Daniel TOKARSKI • Bartosz ZEGARDŁO

COSTS AND ECONOMIC BENEFITS OF RECYCLING ELECTRICAL INSULATORS IN SPECIAL CONCRETES PRODUCTION

Daniel **Tokarski**, PhD (ORCID: 0000-0002-3475-1115) – *University of Lodz*
Bartosz **Zegardło**, PhD (ORCID: 0000-0002-1292-3107) – *University of Natural Sciences and Humanities in Siedlce*

Correspondence address:
Revolution 1905 Street 37/39, 90-214, Łódź, Poland
email: daniel.tokarski@uni.lodz.pl

ABSTRACT: The article is a continuation of the research work undertaken to indicate the economically and ecologically justified recycling of ceramic waste material from used electrical insulators. During the renovation works of old electric lines, relatively large amounts of insulators are obtained, the disposal of which is now quite a costly undertaking. Based on previous experiences (Zegardło, Ogrodnik, Woliński, 2016; Zegardło et al., 2018), the authors of this article indicate the potential possibility of using the used insulators in the production of aggregates for special concretes. Such aggregates meet all parameters and requirements, and the concretes obtained from them have parameters higher than those obtained from traditional aggregates. Based on the analysis of data taken from the archives of the company dealing with electrical and repair works, the areas from which insulators are obtained were presented. The scale of the said project on a national scale was discussed. The aim of the study is to estimate the costs and economic benefits related to the disposal of insulators and their reuse as aggregates for special concretes. Despite the calculations that show that such a project would not be associated with significant financial profits, the authors indicate other benefits that would flow from this type of management of the mentioned waste.

KEYWORDS: electrical insulators, recycling, special concretes

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Introduction

The guidelines of environmental protection authorities require that all new products manufactured should be provided with effective recycling methods. The best way to recycle products is to use them in primary production – as is the case, for example, with steel products. However, there are many industries in which these products cannot be reused for the production of new products. Ceramic products are an example of such an industry. Due to the specificity of the production of fired clays, processes occur during their production that cannot be reversed. Such a production system means that the used products cannot be reused for the production of new products. One of the ceramic products covered by the described procedure is electrical insulators. Despite the fact that these products are very durable while modernizing electric lines, relatively large amounts of this matter are produced. For this reason, new and innovative solutions for their recycling are sought. In this article, referring to previous research works, the authors present the possibility of using used insulators for the production of aggregates for concrete. The work describes this issue in economic terms. The article presents an analysis of the costs and economic benefits that would be associated with the disposal of insulators by using them as aggregates for concrete. Despite the fact that the conclusions confirm that such activity would not be associated with large financial profits, other benefits of this type of solutions were presented.

Motivation and purpose of the analysis

Various mineralogical compositions, aggregate states and colours of clays from which ceramic products are made (Awgustinik, 1980; Haase, 1961) give a wide possibility of their classification. The basic division of clays (Zegardło et al., 2018; Węgrowski, Przeździecka, 1979) in terms of their use for the production of products is the division into common clays (brown to yellow in colour, widely used in the production of construction products such as bricks, wall and ceiling blocks, chimney fittings, roof tiles) and precious clays (white in colour, for the production of porcelain or similar porcelain products, of which, inter alia, ceramic electrical insulators). The production process of these products consists of several stages, as a result of which the ceramic material receives its unusual features. The first stage of production is the preparation of ground components from which insulators are formed. The next stage is the drying stage, in which the elements are subjected to a temperature of about 45 °C, thanks to which the ingredients become solid, and the product receives its final shape. This process is followed by glazing, i.e., covering the elements with a thin layer of glaze. The final process that decides about posting products of the final characteristics is a firing stage, carried out at a temperature of approx. 1280 °C, during which the final processes of formation of ceramic bonds occur. Thanks to them, the ceramic material has high strength parameters, up to 400 MPa, compressive strength, and is resistant to high temperatures. Ceramic electrical insulators are elements used in the power industry to support and insulate conductive elements (Maksymiuk, 1997; PN-IEC 60050-151:2003). Despite the fact that in the production technology of electrical insulators, there are modern materials (Zegardło et al., 2016). such as resin composites or silicone rubbers, which also meet the requirements, the largest percentage of insulators is still produced, and the largest amount of waste electrical insulators associated with it is made of ceramic. The entities undertake activities aimed, for energy and ecological reasons, to fully manage all waste, including ceramic waste. Here, in addition to simple, non-structural applications, such as land levelling, the aim is to ensure that the waste substances can also be implemented on the wider market of load-bearing materials. However, this issue is quite complex, and many areas of this type of possibility have not yet been explored. Preliminary results show that concretes produced with ceramic waste products can be used, for example, in communication construction (Ogrodnik, Zegardło, 2015; Zegardło et al., 2016) for the production of asphalt concretes for use in road binding layers and wearing courses. Another type of use of waste electrical insulators is presented in (Zegardło et al., 2016), where the conducted tests proved that the aggregate obtained from ceramic electrical insulators is a suitable aggregate for cement concrete, and the concretes made with its use exceed the strength characteristics of concretes prepared using traditional aggregates. The results of these studies are presented in table 1.

Table 1. Average values of the examined properties of the compared concrete

Feature	Unit	Concrete on aggregate from electrical insulators	Concrete on basalt aggregate	Concrete on traditional gravel aggregate
Tensile strength	MPa	7.20	6.70	4.30
Compressive strength	MPa	86.40	76.50	49.90

Source: author's work based on research results.

The results of endurance tests carried out according to (Jamrozy, 2016; Neville, 2012) showed a clear improvement in the properties of the obtained concrete after replacing the traditional aggregate with ceramic aggregate obtained from crushing waste ceramic insulators. Despite obtaining excellent parameters for the recipe concrete containing basalt aggregate in its composition (compressive strength 76.50 MPa, tensile strength 6.7 MPa), the results for the recycling aggregate were 12% for compressive strength and 7% for tensile strength, respectively higher (compressive strength 86.40 MPa, tensile strength 7.2 MPa). Similar results of research studies in which concrete was used for the production of ceramic aggregates were presented in the works (German construction standard 1951-DIN 4163; De Brito and et al., 2005; Senthamarai et al., 2011; Halicka, Ogrodnik, Zegardło, 2013; Lopez et al., 2007; Guerra et al., 2009). The results of these tests confirmed that the higher the addition of ceramic materials, the better the parameters of the concretes obtained with them. In the summary of the above-mentioned articles, the authors emphasize that the use of recycling aggregates from ceramic insulators for concrete may have a double effect. Concrete producers can obtain cheap aggregate from waste difficult to utilize, thanks to which such disposal will be economically justified. On the other hand, such action may bring about an ecological effect, the residual waste will be disposed of, and the extraction of natural aggregate resources will decrease.

Estimating the costs and economic benefits of recycled waste

Cost-benefit analysis is a complex method of assessing the effectiveness of investments and projects, taking into account all expected benefits and costs, including qualitative and quantitative elements, allowing to determine the degree of effectiveness of a given investment in the environment (Becla, Czaja, Zielińska, 2012). Apart from the economic aspects of the project, the cost-benefit analysis also takes into account social, cultural, and environmental areas, classified as external costs (Boardman et al., 2006). Cost-benefit analysis is particularly useful in assessing projects whose implementation involves a significant number of stakeholders, and where the main selection criterion is not profit maximization. The theoretical basis of the above analysis is welfare economics (Szot-Gabryś, 2013). The article estimates the costs and potential economic benefits of recycling electrical insulators; a detailed analysis is part of a separate study.

The solution proposed in this article for the utilization of the said waste was to transfer it to companies dealing in commercial production of concrete. The assumption was that this aggregate is provided free of charge – which was a profit for electric companies that would not pay for waste disposal. It was assumed that concrete companies equipped with crushers would be able to crush the waste and use it for concrete as a substitute for traditional aggregates. The table below presents the costs of transport, aggregate crushing, standardization, and other additional expenses that would have to be incurred by entrepreneurs producing concrete based on waste aggregate.

Table 2. Analysis of the prices of recycling aggregates

Aggregate type / Feature	Unit	Traditional aggregate (sand, gravel)	Concrete destruct of low class concretes	Concrete destruct of high class concretes	Basalt grit	Aggregate from recycled ceramics	
						Traditional red ceramics	Fine ceramics – insulators
Character in the deposit	–	aggregate directly for use	large-size ele-ments	large-size ele-ments	the aggregate produced directly for use	medium-sized elements	medium-sized elements
Price in the deposit (gross at the seller)	PLN/ton	36.9	18.45	30.75	61	18.45	0
Estimated transport distance	km	50	50	80	300	80	50
Price of transport	PLN/ ton	12	12	19.2	72	19.2	12
Need to adapt to commodity production	yes/no	no	yes	yes	no	yes	yes
Type of customization	–	–	cleaning and crushing	crushing	–	cleaning and crushing	cleaning and crushing
Estimated cost of adaptation	PLN/ton	–	21.07	14.76	–	21.07	34.15
Total cost in the concrete plant	PLN/ton	48.9	51.52	64.71	133	58.72	46.15
Special requirements in the production of concrete mix	type	–	increasing the amount of cement	increasing the amount of cement	–	increasing the amount of cement	increasing the amount of cement
The cost of the outlay on a scale of 1 ton of aggregate	PLN/ton	–	12.3	12.3	–	12.3	12.3
Total cost including additional expenditure	PLN/ton	48.9	63.82	77.01	133	71.02	58.45

Source: author's work based on the results of the analysis.

The presented average costs related to 1 ton of waste were obtained from entrepreneurs providing these services. The additional cost of increasing the amount of cement during the production of concrete with recycled aggregates resulted from the fact confirmed by tests (Halicka, Ogrodnik and Zegardło, 2013). The analysis of the prices of recycling aggregates, taking into account the cost of purchase, transport, standardization, and additional expenditure compared to the prices of traditional aggregates is presented in table 2.

When analyzing the data included in the list, it is noted that the most economically justified in the production of traditional concretes is the use of sand and gravel aggregates. These aggregates have the lowest price, i.e., about PLN 49/ton (total cost in the concrete factory) and the broadest range of applications. The presented prices of insulating ceramic aggregates, despite relatively high rates, may be an interesting object for entrepreneurs. Their main advantage is that they can be used to produce concrete of higher classes and concretes with special properties such as resistance to high temperatures or abrasion resistance. For this type of application, commodity concrete plants currently buy aggregates in the form of basalt grits, the price of which, after being transported to the concrete plant, is higher and amounts to approximately PLN 133/ton. The limitations of the use of traditional sand and gravel aggregates, in this case, are significant, as the maximum concrete classes that can be obtained with their use reach about 40-50 MPa. These aggregates also do not work well at high temperatures and high abrasive loads, where electrical insulators can be used in these applications. The final price of electrical insulators crushed to the aggregate form is also more favourable than other recycled aggregates. It should be noted, however, that the tests proved that its parameters are better than those tested for aggregates made of red ceramics or recycled concrete.

Conclusions

As can be seen from the considerations presented above, the market of recycling aggregates from electrical insulators can be economically justified, but not in the case of large-scale production of traditional concretes. These aggregates require additional logistics both in their acquisition, adaptation and in the production process itself (crushing), which discourages entrepreneurs from using them. The use of insulators for the production of special concretes would be economically justified – however, such activities are carried out on a small scale; therefore, it is claimed that such activities would not be associated with significant financial profits. However, for the sake of the good of the environment and the desire to effectively manage unwanted waste or reduce the amount of natural aggregate extraction, it is more and more often claimed that even non-economic measures should be used here. The only possibility is seen in the apparatus of state authorities. The forced, non-economic use of waste in construction in Poland is already taking place, although – so far only theoretical. This is possible thanks to the compact system of environmental law and the increasing activity of the Ministry of Environment, provincial and local environmental protection departments and building supervision departments. Building permit decisions may require the use of local waste material and enforce this condition with the full force of law – this solution, however, is not used on a larger scale. Along with the disappearance of sources of natural aggregates and their depletion of resources, their prices are expected to increase over the years. An alternative solution will be the desire to use aggregates from unconventional – recycling sources. Taking into account the fact that a large amount of natural resources and energy are consumed, which is used to produce electrical insulators, it can be concluded that the potential of this waste is currently unused. In this situation, the proposed solution is to search for more advanced recycling methods than the use of aggregates for hardening areas. Research should be carried out to use the specific features of insulators, such as their high strength or presumed resistance to high temperatures or chemically aggressive environments. The possibility of producing, for example, special concrete, e.g. heat-resistant, from this material, would make the waste a valuable substrate in production. The use of recycled electrical insulators as a substitute for the sophisticated and expensive special aggregates currently used would make them a sought-after material and perhaps there would be no need to pay for their disposal. For this purpose, it is necessary to intensify the research work that will prepare the necessary state of knowledge for recycling aggregates, including those from ceramic electrical insulators, to be implemented without restrictions in the production of concrete.

The contribution of the authors

Daniel Tokarski – 50% (conception, analysis, and interpretation of data).
Bartosz Zegardło – 50% (literature review, acquisition of data).

References

Awgustinik, A.J., 1980. Ceramics. Arkady, Warsaw.

Becla, A. et al., 2012. Cost-benefit analysis in the valuation of the natural environment. Difin, Warsaw.

Boardman, A.E. et al., 2006. Cost-Benefit Analysis: Concepts and Practice, 3rd edition. Upper Saddle River. Pearson Prentice Hall, New Jersey.

De Brito, A. et al., 2005. Mechanical behavior of non-structural concrete made with recycled ceramic aggregates. Cement and Concrete Composites, 27, 429-433, https://10.1016/j.cemconcomp.2004.07.005.

German construction standard 1951-DIN 4163: Concrete with crushed bricks – Specification for production and use.

Guerra, I. et al., 2009. Eco-efficient concretes: The effect of using recycled ceramic material from sanitary installations on the mechanical properties of concrete. Waste Management, 29, 643-646, https://doi.org/10.1016/j.wasman.2008.06.018.

Haase, T., 1961. Ceramics. Leipzig. 2 ed. VEB German, Verlag fur Grundstofindustire.

Halicka, A. et al., 2013. Using ceramic sanitary ware waste as concrete aggregate. Construction und Building Materials, 48, 295-305, https://doi.org/10.1016/j.conbuildmat.2013.06.063.

Jamrozy, Z., 2006. Concrete and its technologies. PWN, Warsaw.

Lopez, V. et al., 2007. Eco-efficient Concretes: Impact of the Use of White Ceramic Powder on the Mechanical Properties of Concrete. Biosystems Engineering, 96(4), 559-564. https://10.1016/j.biosystemseng.2007.01.004.

Maksymiuk, J., 1997. Electrical apparatus in questions and answers. Scientific and Technical Publishing House, Warsaw, 88-95.

Neville, A.M., 2012. Properties of concrete. Polski Cement, Warsaw.

Ogrodnik, P., Zegardło, B., 2015. Analysis of the possibility of using waste ceramic substances in building and engineering structures for transport construction. TTS Rail Transport Technique, 12, 1732-1738, http://yadda.icm.edu.pl/baztech/element/bwmeta1.element.baztech-0f9c57a2-8f3d-420d-9a41-9c6c20883dd7.

PN-IEC 60050-151:2003 International vocabulary of electrical terminology – Part 151: Electrical and magnetic devices.

Senthamarai, R.M. et al., 2011. Concrete made from ceramic industry waste: Durability properties. Construction and Building Materials, 25, 2413-2419, https://10.1016/j.conbuildmat.2010.11.049.

Szot-Gabryś, T., 2013. The concept of cost-benefit accounting in corporate social responsibility accounting. Difin, Warsaw.

Węgrowski, W., Przeździecka, K., 1979. Glass and ceramics. State School Publishing Works, Warsaw.

Zegardło, B. et al., 2016. Initial analysis of the basic parameters of recycled ceramic sanitary cullet in terms of its possible use in the production of asphalt mixtures. Bus 2016, 12, 1715-1718, http://yadda.icm.edu.pl/baztech/element/bwmeta1.element.baztech-8040cdea-4df0-420b-b548-87bb37324b28.

Zegardło, B. et al., 2016. Investigation of the possibility of using waste ceramic electrical insulators as recycling aggregate for concrete. Electro Technical News, 4, 6-7, https://doi.org/10.15199/74.2016.4.2.

Zegardło, B. et al., 2018. The use of ceramic dust produced from exhausted electrical insulators as a filler for cement mortars. Electro technical News, 86(1), 36-38, http://yadda.icm.edu.pl/baztech/element/bwmeta1.element.baztech-b8882e69-c15f-4325-a32e-085dd3313ec9.