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Filter Medias from Recycled Concrete, Properties Investigated for Sorption Processes

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Abstract. Every year construction demolition waste amount increases. 75 percent of this waste consists of concrete, masonry products and tile products. Concrete and reinforced concrete waste can be recycled and reused for new concrete product production, road installation, as well as formed water treatment. Crushed concrete particles are characterized by large surface area and many voids. These particle characteristics depend on used crushing-granulating method. Particles obtained by the milling method have larger number of voids, higher water absorbance and higher number of open pores. Crushed concrete particles, of which high amounts are formed in building or waste recycling sites, can be used as filler for water treatment filters.

Keywords: concrete recycling, water treatment.

Conference topic: Water engineering.

Introduction

One of waste types that in the past years has formed enough or even excess amount is building and demolition waste. Building and demolition waste (SGA) usually forms during building, reconstruction, repairing or demolition. SGA amounts in different regions and countries vary. In some regions biggest amount of waste consists of timber waste, others – concrete waste. This depends on the past building traditions of those regions and natural resources of those countries. SGA composition can be varied and depends on demolished building type. If the demolition was of unfinished building structure, then the waste consists of concrete, metal, ceramics. If the demolition was of old building after moral and constructional wear without renovation and aren't further exploited, then such demolished building waste consists of concrete, ceramic bricks, roofing, timber, warmth isolation materials, metal, gypsum board and other various decoration materials. Building waste amount distribution according to (Finoženok *et al.* 2011) is shown in Figure 1.

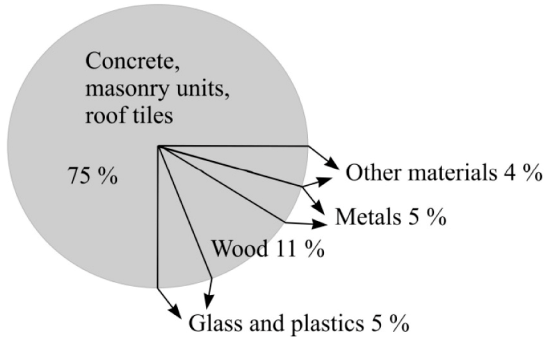

Fig. 1. Quantities of different types of waste materials in overall amount of construction waste

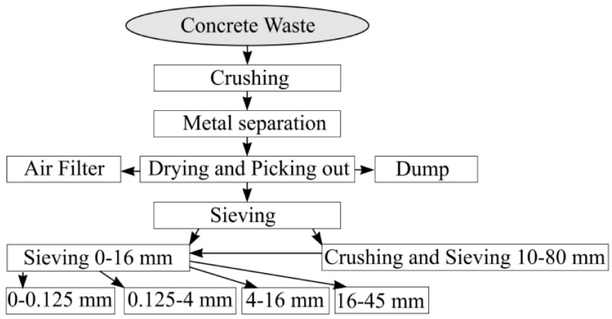

Fig. 2. Technological scheme showing the preparation of concrete break-stone of various fractions from the construction and demolition waste

Main rise of SGA in the world happens due to several reasons:

- there is a lot of building, which aren't fit for exploitation and they are reconstructed or demolished;
- buildings, even fit for exploitation (e.g. old factories, companies or other), lose their functionality, change their purpose, and in the end result they are demolished. In their place new, modern structures are built;
- building waste which appear by itself due to natural forces – earthquakes, storms or due to past wars.

SGA recycling usually happens by using special granulation and sorting equipment. Regardless of demolished building type and recycling method, SGA recycling main stages are the same: SGA initial preparation, crushing, recycling, metal, which armored reinforced concrete constructions, separation, first sieving, granulation, metal separation, sieving. While demolishing building usual equipment used is excavators, hydraulic crushing scissors, metal separation aggregates. After demolition work, waste is recycled using special granulation and sorting equipment. These processes usually involve crushers, granulators, magnetic separators, sieves and air separators which separate thermal insulation, wallpaper and other impurities from concrete pieces. Rubble from concrete waste principal technological production scheme is presented in Figure 2.

After thoroughly performing all production stages varying fraction large, small and micro fillers are obtained. Depending on size gotten fillers can be used for drive-way and road laying, forming paths and sidewalks. Also, small secondary concrete rubble can be used for water treatment and wastewater treatment, in new construction concreting foundation and using as filler in concrete production.

Methods and materials

In the work two types of concrete waste is used. First type crushed concrete waste was brought from building waste crushing site in Vilnius (M1), second type – gotten from milling Šiauliai viaduct concrete coating (M2). Building waste crushing site concrete constructions were crushed with a jaw crusher. After crushing concrete pieces were separated from metal and were brought to the laboratory. In the laboratory concrete pieces were dried, crushed with laboratory jaw crusher and sieved. Second type waste after milling with mill WIRTGEN were crushed to 0–70 mm size pieces. These concrete pieces were collected and brought to the laboratory where they were dried and sieved. In the word there were used concrete wastes which fraction was from 0.125 to 4 mm. In such a way two types of concrete waste were used for research: crushed with jaw crushed and crushed with mill. These two research material particle appearance differs in macro particle appearance shown in Figures 3 and 4.

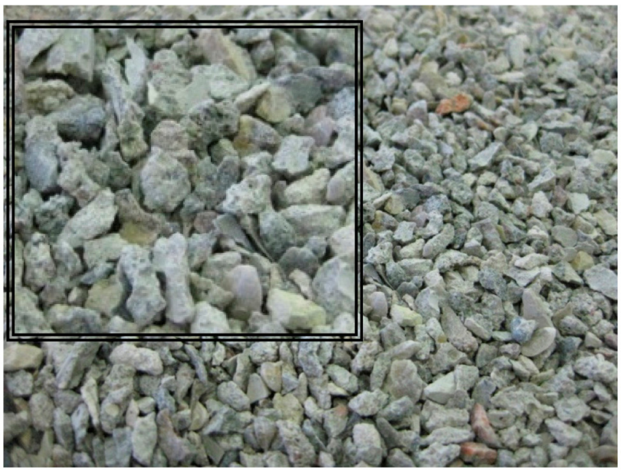

Fig. 3. Small filler from crushed concrete waste gotten through jaw crushing equipment (M1)

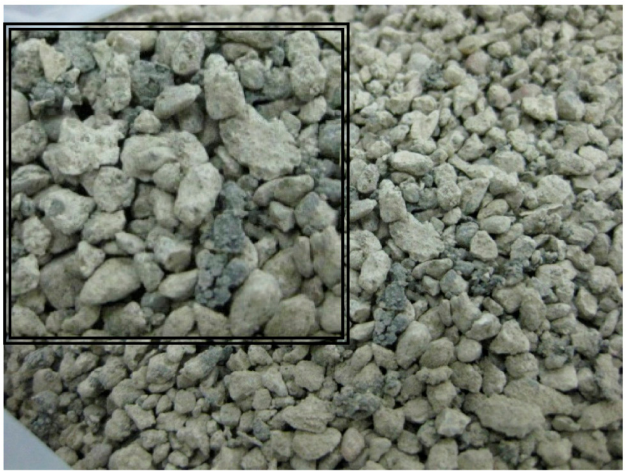

Fig. 4. Small fraction from crushed concrete (M2)

Crushed concrete large fraction piece consists of irregular form triangular or quadrangle pieces, in smaller piece fractions oblong and flat particle amount is bigger, however, it depends on the equipment used for crushing. After comparing Figure 3 and 4 it can be absorbed that less oblong particles has the smaller concrete filler gotten by milling concrete layer with milling equipment. Researching different fraction crushed concrete it can be observed that oblong and flat particle amount depends on fraction size and used concrete crushing equipment.

The granulometric composition was determined by employing standard methods described in LST EN 933-2, bulk density—according to LST EN 1097-3, and particles' density—according to LST EN 1097-6+AC. Comparative characteristics of the aggregates were taken from the standard LST 1974, currently being prepared by of Lithuanian Standards Board.

During the investigation the mineral composition of the filler aggregate was determined. X-ray analysis of the filler aggregate was implemented by using diffraction meter DRON-2 (Cu anode, Ni filter, monochromator, cracks with the size of 1:8:0.5 mm). Operation mode of the tube of diffractometer: U = 30 kV, I = 10 mA. The recorded diffractogram was decoded by comparing the obtained experimental values of multilayer distances d and specific integral intensity I/I0 values of the lines with the corresponding values in ASTM file.
Investigation of microstructure was carried out by employing SEM "Zeis" with SE detector.

Properties, which show particle interaction with water, were determined by soaking particles in water for a set amount of time and particle absorption was also determined by vacuum method according to special technique: particles were put in a nylon bag in which the pore size was smaller than 0.125 mm. While determining particle absorption these bags where put in 20 ºC water and soaked for a determined amount of time, after soaking, bags with particles were pulled out of the water and for 3 min were held on metal grill after excess water was absorbed with a wet cloth. Afterwards the bags with particles were weighted. Determining absorption with vacuum method (Fig. 5) bags with dry particles were put in the vacuum equipment. In tightly closed equipment vacuum was created. With such conditions they were held for 1 hour. After an hour the dish in the vacuum equipment which held the bags with particles was filled with 40 ºC water in a way that it would submerge all of the particles. After filling with water the vacuum equipment was turned on again and held in such a state for 1 hour. After this period the vacuum equipment was turned off and the air was let in the vacuum equipment. Bags with particles after being taken out of the vacuum equipment were put in 5 ºC temperature water and held for 19 h. After this period bags with particles were processed like after the soaking in water and weighted.

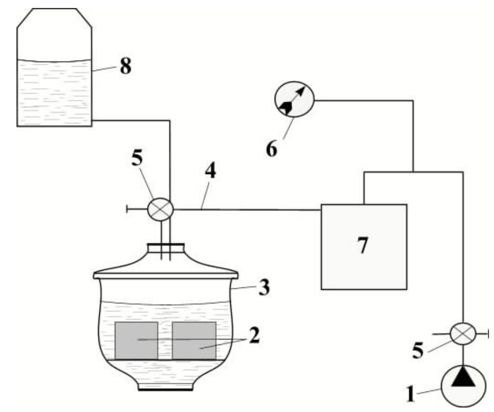

Fig. 5. Sample vacuuming device scheme: 1 – vacuum pump; 2 – bags with particles; 3 – vacuum desiccator; 4 – vacuum hose; 5 – vacuum crane; 6 – vacuum-meter; 7 – water steam absorber; 8 –water reservoir

Results and discusions

Both material granulometric compositions were determined. This composition is shown in Figures 6 and 7. M1 and M2 particle granulometric composition is similar, except that M2 mix has smaller particles which size is up to 0.25 mm. Higher small particle amount was obtained by processing concrete constructions with milling equipment.

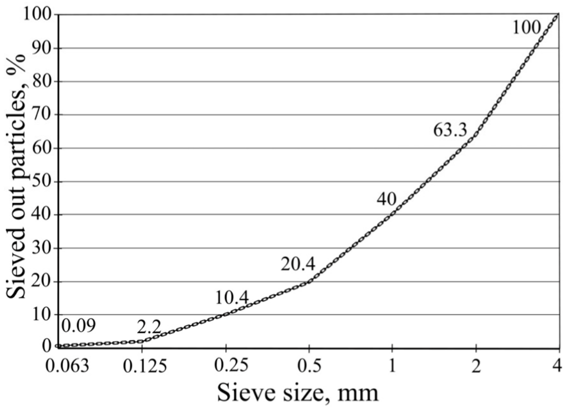

Fig. 6. Smaller fraction from crushed concrete granulometric composition (M1)

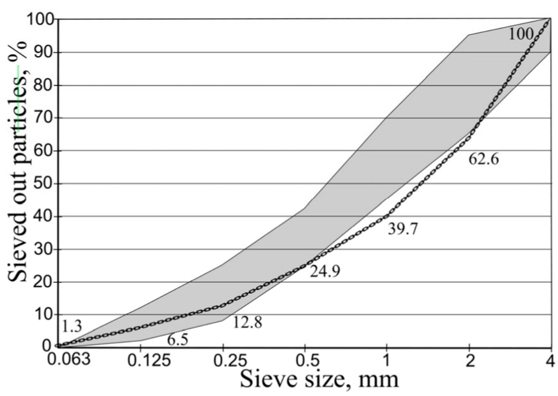

Fig. 7. Smaller fraction crushed concrete granulometric composition curve (M2)

In microstructural particle surface photo it is visible (Fig. 8) that particles have strongly developed surface, in their fracture surface different structure materials (former concrete composite parts) are visible: cement stone, small filler (sand) and large filler particles. Sand particles usually stay in the particle without cracking or fall out from crushed bit. Large filler particles in analyzed material stay only partly, their particles are crushed or cracked. In microstructural photo (Fig. 8) all mentioned particles and opened pores that were in cement stone are visible. All of this quite strongly raises crushed particle surface area which also raises number of fractures formed during concrete crushing.

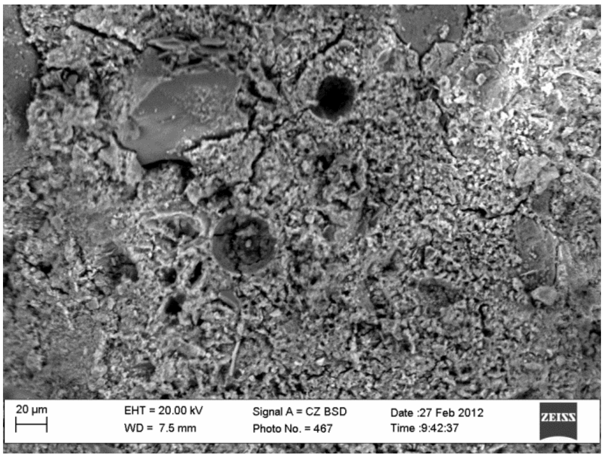

Fig. 8. Particle's fracture SEM surface image (500×)

After the X-ray analysis of the smaller filler implemented during the research, its mineral composition was determined. X-ray pattern is shown in Fig. 9. We can notice that the main minerals of this raw material are as follows: quartz Q, calcite K, dolomite D, feldspars F, portlandite P $Ca(OH)_2$ dominates as well, illite I. All these minerals are inherent to hydrated cement stone. Researched particles not only consist of hardened cement stone but also sand, large filler aggregate particle residue.

Crushed concrete particle electrical conductivity in water was determined. According to Fig. 10 it can be noticed that electrical conductivity in starting period rises to 2.8 µS/cm and afterwards decreases and after 80 min stays steadily fixed at 2.3 µS/cm.

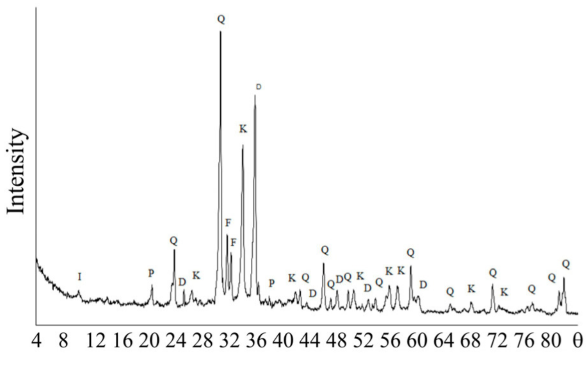

Fig. 9. X-ray pattern of fine aggregate: Q – quartz; K – calcite; D – dolomite; F – feldspars; P – Portlandite; I – illite

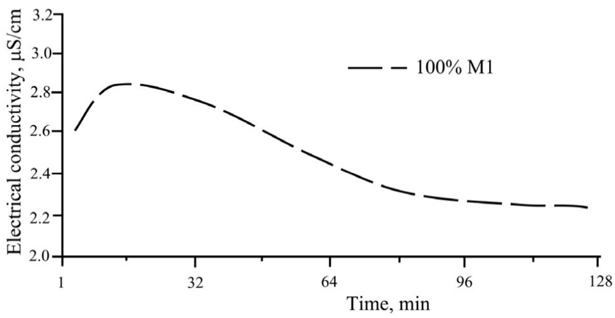

Fig. 10. Electrical conductivity of recycled concrete M1

In Table 1 particle mix density, bulk density and particle density are presented as well as calculated void. It can be observed that both mixes' (M1 and M2) bulk and particle densities are similar, calculated void also shows little difference. Comparing these characteristics with natural sand characteristics it can be examined that sand bulk density is higher as well as calculated void is smaller. The reason behind that is that sand particles have not so strongly developed surface, they have a more sleek form. Comparing sand's granulometric composition with crushed concrete particle granulometric composition it can be noticed that crushed concrete particle distribution is similar in a general sense when examining sand particle distribution boundaries (Fig. 7). Due to surface characteristics natural sand particles distribute more evenly in the mix and the gotten void is lower – only 35%.

Wanting for the particles to fill the foreseen area and that the void between them would be minimal it is necessary that every small particle would be four times smaller (d_2) than the one before it (d_1). That is well illustrated in conditional particle (spheres) filler scheme which is shown in Fig. 11. When chosen these inconsistent granulometric particles' density has to be filled to the maximum and the mix' void must be minimal. Crushed concrete particles are of irregular form, their granulometric composition is consistent and mutual void of these mixes is quite high, reaching even 48%.

Table 1. Characteristics of crushed concrete filter media and natural sand

Crushed concrete particles	Initial water absorption, %	Water absorption after 72 h, %	Water absorption after vacuum, %
Particles M1	3.5	8.9	10.3
Particles M2	4.1	9.8	11.4

Table 2. Characteristics of crushed concrete filetr media

Crushed concrete particles	Bulk density, g/cm³	Particle density, g/cm³	Void, %
Particles M1	1.24	2.33	45
Particles M2	1.21	2.31	48
Natural sand 0.125/4	1.63	2.43	35

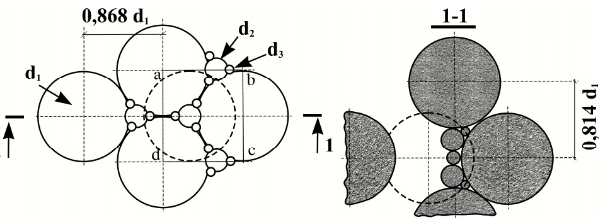

Fig. 11. Determined area filling with conditional ideal form particles

Particle mix characteristics shown in Table 2 are related with influence of water, that's initial water absorption, which is determined after 7 min, water absorption after 3 day soaking and absorption determined by samples being additionally vacuuming according to the described method. It can be observed that the particle water absorption is average and it reaches about 9–10%. This size is two-three times bigger than that of natural fillers – gravel or sand, since during the crushing closed pores were opened which were prevailing in cement stone. Other researchers present similar characteristics of crushed concrete waste itself.

Researchers (Gonzalez-Fonteboa, Martinez-Abella 2008) have determined that the density of 0–5 mm fraction size fine aggregate (produced from the concrete and demolition waste) is 2.13 g/cm³, water absorption 9.3%. Other scientists (Kou, Poon 2009) have identified that the density of the aggregate, which particles' size is smaller than 5 mm, is 2.3 g/cm³, and water absorption is 11.9%. The density of the fine aggregate (produced from the concrete waste) used in other research (Chan, Poon 2006) was 2.31 g/cm³, and water absorption was 10.3%.

After the analysis of aggregates' properties determined by various scientists, it can be stated that the water absorption of the aggregates produced from concrete waste is larger than the one of natural aggregates. This increase of water demand can be explained by considering that the structure of the aggregate produced from waste is open-porous, the aggregate has a net of created capillaries, which rapidly absorb water. In addition to this, cement stone's structure, which was opened during the crushing, has larger water absorption, comparing to the natural rock aggregates.

In Table 2 the presented absorption after sample vacuuming according to special method shows what amount of open pores and voids are left in particles after their long-term absorption experiment. This method helps to determine what amount of open pore amount is in the particles, their pores and capillaries fill with water gradually as particles soak for a longer time period (a month or two). Other pores and capillaries are closed and water doesn't soak into them.

Conclusions

Crushed concrete particles of 0.125-4 mm size can be obtained by demolishing old buildings or disassembling unused concrete structures. Concrete waste in construction can make up to 75% from overall waste amount. Concrete can be crushed with jaw crushers or granulated by milling surfaces.

Crushed concrete particle surface area is large; on them obviously stands out during hydration formed cement stone minerals, also are visible sand and crushed large filler aggregate pieces. According to X-ray mapping composition it can be observed that quartz and calcite prevails from partially mechanically demolished quartz hydro-silicate minerals and sand particles.

Due to the determined particle characteristics in the work (bulk density, particle density, void) it can be observed that crushed concrete filler filters should have bigger flow loosing characteristics, bigger surface area and this filler amount loading into filters or equipment should be lower than natural sand.

Crushed concrete filler water absorption is considerable bigger than that of natural sand (or other high density sedimentary rock) due to high surface area and open pores as well as voids formed during the crushing. These materials also have a 1–2% pores and voids into which water enters only through adjoin capillaries and such pores fill with water only through a long time period.

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References

Chan, D.; Poon, C. S. 2006. Using recycled construction waste as aggregates for paving blocks, in *Proceedings of the Institution of Civil Engineers, Waste and Resource Management* 195: 83–91. https://doi.org/10.1680/warm.2006.159.2.83

Finoženok, O.; Žurauskienė, R.; Žurauskas, R. 2011. Influence of various size crushed concrete waste aggregates on characteristics of hardened concrete, *in The 3rd International Conference "Civil Engineering'11",* 12–13 May, 2011, Jelgava, Latvia: 7–13.

Gonzalez-Fonteboa, B.; Martinez-Abella, F. 2008. Concretes with aggregates from demolition waste and silica fume. Materials and mechanical properties, *Journal of Building and Environment* 43: 429–437. https://doi.org/10.1016/j.buildenv.2007.01.008

Kou, S. C.; Poon, C. S. 2009. Properties of self-compacting concrete prepared with coarse and fine recycled concrete aggregates, *Journal Cement & Concrete Composites* 31(9): 622–627. https://doi.org/10.1016/j.cemconcomp.2009.06.005

LST EN 933-2:2001 Tests for Geometrical Properties of Aggregates–Part 2: Determination of Particle Size Distribution–Test Sieves, Nominal Size of Apertures. Lithuanian Standards Board, Vilnius, 5.

LST EN 1097-3:2002 Tests for Mechanical and Physical Properties of Aggregates–Part 3: Determination of Loose Bulk Density and Voids. Lithuanian Standards Board, Vilnius, 14.

LST EN 1097-6+AC:2013 Tests for Mechanical and Physical Properties of Aggregates–Part 6: Determination of Particle Density and Water Absorption. Lithuanian Standards Board, Vilnius, 26.

LST 1974:2012 Application rules of LST EN 206-1 Concrete. Part 1: Specification, performance, production and conformity. Lithuanian Standards Board, Vilnius, 15.