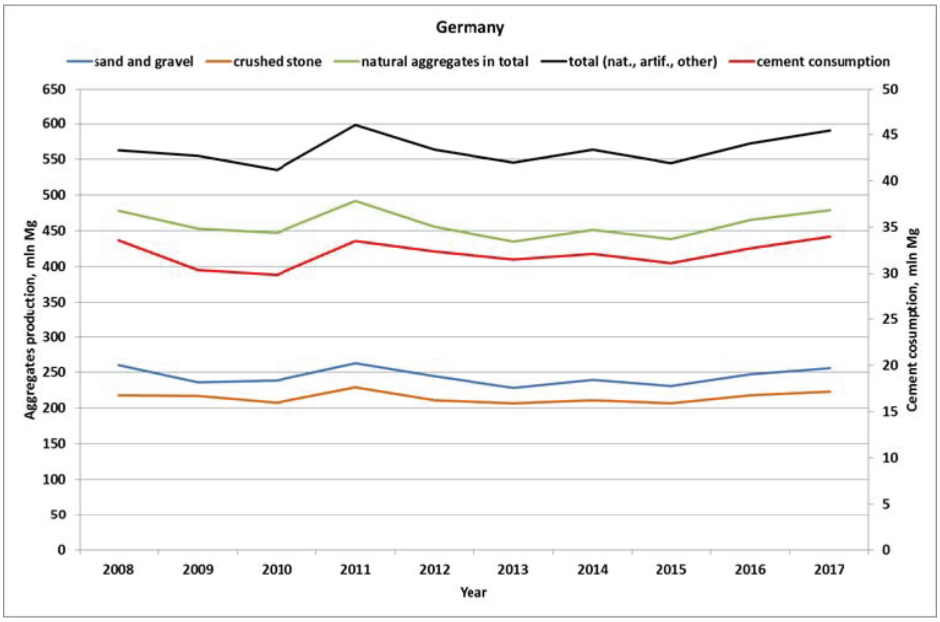

Fig.7. The production of construction aggregates and the consumption of cement in Germany in the years 2008 – 2017

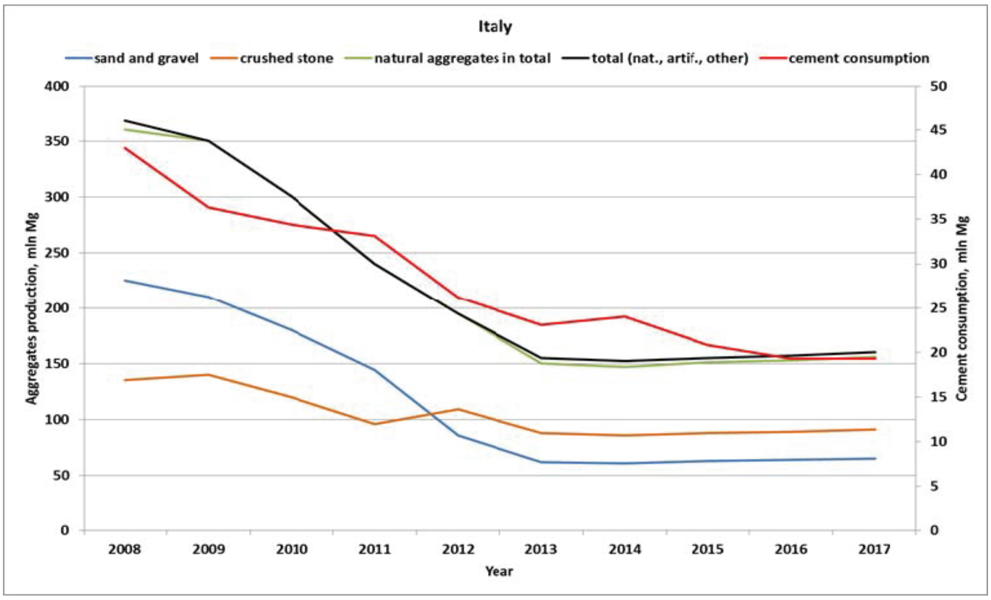

Fig. 8. The production of construction aggregates and the consumption of cement in Italy in the years 2008 – 2017

Despite the different trend of changes in aggregate production and cement consumption in the analysed countries – i.e. increasing in Poland, rather stabilised in Germany, decreasing in Italy – the graphs for aggregates and cement have a similar course, which indicates a clear correlation. For these dependencies, linear regression parameters and Pearson correlation coefficients were calculated (Fig. 9 – 11). For Poland, the graphs show linear regression models for the dependence of the production of sand and gravel construction aggregates on cement consumption as well as the dependence of the production of sand and gravel construction and crushed mineral aggregates on cement consumption; whereas for Germany and Italy, the dependence of the total production of construction aggregates (natural, artificial, etc.) on cement consumption, because for these dependencies the correlation coefficients were higher. The obtained values of Pearson correlation coefficients R^2 are significant at the level of 0.001 or 0.01, which indicates high or even almost full dependence. This particularly applies to the dependence of the production of sand and gravel aggregates and the total production of natural aggregates on cement consumption. Strong dependence was also confirmed for France and Great Britain [1], as well as for the USA. In the USA, in the years 1990 – 2017, there were about 10 tonnes of produced (consumed) sand and gravel aggregates per each tonne of cement [14]. For Poland, the production rate of sand and gravel aggregates for cement production in recent years has been in the range of 9.5 to 12 Mg/Mg. The values of this indicator are variable for each country, mainly depending on the share of different types of aggregates (sand and gravel, crushed, recycled, artificial, etc.) in total aggregate production. For EU countries, this indicator is (in 2017) about 6.3. For countries where the share of sand and gravel aggregates is relatively small in total aggregate production, a much better (more stable) indicator seems to be the dependence of total mineral construction aggregates production on consumption (cement production). In 2016 – 2018, the value of this indicator was about 14.5 for Poland and about 14 for EU countries.

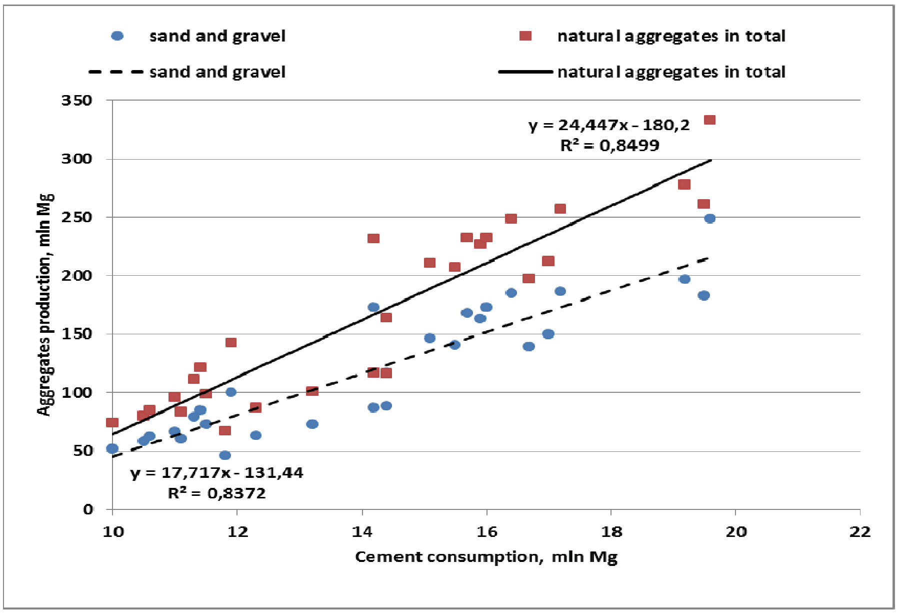

Fig. 9. The dependence of gravel and sand aggregates production on the cement consumption in Poland in the years 1992 – 2019

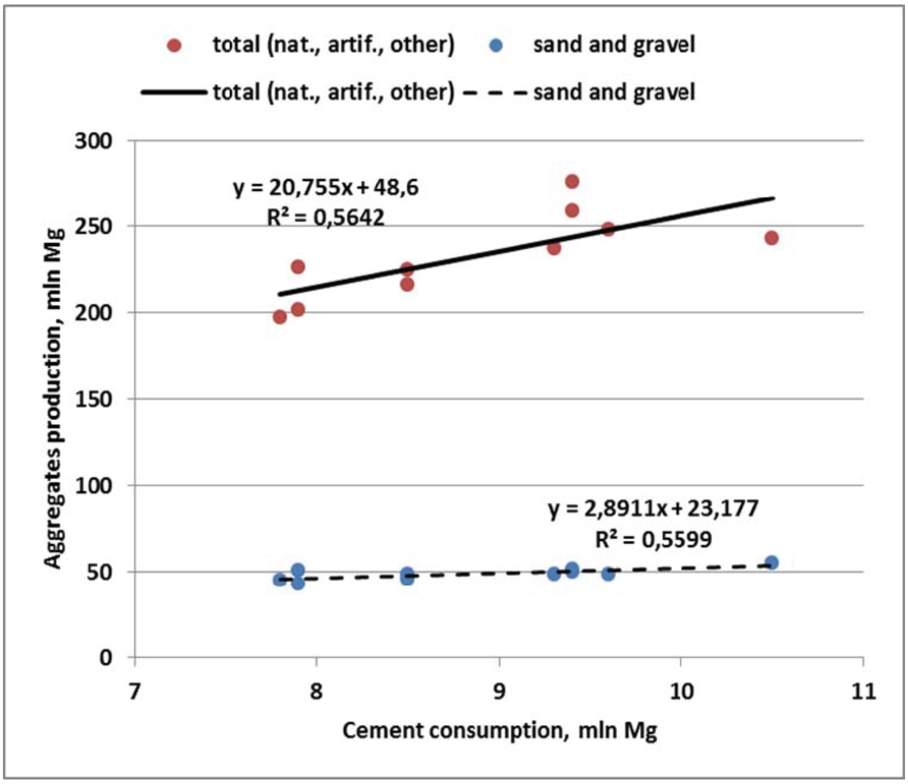

Fig. 10. The dependence of the construction aggregates production on the cement consumption in Germany in years 2008 – 2017

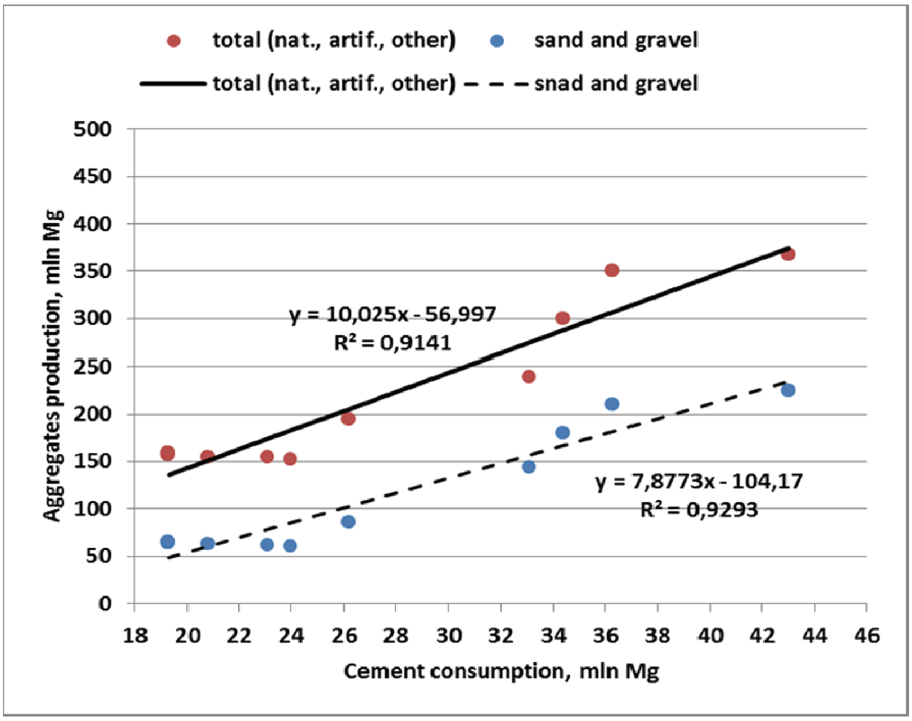

Fig. 11. The dependence of the construction aggregates production on the cement consumption in Italy in years 2008 – 2017

4. Conclusion

Mineral aggregates are a commonly used building and road material. In many applications they are a basic material, accounting for up to 90% of the raw materials and construction materials used. Aggregates are most commonly used in the production of concrete, prefabricated concrete elements, roads, motorways, flats, houses and many other facilities of transport and cubature infrastructure. The growth of the world's population, urbanisation and economic and industrial development contribute to a continuous increase in demand. It is estimated that the current global production of mineral aggregates is about 50 billion Mg, which is about 6.5 Mg per statistical inhabitant. In 2030, when the world's population will have reached around 10 billion, the demand for aggregates is likely to exceed 60 billion Mg [13,14]. Despite this large scale, aggregate production is one of the least regulated sectors of human activity in many countries and regions of the world. This is particularly the case in Asia, Africa and South America, where both the resources and extraction of aggregates, especially sands and gravel, are not monitored and recorded or where records are very inaccurate. This has a major negative impact on the natural environment. In the reports and records, local terminology of aggregates often functions, based on the methods of their applications or ways of extraction, which makes it difficult to compare them and prepare relevant balances. To some extent, this also applies to EU countries, despite the fact that EU countries have common European standards and are in the best position compared with other countries and continents. For these reasons, global information on the production of mineral aggregates is generally incomplete and difficult to compare and elaborate on. In order to address the disadvantages associated with the management of natural aggregate resources, including mainly construction aggregates, one of the main conclusions of the UN Report [14] states the need for a widespread introduction of planning and monitoring of natural aggregates extraction.

Statistical research conducted so far carried out regarding the dependence of aggregate production on various indicators of economic development has confirmed that GDP is the relatively best indicator; however, the dependence models developed for both Poland and other countries are generally not accurate [7, 10, 11], hence the search for more accurate econometric models is still ongoing. The paper presents statistical dependencies for two indicators, namely the general economic climate in construction and cement consumption. These indicators in Poland are given in GUS statistics [16]. For both indicators, significant correlation dependencies at the level of materiality of at least $P = 0.05$ have been confirmed. However, Pearson's correlation coefficients R^2 are much more advantageous for the dependency of construction aggregate production on cement consumption. For Poland and several other analysed countries, the linear correlation coefficients R^2 for the dependence of aggregate production on cement consumption assume values between 0.6 and more than 0.9, which means that they are significant at the level of at least 0.01 and in most of the analysed dependencies 0.001, which indicates high or even almost full correlation. In Poland, the production indicator of sand and gravel aggregates used for cement consumption in recent years has oscillated between 9.5 and 12 Mg/Mg. The values of this indicator are variable for individual countries, mainly depending on the share of different types of aggregates (sand and gravel, crushed, recycled, artificial, etc.) in total production. In 2017, for the EU member states, this indicator amounted to approx. 6.3. In the USA, there are approx. 10 tonnes of sand and gravel aggregates produced per each tonne of cement consumed. For countries where the share of sand and gravel aggregates is relatively small in total aggregate production, a much better (more stable) indicator is the dependence of total mineral construction aggregate production on cement consumption. In 2016 – 2017, for Poland the indicator had a value of about 14.5, and for EU countries – on average, about 14. Although the indicator values vary considerably from country to country and from region to region in the world, its advantage is that cement production is identified and included in the industrial production balance sheets of most countries, which is not the case when it comes to the identification or accurate record for the production of construction aggregates. The adoption of this indicator makes it possible to monitor the extraction of natural construction aggregates for individual countries and regions more accurately, as called for – among other things – by UN resolutions.

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Zależność wydobycia i produkcji kruszyw budowlanych od wybranych wskaźników rozwoju gospodarczego polski

Słowa kluczowe: mineralne kruszywa budowlane, wydobycie i produkcja, prognozy, produkcja cementu, wskaźnik koniunktury w budownictwie

Streszczenie:

Wzrost ludności świata, urbanizacja oraz rozwój gospodarczy i przemysłowy przyczyniają się do ciągłego wzrostu zapotrzebowania na kruszywa mineralne. Szacuje się, że obecna światowa produkcja kruszyw mineralnych wynosi ok. 50 mld Mg, co stanowi ok. 6,5 Mg na statystycznego mieszkańca. Pomimo tak dużej skali, w wielu krajach i regionach świata produkcja kruszyw należy do najmniej uregulowanych sektorów działalności człowieka. Dotyczy to szczególnie krajów Azji, Afryki i Ameryki Południowej, w których to krajach zarówno zasoby jak i wydobycie kruszyw, szczególnie piasków i żwirów nie są monitorowane i ewidencjonowane lub też prowadzone ewidencje są mało dokładne. Nie kontrolowana eksploatacja ma duży wpływ na niekorzystne oddziaływanie na środowisko przyrodnicze, w postaci niszczenia koryt rzek i starorzeczy, erozji wybrzeży morskich, wysychania obszarów uprawnych, itp. Dla uregulowania tej nie korzystnej sytuacji związanej z gospodarką zasobami kruszyw naturalnych, jeden z głównych wniosków Raportu UNEP2019 (agenda ONZ), postuluje konieczność powszechnego wprowadzenia planowania i monitorowania procesu pozyskiwania kruszyw naturalnych. W pracy przedstawiono możliwość monitorowania i prognozowania wydobycia i produkcji kruszyw na podstawie różnych wskaźników rozwoju gospodarczego. Dotychczas podstawowym wskaźnikiem wykorzystywanym do opracowania takich prognoz zarówno w kraju jak i zagranicą był PKB. W artykule przedstawiono zależności wydobycia i zużycia budowlanych kruszyw mineralnych od dwóch wskaźników :

- wskaźnika ogólnej koniunktury w budownictwie,
- zmian zużycia cementu

W Polsce GUS w okresach co miesięcznych i co kwartalnych podaje wskaźniki koniunktory w przetwórstwie przemysłowym w tym miedzy innymi w budownictwie. Wskaźniki koniunktury dla budownictwa ustalane są na podstawie badań ankietowych ok. 5 000 przedsiębiorstw. Zakres przedmiotowy badań stanowią odpowiedzi na pytania dotyczące : działalności budowlano-montażowej, ogólnej sytuacji gospodarczej przedsiębiorstwa, barier działalności, portfela zamówień, mocy produkcyjnych, zagwarantowanego okresu działania, produkcji, sytuacji finansowej opóźnień płatności za wykonane roboty, przewidywanego zatrudnienia, przewidywanych cen. W pracy dla analizowanej zależności dynamiki zmian produkcji budowlanych kruszyw naturalnych (żwirowo-piaskowych i łamanych) od uśrednionego rocznego wskaźnika koniunktury przedsiębiorstw budowlanych uzyskano współczynnik korelacji

liniowej Pearsona r w wysokości 0,47, co oznacza jej istotność na poziomie 0,05. Z analizy równania regresji liniowej wynika, że w badanym okresie 2000–2019, nawet przy zerowym wskaźniku koniunktury możliwy był wzrost produkcji kruszyw, średnio w roku o ok. 6,5%, a więc stosunkowo dużo. W badaniach tych nie uwzględniono danych za 2020 r. jako, że badania wykonywane były w trakcie tego roku. Znacznie korzystniejsze wyniki analizy statystycznej uzyskano dla zależności wydobycia i produkcji budowlanych kruszyw mineralnych od zmian wielkości zużycia cementu, podstawowego materiału budowlanego. Produkcja cementu na ogół jest dość dokładnie identyfikowana w statystykach rozwoju gospodarczego większości krajów. Zużycie cementu w gospodarce światowej szybko wzrasta, w ostatnich dwóch dekadach wzrosła ponad dwukrotnie i w 2017 r. wynosiła ok. 4,1 mld Mg. Ponad 2/3 światowej produkcji cementu występuje w krajach azjatyckich w Chinach (58,5%) i Indiach (6,6%). W UE produkcja cementu wynosi ok. 175 mln Mg (4.3% produkcji światowej) , a w USA – 88.5 mln Mg (2,2%). W Polsce produkcja cementu w latach 2018 – 2019 wyniosła ok 19 mln ton, a zużycie – ok. 19,5 mln ton/r, z uwagi na wzrost importu. Wykorzystanie kruszyw mineralnych do betonu i wyrobów prefabrykowanych szacuje się na 28,7 do 32,8 mld Mg, czyli około 2/3 produkcji kruszyw zużywana jest razem z cementem do produkcji betonów, prefabrykatów betonowych, kostki brukowej i itp. W zależności od klasy betonu do jego produkcji zużywa się 5–7 Mg kruszyw na 1 Mg cementu, w tym ok. 65% kruszywa grubego (żwiry, grysy) i 35% piasków. W pracy przedstawiono wykresy tendencji zmian wydobycia (produkcji) kruszyw budowlanych i zużycia cementu w Polsce oraz w Niemczech i Włoszech. Pomimo różnej tendencji zmian produkcji kruszyw i zużycia cementu w analizowanych trzech krajach: rosnącej – w Polsce, raczej stabilizacji w Niemczech, malejącej – we Włoszech przedstawione wykresy wskazują na wyraźne zależności. Uzyskane wartości współczynników korelacji Pearsona R^2 (0,6 – 0,9) są istotne na poziomie 0,01, a nawet dla niektórych zależności – 0,001, co wskazuje na wysoką lub nawet niemal pełną zależność. Dotyczy to szczególnie zależności produkcji kruszyw żwirowo-piaskowych i łącznej produkcji kruszyw naturalnych od zużycia cementu. Dobre zależności potwierdzono również dla innych krajów, a także dla USA. W USA w latach 1990 – 2017 na każdą tonę produkowanego (zużywanego) cementu przypadało ok. 10 ton produkowanych (zużywanych) kruszyw żwirowo-piaskowych. Dla Polski wskaźnik produkcji kruszyw piaskowo-żwirowych do produkcji cementu w ostatnich latach kształtował się w przedziale 9,5 do 12 Mg/Mg. Wartości tego wskaźnika są zmienne dla poszczególnych krajów , głównie w zależności od udziału różnych rodzajów kruszyw (piaskowo-żwirowych, łamanych, z recyklingu, sztucznych, itp.) w łącznej produkcji kruszyw budowlanych. Pomimo zróżnicowania w różnych krajach i regionach świata wartości analizowanego wskaźnika, jego zaletą jest to, że produkcja cementu jest identyfikowana i uwzględniana w bilansach produkcji przemysłowej większości krajów, w odróżnieniu od braku takiej identyfikacji lub nie dokładnej ewidencji dla produkcji kruszyw budowlanych. Przyjęcie tego wskaźnika umożliwia opracowanie analiz i prognoz wydobycia i produkcji naturalnych kruszyw budowlanych dla poszczególnych krajów i regionów, co jest postulowane między innymi przez uchwały ONZ.

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