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Aggregates from waste materials

Comprehensive management of municipal and industrial waste

The article will present – in the context of the EU raw materials policy – a way of utilizing municipal waste in combination with mineral waste, resulting in a marketable product. The properties of the material obtained and its applicability have been shown.

The issue of ensuring access to mineral resources and their obtainment becomes a strategic goal of the European Union. Raw material deposits, their exploration, and excavation are increasingly hampered by competitive ways of the land use (e.g. the Natura 2000 programme) and many environmental regulations (e.g. waste disposal law, environmental protection law, etc.), and technological constraints in the access to mineral resources. Hence the great importance attached in the EU to the possibilities of securing the supply of raw materials by increasing resource efficiency and recycling.
An important assumption of the EU raw materials policy is the implementation of sustainable development principles, based on two pillars:

- improving the efficiency of resource utilization in all sectors,
- active environmental protection against overexploitation and pollution.

The basic assumption of the European strategy for sustainable resource management is to take action to create and promote solutions that include both the conservation of existing resources and the use of recyclables and waste, in accordance with a closed value chain rule.
The challenge is to reinforce the efforts to switch the economy to a culture of saving, reusing and recycling to achieve smart and more environmentally-friendly growth.
The aim is to enable and accelerate the development of environmental technologies that contribute to material outlays reduction, resource productivity increase, minimizing waste and recycling of waste as a source of secondary raw materials.

Resources of waste raw materials for the production of aggregates

The waste raw materials base for the aggregate production includes secondary raw materials from the metallurgy and power industry, raw materials from the extractive industry, and "old" building materials.
Comparing to natural resources, secondary raw materials represent a significant resource base (about 25%). With the full use of raw materials only produced annually, the potential aggregate production on their basis may reach about 30% of the total annual aggregate production in Poland.
The estimates above do not take into account the possibility to obtain new raw waste materials for the aggregate production. Municipal waste, including sewage waste and waste from municipal incineration plants, could be an example.
In 2002, about 750,000 Mg SI sediments accumulated on the site of sewage plants and the annual material revenue of about 450,000 Mg SI were estimated. Approximately 40% of the sludge is agriculturally, industrially or thermally managed or composted.
Sewage sludge generally does not meet the standards for its agricultural use (metal content – cadmium, zinc, lead, nickel, mercury). To a limited extent, it can be used naturally for reclamation purposes, provided sewage sludge meets specific requirements and has an access to a suitable ground.
In developed EU countries, the incineration of municipal waste with the use of its own combustion

KEYWORDS
lightweight artificial aggregate, EU raw materials policy

heat is a preferred direction in municipal waste utilization, being one of the main sources of energy. However, according to the published data on the mass balance of municipal waste incineration plants, after the incineration process and processing of such waste as slag and metal scrap about 6.42% of the initial mass of incinerated waste is disposed, and this disposal includes 2.95% of fly ash. Prior to the incineration, municipal waste is not classified as a hazardous waste, but after the incineration at the temperature of about 850-950°C mineral waste remains, in which potentially hazardous substances (heavy metal compounds) accumulate in much more mobile form, e.g. chlorides, and oxides. The waste produced is unstable in the natural environment and must be, in accordance to an applicable law, processed by conditioning or stabilization before placing in a landfill.

Incineration plants that already operate (Czajka in Warsaw) or in near future will reach full capacity (Kraków, Białystok, Szczecin, Poznań, Bydgoszcz, Konin, Gdańsk, Koszalin, Radom, Wrocław) will incinerate at least 1,000,000 Mg of municipal waste, so about 30,000 Mg of hazardous waste (including fly ash from exhaust gases dust removing installations) in which potentially hazardous and dangerous substances such as heavy metals are accumulated and which require neutralization and/or stabilization.

Lightweight artificial aggregate

The attractive method of the utilization of sewage sludge and stabilization of fly ashes from municipal waste incineration plants, adapted to the physicochemical features of this type of waste, is the technology of the lightweight artificial aggregate obtainment developed in the Institute of Mechanised Construction and Rock Mining. In addition, this method is economically effective since it enables obtaining a construction product suitable for universal use, the price of which provides economic profitability.

The Institute of Mechanised Construction and Rock Mining (IMCRM) is the author of a patented thermal method of converting sewage sludge and mineral waste into aggregates for construction. This is a method of the comprehensive management of sewage sludge from municipal sewage treatment plants, fine grain mineral waste or waste from different areas of the economy. The aggregate is produced in a waste-free technology, and the technology itself enables obtaining a product of specified parameters, which allows the construction product to be adapted to the intended use.

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It should be emphasized that the IMCRM artificial aggregate is a fully ecological product. The structure of the aggregate, made on the basis of silicate compounds, is analogous to natural minerals, the aggregate does not contain any natural reactants, even after crushing, no chemical compounds are released during exploitation (as is the case with the cementation of waste). The

Aggregate feature	IMCRM artificial aggregate
Bulk density [g/cm^3]	480-720
Water absorption [%]	5-32
Crushing resistance [MPa]	1,5-11
Frost resistance [%]	0
Comminution resistance [LA]	32-35
Polishing resistance [PSV]	60-69
QD Luminance ratio [mcd/m^2/lx]	200

Tab. 1. Example values of aggregate utility parameters according to the IMCRM technology

Fig. 1. Raw waste materials used in the IMCRM technology of obtaining artificial aggregates: sewage sludge, fine-grain silica, cullet

technology of the aggregate production on the basis of sewage sludge is currently being implemented industrially.

The characteristics of artificial aggregates from waste

The technology of producing aggregates from waste is a safe, low energy-consuming, environmentally friendly and economically efficient way of managing municipal waste (sewage sludge, incineration products, cullet). In addition, it allows to use mineral waste containing fine-grained silica as the main component. The advantage of the IMCRM technology is the ability to change the features of aggregates in a wide range, by varying the proportion of components, the use of modifying admixtures and the characteristics of the thermal process. This allows to obtain aggregate adapted to the intended use. The examples of the IMCRM artificial aggregate features are shown in Table 1.

Selecting the stabilization method

In the economically developed countries of Europe, the management of residues after the incineration of municipal waste is usually solved in one of two ways. The first is stabilizing dangerous compounds from ashes in cement compositions, thus solidifying in blocks and storing such processed residues in non-hazardous waste landfills. This is a controversial method because the corrosion process of concrete structures causes the leaching of toxic substances to only be delayed.

The other, a much more expensive way of managing residues after the incineration of waste, is their detoxification, which involves the removal of all harmful substances. The result is a completely non-toxic product, safe for storage or use as raw material in the construction industry and ceramics. Such disposal and storage methods generate significant costs, within the range of EUR 50-150 per Mg, and do not provide long-term efficiency.

The solution developed in IMCRM is to carry out the stabilization process in such a way as to obtain a commercial product rather than waste. The method of neutralization proposed by the Institute has an advantage over the above methods –– it produces a desired marketable product – lightweight artificial aggregate whose sales price fully compensates the cost of thermal operations and can even be competitive as compared to lightweight aggregates available on the market.

It must be said that reaching for aggregate from waste does not have to mean compromising on lower quality. On the contrary, it can mean obtaining a material with desirable features unattainable to natural aggregates.

The scope of using waste as raw material for aggregate production is unlimited, provided that the obtained aggregate meets the standards. The scope of the use of lightweight artificial aggregates is identical to that of natural aggregates. All aggregates are equal, the only criterion is their features. The existing regulations do not inhibit the use of this type of raw materials. They treat separately the non-hazardous waste and reasonably reduce environmental hazards. That prevents quality deterioration as a result of changing raw materials.

Aggregates produced from waste in thermal processes will not be cheaper than those produced naturally. But in this valuation all aspects should be taken into account, such as obtaining the aggregate of the expected quality, saving natural deposits, as well as effective and safe disposal of hazardous waste. ❑