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EFFECTIVE USE OF CONSTRUCTION AND DEMOLITION WASTE AND STONE DUST IN CONSTRUCTION FOR THE PRODUCTION OF MANUFACTURED AGGREGATES IN TWO PILOT REGIONS OF THE CZECH REPUBLIC

The authors present a unique possibility of utilizing hitherto unused and difficult-to-store types of waste such as dust generated during the extraction and treatment of a natural stone, and still difficult to recycle part of construction and demolition waste – residual mineral inert material. Stone dust mixed with residual mineral inert material, water, and binders in various proportions formed five types of mixtures which were transformed into manufactured aggregates using hyper-pressing. The properties of these manufactured aggregates – resistance to crushing and bulk density – presented on laboratory--based samples were similar to those of natural aggregates. The production of manufactured aggregates, the processing of unused types of construction and demolition waste, together with stone dust, fully comply with the rules of circular economics. The availability of stone dust has been checked based on data obtained by personally interviewing the authors in the quarries of the pilot regions of South Bohemia and Pilsen. Data on the amount of construction and demolition waste produced were obtained from the publicly available database of produced construction and demolition waste – *Waste Management Information System* (ISOH).

1. INTRODUCTION

The use of construction and demolition wastes (CDWs) has boomed over the last decade. CDWs constitute a very valuable resource [1, 2]. In the Czech Republic, CDWs have been already used in several enlightened construction companies for standard cons-

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truction production, especially for producing ready-mixed concrete, selected monolithic structures, and products [3, 4]. This trend is further developing because the availability of natural raw materials will be limited, not only in their quantity but also in price [5, 6].

In addition to CDWs, the use of other potentially advantageous waste materials is also slowly developing. During the last 30 years, no significant quarry for the extraction of natural stone has been opened in the Czech Republic, so shortly, it can be expected that construction companies, in particular, will use every available source of aggregate [7]. Waste is also produced during the extraction and processing of natural aggregates, especially stone dust. These are currently used to a much lesser extent because their use is tied to the technical equipment of quarries (existence of dedusting technologies) and storage facilities for their dry storage. Dedusting technologies [8, 9] in quarries are being built at a relatively fast pace, but mining companies and consumers lack sufficient capacity for continuous storage of dust particles for their constant use, which is why they are massively expensive landfilled. The authors' survey of selected mining companies in the southwestern region of Bohemia found that the production of dust in quarries ranges from 1.5 to 2.5% of the total amount of raw materials extracted.

1.1. RAW MATERIAL RESOURCES

In the Czech Republic, there has been an increase in the volume of CDWs production in recent years. According to various assumptions, this trend will continue. Most CDWs are not currently used, and more than 80% end up in a landfill. Even the remaining part of construction and demolition waste cannot be used directly in the construction industry without further special treatment. However, several construction companies already know and process recycled brick and mixed concrete to produce ready-mixed concrete and concrete products. CDWs processing is carried out based on Czech know-how and sufficient legislative support. To ensure even greater use of CDWs in construction and the conventional approaches of construction companies, it will be necessary to provide a sufficient amount of this treated waste at a competitive price.

Part of the construction and demolition waste comes from large constructions, the disposal of which is provided by construction companies through authorized persons who have the potential to treat construction and demolition waste so that its use is safe and advantageous [5, 10–12]. Part of the CDWs also reaches the processors from the citizens, either directly or through collection yards, where they accumulate. The collection yard operators, which are taking over CDWs from citizens until the beginning of this year, have not taken any significant measures to increase the sorting of this waste. At present, the situation is such that the citizen being the waste generator is obliged to separate individual significant types of construction waste (concrete, stone, brick materials, etc.) at the moment of liquidation of the building. In the collection yard, these components are not sorted mostly for capacity reasons. Since the CDWs in the collection yards have

not yet been sorted in any way, it is subsequently handed over to most landfills without the possibility of any further use and at high prices.

Based on a personal authors' survey, it was found that, for example, in 2020, 6500 citizens who had access to the collection yard in Horažovice handed over 450 tonnes of CDWs. That is approximately 70 kg/citizen/year. The most important component – approximately 67% – were brick materials (brick blocks and roof tiles), non-reinforced concrete, and stone. The remaining part consisted of various mortars, cladding material (tiling and paving), and soil. This means that approximately 300 t of CDWs from this site could be used almost without cost, after appropriate modification, directly in the Horaždovice region, for various construction applications. The costs saved are related to eliminating the need for transport and landfilling outside the place of origin of the CDWs. The economics of CDWs processing will be as much efficient as the higher competitive price for alternative materials. By observing the rules of the circular economy, the saving of non-renewable natural resources cannot be neglected.

The remaining part, 150 t of CDWs, consisted of about 16% (i.e., 5% of the total CDWs) of soil, organic matter, and 84% (i.e., 28% of the total CDWs) of residual mineral inert materials (RMIM). Thus approximately 24 tonnes of soil and other organic admixtures could be treated together with municipal biodegradable waste with thorough control of the collection staff. About 126 t of RMIM, which consists of shards from tiles and plasters, plasters, and fasteners of various strengths, cannot be used today with conventional modifications. However, there are modern procedures for which the size, species, and various mechanical and physical properties of RMIM do not represent a limitation in further material use.

1.2. CDWS PRODUCTION

Figure 1 shows the total production of CDWs in the Pilsen and South Bohemian regions, which in 2020 was 2716211.4 tonnes. The data was obtained from the publicly available VISOH database [13].

In regional conditions, there is also another relatively significant production of inert mineral waste, which arises during the mining and processing of natural stone. Figure 2 shows the amount of excavated building stone and gravel since 2009. The above data shows that the extraction of these raw materials on a national scale does not change much during the period but rather does not increase. This is confirmed because no new quarries are opened in the Czech Republic. On the contrary, at the regional level, in comparison with the South Bohemian and Pilsen regions, mining in the South Bohemian region increased significantly during the mentioned period (Fig. 2). The data was obtained from the publicly available VISOH database [13].

Assuming that the production of stone dust during stone mining and processing and its subsequent treatment is on average 2%, it is probable that its production in the whole of the Czech Republic is at least one million tonnes per year. This waste is used to a minimal

extent, although its potential is great. For the most part, it is landfilled at construction and demolition waste landfills, directly in the excavated parts of the quarries, or is used in remediation landfills. To a lesser extent, it is used as an admixture to produce concrete and construction products.

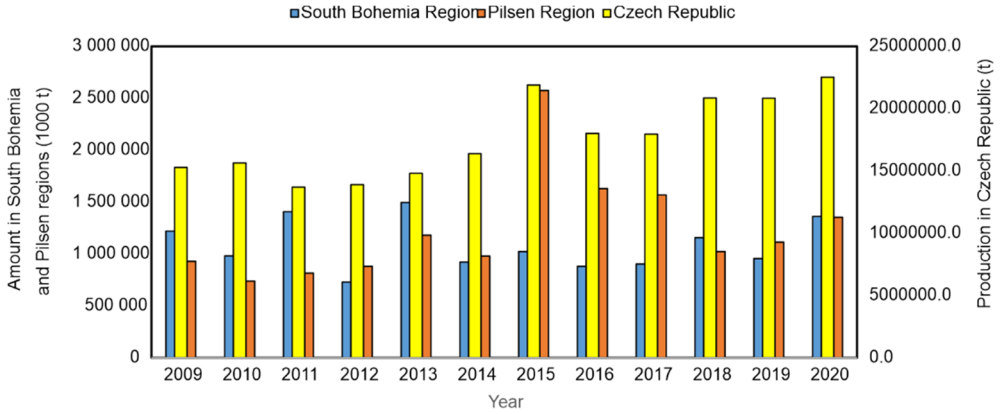

Fig. 1. Production of construction and demolition waste in the South Bohemian Region, the Pilsen Region, and in the Czech Republic in 2009–2020

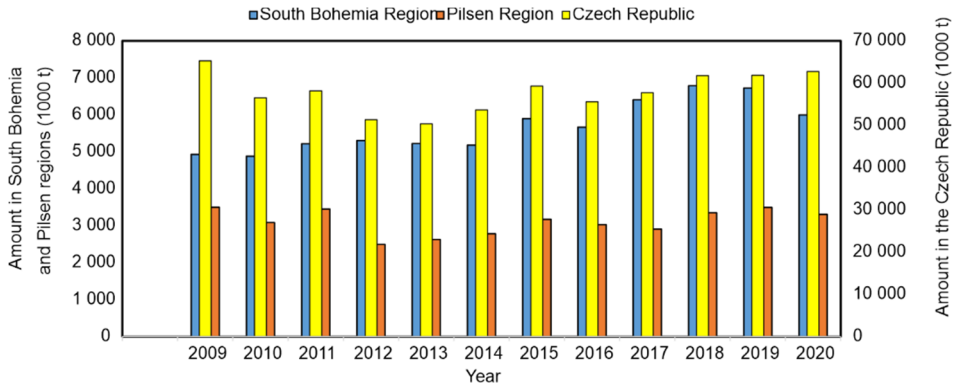

Fig. 2. The total amount of excavated building stone and gravel in the South Bohemian Region, the Pilsen Region, and in the Czech Republic in 2009–2020

Figure 3 presents an estimate by our calculation of stone dust production in the South Bohemian Region, the Pilsen Region and the Czech Republic in 2018–2020. A personal survey of the author's obtained the data. It can be assumed that CDWs contain 28% of RMIM with very different properties and can produce hundreds of thousands to millions of tons of material throughout the Czech Republic and the South Bohemian and Pilsen regions (Fig. 4), which may have the potential for further use in construction. A personal survey of the authors obtained the data.

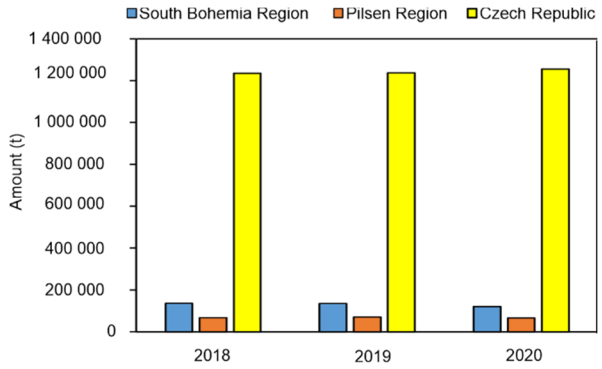

Fig. 3. Stone dust production in the South Bohemian Region, the Pilsen Region, and in the Czech Republic in the years 2018–2020

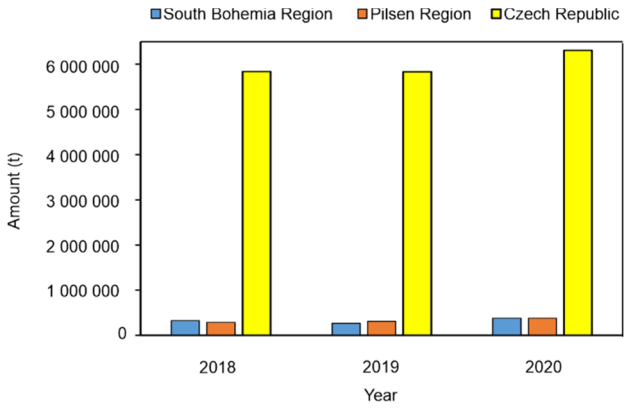

Fig. 4. The estimated amount of RMIM in CDWs in the South Bohemian Region, the Pilsen Region, and in the Czech Republic for the years 2018–2020

In almost every region of the Czech Republic, there is a large amount of waste materials in the form of stone dust and CDWs in the form of RMIM, which are currently landfilled. CDWs in the form of RMIM are approximately five times more than stone dust (in the whole Czech Republic and the Pilsen Region, the South Bohemian Region, this share is 3:1). Both types of these waste materials could be used to produce manufactured aggregates, provided that they will have parameters for use in construction and their production costs will be comparable to the price of mined aggregates in the region.

2. EXPERIMENTAL

A large part of building mixtures for the production of building products and structures uses natural aggregates, which exceed the strength of the products and structures themselves even several times [12, 14]. Thus, a significant group of building products and

structures unnecessarily consume high-quality natural resources, which alternative waste materials can replace. In 2020 and 2021, the production of manufactured aggregates from CDW-RMIM and stone dust was tested experimentally and in pilot operation.

The method of hyperpressing under a pressure of 12.7 MPa and a preselected and modified mixture of CDW-RMIM and stone dust was chosen for the experimental work. CEM I 42.5 R cement was used as a binder in all experiments in 12.5% of the total amount of CDW-RMIM and stone dust. Water was dosed in 12% of the total amount of CDW-RMIM and stone dust. CDW-RMIM was grounded to a particle size of up to 2 mm on a rebound crusher. Subsequently, this mixture was mixed in various proportions with stone dust from the Lašovice quarry, cement, and water. The mixture was pressed on experimental equipment into cylinders with a diameter of 100 mm.

3. RESULTS

The result of the laboratory work in the form of manufactured aggregates is shown in Fig. 5. The crushing resistance parameter was chosen to evaluate individual mixtures, which assesses the strength of manufactured aggregates according to ČSN EN 13055-1, *Lightweight aggregates – Part 1. Lightweight aggregates for concrete, mortar, and grout*. The selection of the identified parameters for the proposed CDW-RMIM and stone dust compositions is shown in Table 1 and Fig. 6. The proposed method of hyperpressing using commonly available hydraulic and air binders is possible to produce manufactured aggregates from waste with lower bulk density than natural aggregates and sufficiently high strengths, whose values do not decrease during measurement (28–90 days) but, on the contrary, they are growing. It has been proven that with this aggregate, it is possible to produce concrete mixtures with compressive strengths above 30 MPa.

Fig. 5. Manufactured aggregates from various mixtures of CDWs

Table 1 shows the results of the crushing resistance of manufactured aggregates in the function of the proportion of CDWs and stone dust and pressing pressure at the age of 28 and 90 days.

Table 1

The crushing resistance of manufactured aggregates in the function of the proportion of CDWs and stone dust and constant pressing pressure at the age of 28 and 90 days

Parameter	Value				
CDW-RMIM content, wt. %	100	85	70	50	0
Stone dust content, wt. %	0	15	30	50	100
Pressing pressure, MPa	12.7	12.7	12.7	12.7	12.7
Density, kg/m^3	1680	1740	1810	1962	2212
Bulk density of dried manufactured aggregate, kg/m^3	763	787	841	982	1,051
Crushing resistance of the fraction 4-8 mm (28 days), MPa	3.5	4	7.2	8	9.04
Crushing resistance of the fraction 4–8 mm (90 days), MPa	3.8	4.5	7.6	9.4	9.6

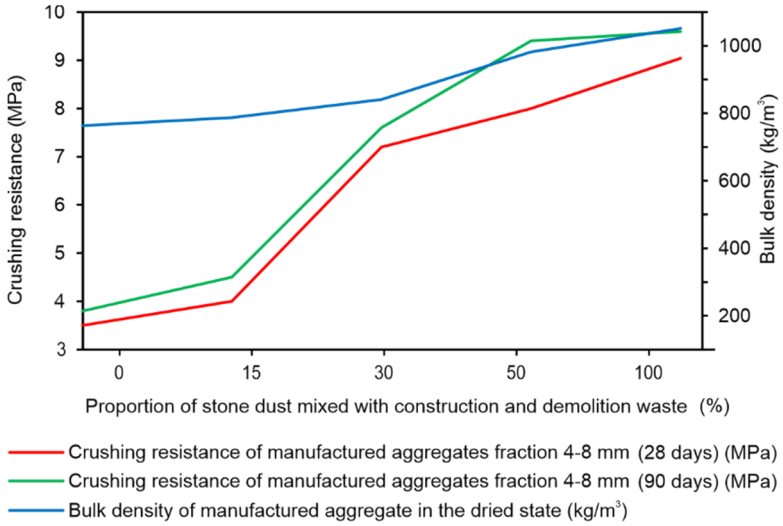

Fig. 6. Crushing resistance and bulk density of manufactured aggregates in the function of the proportion of CDWs and stone dust at the age of 28 and 90 days

4. CONCLUSIONS

The production of manufactured aggregates from construction and demolition wastes (CDWs), stone dust, or a combination of raw materials to produce concrete and the subsequent production of building materials and structures can bring construction companies significant economic savings. The production principles of manufactured aggregates and concrete meet the circular economy requirements in construction as they save non-renewable natural resources and do not represent any additional environmental and economic burden for our society. At the same time, these are new opportunities in the construction industry, the introduction of which brings profit and meets the conditions

for sustainable development in the construction industry. These wastes are available practically everywhere and can be a suitable substitute for natural stone in selected applications such as concretes of strength class at least up to C 20/25. The production of manufactured aggregate fraction 4–8 mm according to this solution is at the prices of liquidation of CDWs and stone dust in the localities of South Bohemia and Pilsen region the same and in some compositions even more advantageous than the price of natural aggregates, with advantages such as more favorable bulk densities of manufactured aggregates.

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