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Lightweight Masonry Block made from Recycled Concrete

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Abstract. This work deals with design of lightweight blocks to be used as a building material for production of both non- and load bearing walls in the field of civil engineering. These blocks were based on foam concrete, containing high amount of recycled concrete at the form of high-speed ground powder. Two mixtures were designed, differed mainly in amount of used foaming additive. While in the first case, heat insulating parameters were preferred, in the second case, it was focused on mechanical properties. Prismatic samples (40×40×160 mm) were made from mixtures and then subjected to mechanical and thermo-physical testing in order to reveal their basic properties. It was shown that compressive strength of mixtures were equal to ca. 1.7 and 19.0 MPa in the case of mixtures containing high and low amount of foaming additive, respectively. Thermal conductivity was ca. 0.16 and more than 0.5 W/mK, in the same order of mixtures.

Introduction

Recycling of waste is a widely discussed topic throughout the European Union. It is obvious, that the problem of waste management strongly influences also the civil engineering. On territory of the Czech Republic, there has been produced more than 18 million tons of construction and demolition waste (C&DW) in the year of 2017. During the past decade, amount of C&DW has exceeded ca. 160 million tons in total sum; whence ca. 25 % belongs to concrete waste originated from building demolitions [1, 2]. It is worth noting that up to 50 million tons of concrete buildings are demolished in the EU per year [3]. Due to Waste Management Plan of the Czech Republic for the period 2015–2024 aiming to landfill restrictions and waste recycling acceleration [4], it is justified to find out new ways how to re-use waste concrete.

It is generally known, that recycling of concrete has been focused especially on re-use of aggregate recently. Unfortunately, a utilization of fine fractions at the form of concrete dust (containing binder and the smallest parts of aggregate) has stayed unused [5], although this material exhibits promising properties like residual binding potential of unhydrated cement grains and an ability to fill micro pores through the new concrete mixtures [6]. Moreover, in cases of autoclaved or foam lightweight materials, dust can replace conventional micro-aggregates due to similar size parameters [7]. Therefore, there is no obstacle to use waste concrete dust as so-called active micro-aggregate for the production of lightweight masonry blocks.

We made lightweight masonry blocks containing ca. 25 wt. % of recycled concrete powder that was obtained using high-speed milling. These were subjected to experiments revealing their properties from the mechanical and thermo-physical point of view.

Materials and Methods

Foam concrete composition. Two mixtures were designed, differed mainly in amount of used foaming additive. The first was determined for fabrication of masonry blocks to be used for the production of perimeter walls, where heat insulation properties plays an important role. The second mixture was designed for blocks for load-bearing walls, where mechanical parameters are the key properties. Both of them were composed from Portland cement, concrete powder, water and foaming additive Mapei. Concrete powder was obtained from structural elements of demolished building in Prague. These elements were roughly crushed by using crushing machine equipped with hydraulic jaws. After separation of steel bars, thus crushed material was finely ground using patented technology of high speed milling in company Lavaris, Ltd. (Czech Republic). Powder was composed from grains of size differed between 0.25–250 μm, as found out by granulometry. Specific surface of grains was equal to 412 m^2/kg, as measured according to Blain's method. The grain curve is shown in the Fig. 1. Prismatic samples (40×40×160 mm) from these mixtures were made and after their hardening (lasting standard 28 days) subjected to experimental tests. The whole composition of both mixtures is summarized in the Table 1.

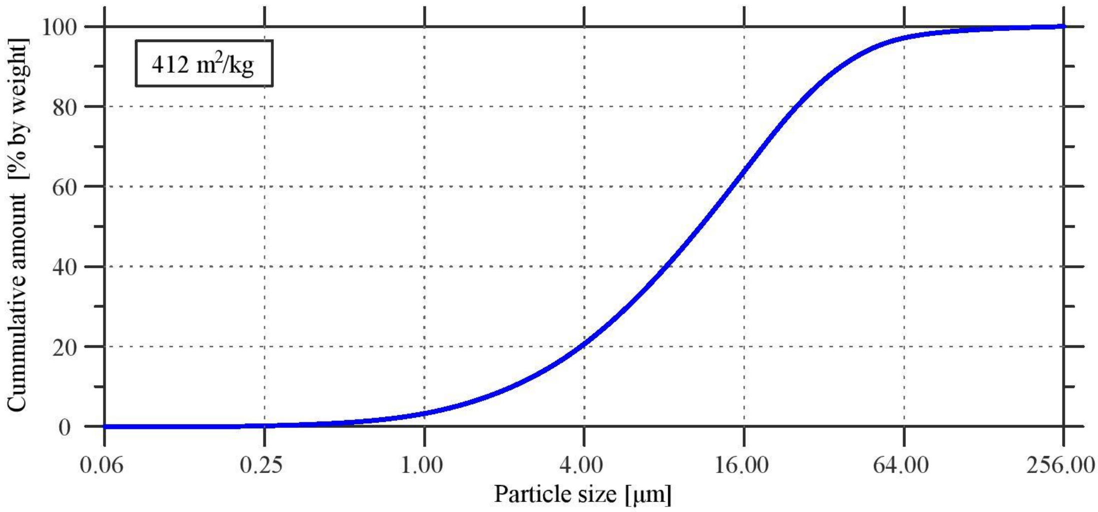

Fig.1 Grain curve of finely ground recycled concrete

Tab.1 Weight-proportional composition of tested mixtures

Mixture	CEM I 42.5 R [wt. %]	Concrete Powder	Water	Mapei Additive
M1	46.3	24.9	28.5	0.4
M2	48.1	25.9	25.9	0.2

Experimental techniques

Mechanical tests. In order to reveal pressure strength of both hardened mixtures, compression destructive test was done using loading frame Web Tiv Ravestein FP100. The experiment was displacement controlled at the constant rate of 1 mm per minute. The loading force was introduced to samples through the steel plate of dimensions equal to 40×40 mm. To obtain statistically relevant data, the measurement was repeated 6-times, then results were averaged.

Dynamic modulus of elasticity was measured by means of indirect non-destructive method. For this purpose, measuring station Brüel & Kjær (3560–B–120) was employed, equipped with piezoelectric acceleration sensor and impact hammer (both system device). The measurements was repeated 5-times on each sample, results were averaged. The process was done according to procedure described in [8].

Thermo-physical tests. Basic thermo-physical properties of samples, such as thermal conductivity and heat capacity, were measured by Isomet (model 2104, Applied Precision). The device was equipped with removable contact probe. The measurement was repeated 3-times, results were averaged. Before this experiment, all of samples were weighed and then measured to calculate their density.

Results and Discussion

Mechanical tests. It was found out from compression tests that compressive strength of M1 and M2 mixture was equal to 1.69±0.67 MPa and 18.95±2.00 MPa, respectively. It is clear that the strength of M1 does not allow blocks to be used for production of highly loaded walls. However, this strength is almost comparable to e.g. commercial aerated concrete blocks. On the other side, mixture M2 exhibited promising compressive strength, similar to lower class of plain concrete.

Modulus of elasticity measurement revealed that samples made from the mixture M1 reached to 2.8±0.8 GPa, which is according to our expectations significantly lower than in the case of samples made from M2. Those exhibited 8.9±0.4 GPa. Both of the two values overcome common aerated concretes.

Thermo-physical tests. Density of samples was 900±35 and 1390±10 kg/m^3 in the case of mixture M1 and M2 respectively. These results explained differences of mechanical parameters between the two mixtures and it is clear that they were caused by using of different amount of Mapei foaming additive (0.4 for M1 vs. 0.2 wt. % for M2).

Thermal conductivity of M1 and M2 samples was equal to 0.160±0.03, resp. 0.527±0.01 W/mK. Based on these findings, it was confirmed that masonry blocks made from M1 mixture can be used for production of perimeter walls of building because of their favorable insulation properties. The heat capacity was ca. 770, resp. 1137 J/kgK, in the same order as mentioned earlier. All of the findings obtained within this study are summarized in Table 2.

Tab.2 Summarization of tested samples basic properties

Mixture	ρ [kg/m^3]	E [GPa]	R [MPa]	λ [W/mK]	c [J/kgK]
M1	900±35	2.8±0.8	1.69±0,67	0.160±0.03	738.0–797.7
M2	1390±10	8.9±0.4	18.95±2.00	0.527±0.01	1128.6–1144.9

Conclusions

This work was focused on design of mixtures used for production of masonry blocks based on light-weighed concrete. It was targeted to use high amount of recycled concrete at the form of finely ground powder. Two mixtures were prepared, differed in amount of used foaming additive (0.4 vs. 0.2 wt. %). The first one was determined for production of masonry blocks to be used for masonry of perimeter walls, where thermal insulation properties play an important role. The second one was designed for production of blocks intended for load-bearing walls. In this case, compressive strength of them was considered as the key parameter.

Amount of used recycled concrete powder was ca. 25 wt. %. It was used as active micro aggregate. This material was obtained from structural element of demolished building in Prague. This waste concrete was roughly crushed using crushing machine equipped with hydraulic jaws. The brush was subsequently milled by means of technology of high speed milling to powder with grains of size differed between 0.25–250 µm.

It was shown that mixture designed for perimeter walls reached to comparable properties to frequently used aerated concrete in terms of heat insulation parameters (thermal conductivity ca. 0.16 W/mK) and compressive strength (ca. 1.7 MPa). On the other side, mixture intended for load-bearing blocks exhibited favorable mechanical strength properties. Their modulus of elasticity was almost 9.0 GPa, while the compressive strength was equal to ca. 18–19 MPa.

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