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RECYCLING OF CONSTRUCTION WASTE AS ONE OF THE ASPECTS OF SUSTAINABLE CONSTRUCTION

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ABSTRACT: The article presents the concept of using construction waste as an alternative to natural aggregates in sustainable construction. Due to the fact that the quantity of concrete produced per year is very large, its complete processing would make it possible to produce large quantities of secondary aggregate. Reuse of recovered debris involves the need to recycle it. Therefore, technologies should be implemented to allow the use of raw materials Recovered and waste treatment should ensure that the highest quality raw material is obtained. Contemporary technologies and knowledge allow for the development of a method that will allow for complete debris remediation as well as the cost reduction of the entire technological process. It is extremely important from the point of view of environmental protection and economic account.

KEY WORDS: construction waste, construction waste recycling, concrete rubble, sustainable construction

Introduction

In Poland for several years, we have been able to observe the implementation of sustainable building principles, the idea of which is to design, build and use for the future, which is conducive to the construction of buildings that do not pollute the environment of various types of waste and make the use of facilities friendly both For users as well as for the environment. The sustainability and quality of design, construction and material solutions, but also the availability and comfort of the buildings and associated equipment, and the beautiful, healthy and green environment are the key objectives of sustainable construction. In shaping urban space, more attention is paid to the expansion of green areas and rest areas, which integrate into built-up areas. Urbanization processes cause a steady increase in construction investment, while current construction is increasingly aware not to diminish the prospect of future generations for a valuable, healthy life. The goal of sustainable construction is also economics, which means that a city, country or continent is more likely to be chosen for a place to live or to locate a business where healthy living conditions exist.

Sustainable building is a priority for reducing energy consumption and ensuring that end-of-life resources can be used for future generations. This is particularly important in the housing sector, where its visible growth has increased the demand for concrete. Its production is related to the use of raw materials of natural origin, especially natural aggregates, which is slowly becoming a problem.

In recent years there has been a growing awareness of society and a less permissible use of natural resources. The number of plants extracting natural aggregates is decreasing, thus damaging the environment. Consequently, it was necessary to look for alternative raw materials whose properties are at least similar to natural ones. This would justify the replacement of natural aggregate with the aggregate in the production of natural aggregates. This is particularly important in the case of concrete whose production is constantly increasing and the amount of aggregate used in its production is significant. The development of construction and thus the consumption of concrete made it necessary to refine its recipe in order to use substitute raw materials. A number of studies have made it possible to improve the way it is manufactured and the possibility of using alternative aggregates. This greatly reduced the consumption of raw materials.

Concrete rubble as building material for reuse

In the construction sector, in addition to building new facilities, there is also the need to demolish buildings unsuitable for further use. Demolition or demolition of structures results in an increasing amount of concrete debris that hits landfills. This is related to many issues related to both the large areas occupied by debris as well as its negative impact on the environment or the need to set up new landfills. Due to environmental, economic and legal conditions, a ban on the storage of concrete debris is prohibited. Increasing ecological awareness of society has necessitated the need to process concrete debris in such a way that it can be reused. For several years, research has been conducted on both methods of processing rubble and the properties of secondary raw materials. At first, alternative aggregates did not exhibit good properties and limited use. Developing technologies, as well as a number of researches, have allowed the method to be refined and thus produce a secondary aggregate with properties similar to natural aggregates.

The processing of concrete rubble for reuse is, however, associated with a large amount of waste generated by its processing in the form of dusts, as well as problems associated with the production of large amounts of CO_2, which does not in principle favor the environmental principles to which it attaches, more weight. It is therefore imperative to improve the technology of debris removal to eliminate any manufacturing defects.

The quantity of concrete debris produced each year is very large, so its complete processing would make it possible to produce large quantities of secondary aggregate. From the point of view of sustainable construction, this would reduce the amount of waste deposited in landfills as well as the quantity of natural aggregates obtained, and thus the balance between ecology, economy and society. This is quite a problem due to the increasing amount of construction waste and the decreasing amount of natural resources. The legal conditions introduced by both the European Union and the government are brought about by this. This is to promote issues especially related to ecology.

Concrete is one of the most commonly used building materials not only in Poland, but also in the world. The construction industry should meet the requirements of durable and ecological construction, but many factors affect the fact that concrete structures may be considered not to meet these basic principles. The problem is the changing climate, the decline in natural resources and the non-organic production of concrete. The cement production process produces significant amounts of gases into the environment causing global greenhouse effects. The decline in natural resources of such valuable raw materials as sand, gravel, and water is due to their use in the

manufacture of concrete. Over the past several decades, the development of design, optimization and refinement processes of concrete has rapidly developed, allowing for more economical and functional solutions. The use of such concrete had a beneficial effect on the reduction of natural resources. In the future, however, it will be necessary, in justified cases, to get rid of objects made of high-strength concretes, and the resulting debris can be used and be reused in new constructions. Growing ecological awareness of society leads to finding new solutions in the construction industry. Action should be taken systematically and the implementation of the principles of sustainable development (Adamczyk, 2010, p. 125-131) should be carried out so that the effects on the environment are visible and lasting. Ecological practices mean that there is a growing trend towards the use of recycled materials. The use of construction rubble as a substitute for natural aggregates in the production of concrete mixtures is growing in popularity among the supporters. This is due to economic and ecological reasons. Using construction rubble is limited to the consumption of expensive natural aggregates, which also minimizes negative impact on the environment. A significant advantage can be achieved when the largest possible amount of recycled aggregates is used for the production of concrete. Environmental aspects have become increasingly important over the years and therefore the growing interest in alternative solutions in the construction industry. Two of the main reasons that make recycling more and more popular are the continuous increase in the amount of concrete waste and the steady increase in the consumption of concrete as building material. Many authors in their publications have presented concrete tests with recycled aggregates, but in most aggregates from conventional concrete (Bołtryk, 2008; Gołda, 2006; Zając, 2010). Few authors are involved in the use of high-grade recycled aggregates in concrete (Ajdukiewicz, 2009; Sadowska-Buraczewska, 2013) as well as in construction (Sadowska-Buraczewska, 2013, p. 2175-2184).

Types of construction waste

As a result of numerous renovations, demolitions and demolitions of old buildings, not only in Poland but also in the world, the problem of large quantities of debris has occurred. In developed countries, this problem was already addressed at the turn of the 1970s by a series of studies to re-use raw materials from the demolition of concrete structures. The main countries where the emphasis was placed on the recovery of aggregate as well as debris binders were Japan and the United States, where huge quantities of waste were deposited due to numerous earthquakes. The focus was mainly on the

properties of the recovered concrete components and the development of their processing technologies (Zając, 2010, p. 134-135).

This problem was also addressed in Poland by the implementation of the Waste Act, which introduced measures to reduce the negative environmental impact of waste generation and the poor management of waste. The waste is defined as the object or substance the owner discards, is intended to be disposed of or is required to be disposed of. This law includes the division of waste into groups based on the origin of the waste. Construction waste is included in group 17, which contains the following subgroups:

- construction rubble made of concrete, reinforced concrete or brick construction,
- structural steel, reinforcing steel and other metals,
- wood,
- finishing materials, including glass, insulating materials, plastics and others,
- earth from trenches and road debris (Ajdukiewicz, 2009, p. 65-69).

Construction rubble can also be divided depending on the degree of contamination. There are then divided into three categories: finishing materials, including glass, insulating materials, plastics and others,

1. unloaded – mineral material, which contains small amounts of organic and inorganic substances. Obtaining such debris is only possible with proper demolition work with segregation of the material obtained.
2. loaded – material that is obtained at demolition without proper selection of the components obtained. Once the work is done, sorting and neutralizing of unnecessary components is completed.
3. contaminated – material contaminated with harmful substances that threaten the health and the environment. It is obtained during the demolition work of buildings such as hospitals or laboratories. In case of such debris, the aggregate can be obtained only under pain of carrying out special disposal of harmful substances (Dworzańczyk-Krzywiec, 2011, p. 229-233).

Recycling of construction waste

Construction waste, to recover raw materials from them, must be recycled. Under the Act, this is a process that leads to the recovery of materials, substances or products that can be reused. The purpose of recycling is to create a closed circuit that allows the raw material recovered to build a new structure. Figure 1 shows a simplified scheme comparing recycling now and in the future.

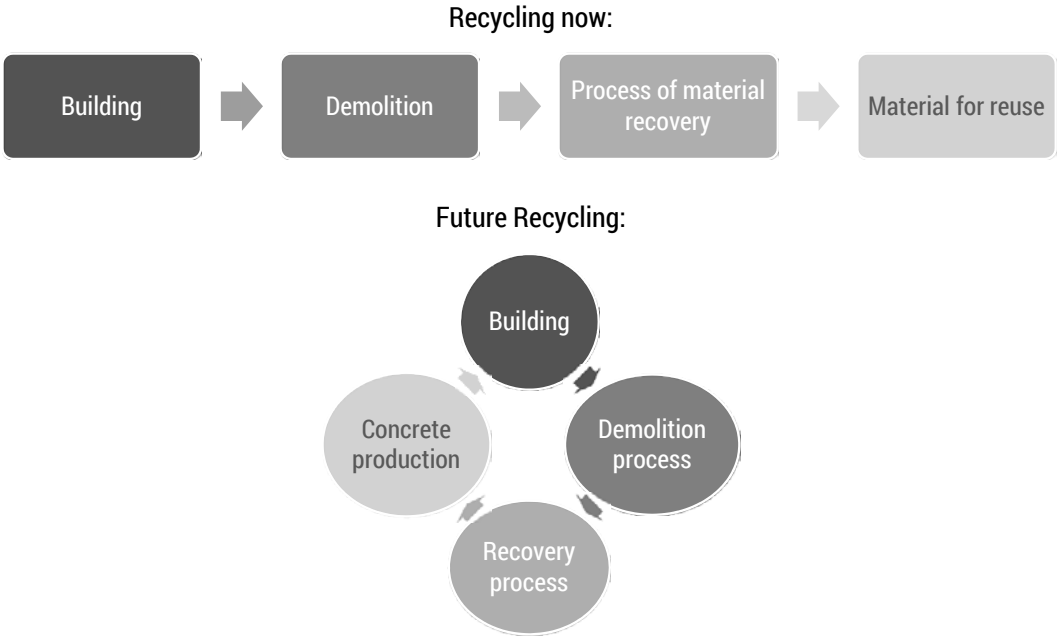

Figure 1. Recycling of current and anticipated recycling in the future

Source: author's own study based on (Zając, 2010, p.134-135).

Several basic factors must be fulfilled for the proper functioning of recycling facilities. First and foremost, the market must be prepared to receive aggregates and recycled mortars. Therefore both construction and other industries should implement technologies that allow the use of recovered raw materials. In order to reduce transportation costs, such plants should be located in areas that allow for permanent concrete rubbish deliveries. These areas should be adapted both for the retention of debris from demolitions, as well as for the easy arrival of trucks delivering waste and disposing ready-made aggregate. An important factor is the fact that the amount of natural aggregates is decreasing, and there are quite large costs of debris storage (Wolska-Kotańska, 2005, p. 18-22).

National waste management plan

After Poland entered the European Union, due to its provisions, a resolution of the Council of Ministers on the National Waste Management Plan was adopted. It aimed at analyzing the state of waste management, providing

forecasts for changes in waste management, and proposing actions that could reduce the problem of waste. According to this plan in the construction sector the largest share of waste in 2008. provided:

- metal scrap (40%),
- soil (30,7%),
- construction materials waste (26.9%) (Uchwała Nr 217 Rady Ministrów).

The introduction of policies promoting the recycling of waste from concrete debris is aimed both at reducing the amount of waste in landfills and by reducing the consumption of natural resources. According to the Resolution a large part of the waste from construction is recovered and reused, among others. Road construction, ground leveling or reclamation of excavations. It is estimated that the use of recycled raw materials in the road infrastructure sector will increase, which will allow the processing of the increasing amount of waste. Figure 2 shows the forecast of the generation of waste from construction in subsequent years.

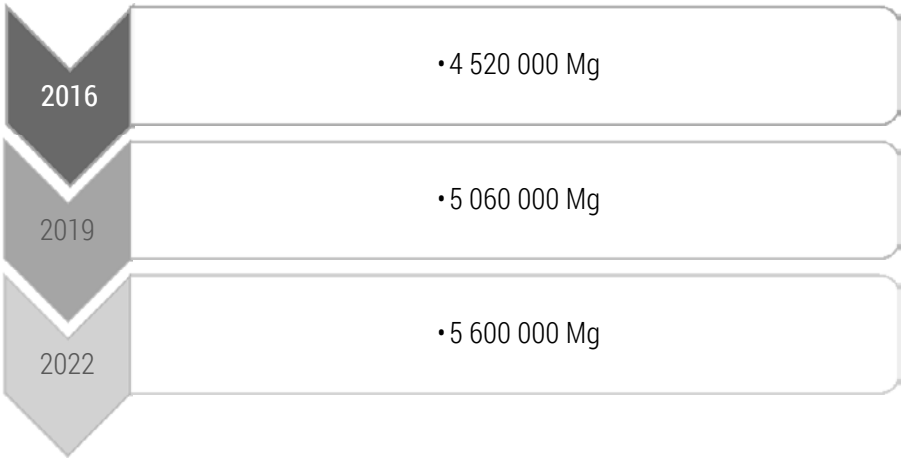

Figure 2. Forecast of generation of waste coming from the construction industry in subsequent years

Source: author's own study based on (Uchwała Nr 217 Rady Ministrów).

It is estimated that the amount of waste recycled or recovered will be about 70% by weight. In order to achieve this, it is necessary to sort the debris properly during demolition. It would be necessary to systematize the whole demolition process, starting from the planning, organization and finally demolition of the individual parts of the building (Ajdukiewicz, 2009, p. 65-69). An aspect that is particularly important when dealing with a problem related to waste is their environmental impact. In the era of ecology this

is a dominant factor. Both preventing the removal of construction waste into a dump and the use of recycled aggregates to reduce the consumption of natural aggregates are beneficial for the environment.

In Western countries: Japan, USA or Singapore recycling and reuse of materials reaches 90%. Large amounts of concrete waste resulting from earthquakes, insufficient natural aggregates, and environmental protection have contributed to the development of recycling in these areas. Also the high storage prices introduced there and the ban on landfill of waste in landfill resulted in increased efforts to recycle as much waste as possible to reuse them (Ajdukiewicz, 2009, p. 65-69). Regulations introduced in the Netherlands allowed the use of recycled aggregates in the amount of up to 20% for the production of concrete, thus replacing the expensive aggregate. 100% can be used in such elements as foundations, ceilings or walls without having to correct the design documentation (Swirydziuk, 2011, p. 79-81). Below Figure 3 shows the recycling aggregate cycle in general and in more developed countries.

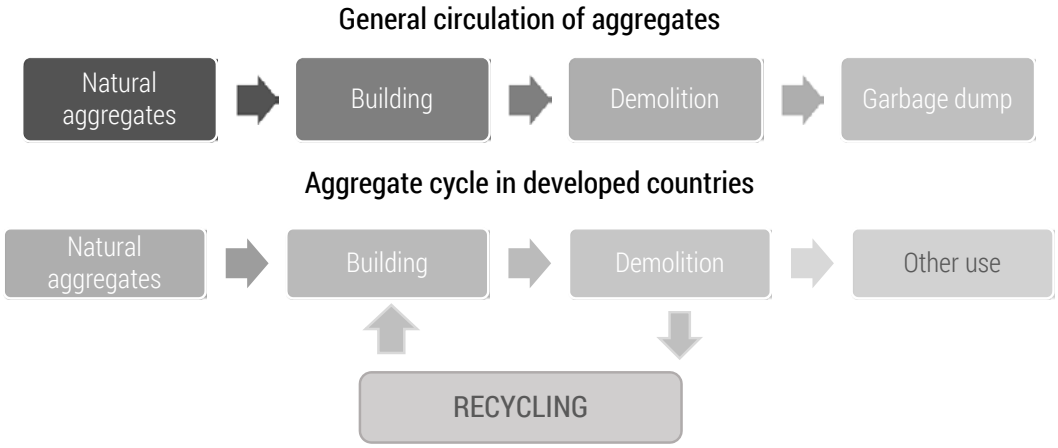

Figure 3. Aggregate cycle in general model and model used in developed countries

Source: author's own study based on (Ajdukiewicz, 2009, p. 65-69).

Stages of processing rubble

Materials obtained from recycled reinforced concrete structures are aggregate and dust with high cement content. In order to obtain the best qualities of the above raw materials, it is suitable to process them using high quality equipment and technology to obtain aggregate from contaminated debris. The steps of processing concrete debris are shown in figure 4 below.

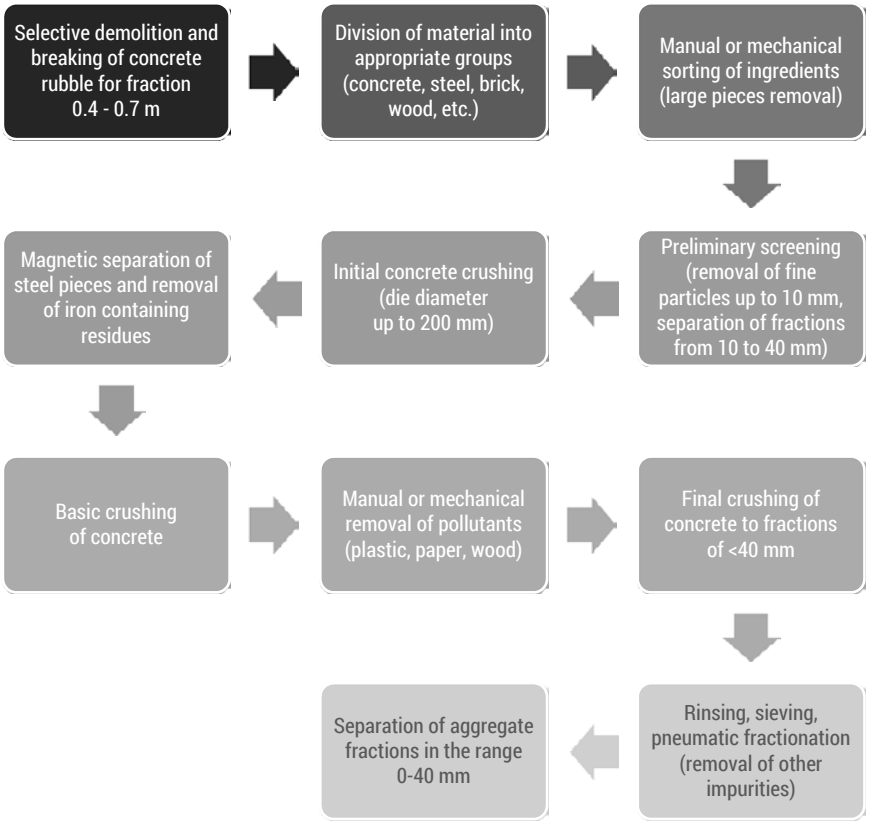

Figure 4. Stages of processing rubble into aggregate

Source: author's own study based on (Ajdukiewicz, 2009, p. 65-69).

In order to unify the way of recycling and thus create the ideal model, a number of studies have led to the release of the report by the International Association of Concrete in 2004. It contained works and documents from teams that carried out a series of studies. There are three areas of recycled aggregates in use:

- material used on the surface of floors and floors,
- material used for non-structural concretes or as an additive for natural aggregates,
- material used for construction concretes as fine and coarse aggregates with appropriate properties (Ajdukiewicz, 2009, p. 65-69).

Methods of obtaining raw materials from recycled construction waste

The country most developed in terms of research and modern methods of obtaining raw materials from recycling is Japan. The most famous are four methods of removing aggregate slurry from aggregate. Belong to them:

- HRM – Heating and Rubbing Method
- MGM – Mechanical Grinding Method
- SMM – Skrew Mill Method
- GCM – Gravity Classification Method.

Most of the aforementioned methods are just a theoretical solution that is not implemented. Most countries base their work on well-structured schemes where the debris processing process takes place in strictly defined stages. It consists of:

- separation of materials,
- segregation of debris into rubble: brick, concrete, ceramics, wood, reinforcing bars, bituminous materials,
- crushing individual, segregated pieces of rubble in impact crushers, jaw or cone crushers,
- sorting aggregates into individual fractions (Zając, 2014, p. 393-395).

Over the past few years there has been a sharp increase in recycling issues in Poland. However, a number of statistics show that the amount of recycled rubble in our country for secondary aggregates is negligible. Below, figure 5 shows the percentage scale of construction waste processing in Poland and in the world.

In addition, highly developed countries, such as the Netherlands, Denmark and Germany, recycle large amounts of concrete, bricks, tiles or asphalt, while in Poland most of the processed waste is wood, glass, metals or gypsum.

The goal of modern recycling is to completely recycle construction debris, both concrete and brick, wood or other. The choice of waste treatment method should ensure both the highest quality raw material and the minimization of non-reusable components, such as too much dust generated by commonly used rubble crushing technologies. Contemporary technologies and knowledge allow for the development of a method that will allow for complete dehumidification as well as cost reduction of the entire technological process.

Economic analysis made by Japan has shown that in order to ensure the economic benefits of a given aggregate production facility, a productivity of 110-275 t/h has to be established, and in order to ensure adequate return on investment, the plant should produce and sell 200,000 tonnes of aggregate

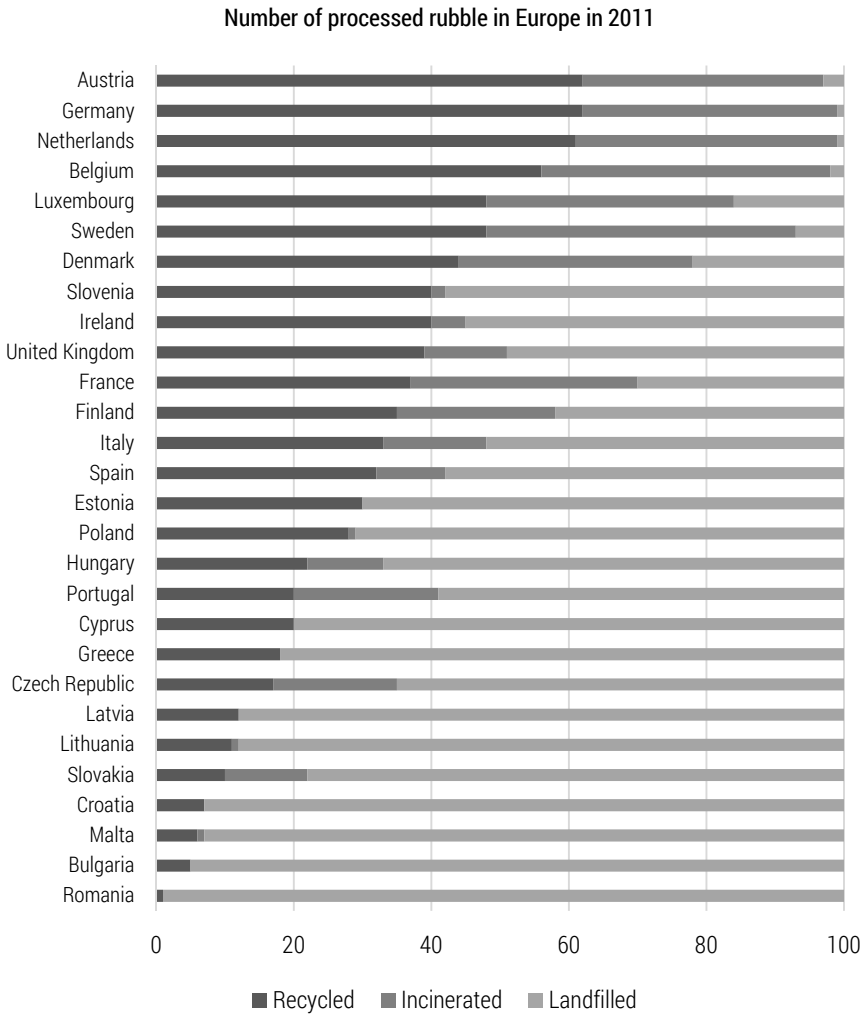

Figure 5. Number of processed rubble in Europe in 2011

Source: author's own study based on (Bhatnagar, 2013).

recycled annually. Apart from establishing capacity, it is also important to ensure the continuity of sales of recycled aggregates. The increase in demand for secondary aggregates is mainly influenced by the price that should be competitive with the prices of natural aggregates. Fulfilling all these requirements, choosing the right method, increasing the quality of the aggregate obtained, reducing the amount of dust produced, adjusting the capacity of the plant, and setting the right price for the raw material you sell will allow you to develop more extensive recycling.

Conclusions

Construction waste is an increasingly serious problem, not only in in Poland and in the world, but also ecological and economic. Finding solutions for the reuse of concrete debris is quite a challenge. This article is intended not only to draw attention to this issue, but also to indicate the possibility of minimizing the use of natural resources, whose resources are running out, and the number of mine points is reduced through the reprocessing of concrete debris. The use of concrete waste is conducive to supporting sustainable construction based on ecological, economic and social issues. The possibility of processing huge amounts of concrete debris, which each year increases, reduces the extraction of natural aggregate.

It is postulated to implement new technologies allowing for the use of recycled raw materials that would ensure obtaining the highest quality raw material from processed waste. Current knowledge and modern technologies give the opportunity to develop new methods aimed at total processing of debris and minimizing the costs of the technological process.

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