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POSSIBILITIES TO REUSE A CERAMIC WASTE AS CONCRETE AGGREGATES

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Every year, huge amounts of natural resources are used to produce concrete. Sand and gravel resources are rapidly draining, therefore, it is necessary to reduce consumption. On the other hand, there are a lot of construction waste which can be reused in concrete production. One of possibilities is to use in concrete production ceramic waste. During the research the coarse aggregates were changed to ceramic bricks waste. The changes of fresh concrete workability, density, hardened concrete compression strength, water absorption and frost resistance were evaluated. The results show that ceramic waste has a negative effect to all concrete properties. Ceramic bricks waste should be used to replace coarse aggregate in a lower ratio, such as the possible option of replacing 10 % of coarse aggregates. The stoneware tiles waste show better results (Skominas et al., 2020). This waste can be used replacing up to 60 % concrete coarse aggregates. According to all results can be concluded that stoneware tiles waste is better choice for coarse aggregates production.

Keywords: concrete, aggregates, ceramic waste, workability, compression strength, water absorption, frost resistance.

INTRODUCTION

Ceramic products are one of the main building materials. Common types of ceramics include bricks, blocks, floor tiles, roof tiles, wall tiles, sanitary, household and technical ceramics. Ceramics are mostly produced using natural materials that contain high content of clay minerals. However, despite the ornamental benefits of ceramics, its wastes among others cause a lot of nuisance to the environment (Awoyera et al., 2018). The main sources of the ceramic waste are originated from the wastes of ceramic industry, leftover of the newly constructed buildings and demolition of old buildings (Bektas et al., 2009).

One of the ways to reuse ceramic waste is production of coarse aggregates for concrete. Last decade there are some researches made in this field. F. Debieb and S. Kenai (2008) find out that ceramic brick waste as a coarse aggregates have relatively lower bulk density and higher water absorption compared to natural aggregates and these aggregates reduced concrete density by 17 % and concrete compression strength by 35 %. The scientists from Poland used sanitary ceramic waste and estimated that compressive strength of concrete with ceramic aggregate decreased by 46% (Halicka et al., 2013). In other research (Nepomuceno et al., 2018) scientists replaced 75 % of natural coarse aggregates with industrial brick waste and also got reduced compression strength but this time only by 11 %. Z. Keshavarz and D. Mostofinejad in their research (2019) got an opposite results: porcelain waste was found to increase concrete compressive strength by up to 41% while red ceramic waste increased it by 29% replacing all gravel. The scientists from Covenant University (Nigeria) and Tshwane University of Technology (South Africa) stated that concrete made with ceramic waste aggregates as a replacement for part of the natural aggregates can be considered a suitable alternative for normal concrete (Awoyera et al., 2018). Utilizing ceramic waste material as coarse aggregate in concrete several economic, environmental and technical advantages can be achieved (Elci, 2016; Meng et al., 2018; Rashid et al., 2017).

Some scientific works have different results and recommendations what is an optimal ceramic waste amount can be used in concrete production. Therefore, the aim of the research is to estimate the optimal ceramic waste used as coarse aggregates amount for concrete.

MATERIALS AND TEST METHODS

To evaluate the impact of ceramic waste on concrete properties, the coarse aggregates partly were changed to crushed ceramic bricks (fraction 4/16 mm). For concrete production were used cement CEM II/A-L 42,5 N, crushed granite (fraction 4/16 mm) and sand (fraction 0/4 mm). The water-cement ratio of concrete was selected W/C=0.5. Aggregates and water meet the requirements described in European standards EN 12620:2002+A1:2008 and EN 1008:2002.

The density and workability of concrete mixture was estimated according to standard methods described in European standards EN 12350-6:2019, EN 12350-2:2019.The compression strength and water absorption of hardened concrete were established according to standard methods (EN 12390-3:2019, EN 13369:2018). The size of tested concrete specimens was 100×100×100 mm with the age of 28 days. Test of fresh and hardened concrete were applied to control concrete and concrete with partly changed coarse aggregates to ceramic bricks waste. The coarse aggregate changing amount was 10, 20, 40, 60, 80 and 100 %.

The impact of ceramic bricks waste on frost resistance was estimated too. Frost resistance was calculated according to compression strength and water absorption of concrete using empirical formulas. All calculation methodology presented in K. A. Vaišvila Č. Ramonas F. Mikuckis, and V. Gurskis article (2004).

TEST RESULTS

Mixing the concrete with different amount of ceramic bricks waste firstly mixture was tested for consistency and density. The results are presented in Table 1. According to results it is possible to state that ceramic bricks waste had a negative effect on fresh concrete density. Changing all coarse aggregates to bricks waste the fresh concrete density decreased by 14 %. The main reason of density decrease is difference of materials used for coarse aggregates density. The density of granite ~ 2700 kg/m^3 and the density of ceramic (bricks) ~ 1700 kg/m^3. Comparing the density results with the density results of concrete of the same composition only using stoneware tiles waste (Skominas et al., 2020), the stoneware tiles waste decreased concrete mixture density less than using bricks waste.

Table 1. Fresh concrete results

Amount of coarse aggregates changed to ceramic waste, %	Bricks waste			Stoneware tiles waste (Skominas et al., 2020)		
	Fresh concrete density, kg/m^3	Slump, mm	Class	Fresh concrete density, kg/m^3	Slump, mm	Class
0	2455	140	S3	2455	140	S3
10	2413	100	S3	2420	160	S4
20	2373	70	S2	2382	170	S4
40	2305	50	S2	2347	170	S4
60	2254	40	S1	2307	140	S3
80	2182	20	S1	2271	90	S2
100	2119	10	S1	2232	80	S2

Increasing amount of bricks waste in concrete had negative effect on concrete mixture consistency too (Table 1). The control concrete mixture without ceramic waste suited S3 slump class (medium workability). Increasing ceramic waste turned concrete mixture with 100 % ceramic bricks waste suiting to S1 class (very low workability). The decrease of workability can be explained by the higher water absorption of ceramic bricks waste (7.1 %) compared to granite aggregates (0.45 %). The ceramic bricks waste take water from concrete mixture ant it become dryer and less plastic. In this consistency concrete is not suitable for reinforced concrete structures. In this case, to make more workable concrete it is necessary to change a composition of concrete (to use superplasticizers admixture or increase amount of cement and water). Comparing the consistency results with the results of concrete using stoneware tiles waste (Skominas et al., 2020) it is possible to state that concrete with stoneware tiles waste had better workability. The consistency class decreased to S2 only changing 80 and 100 % coarse aggregates to waste.

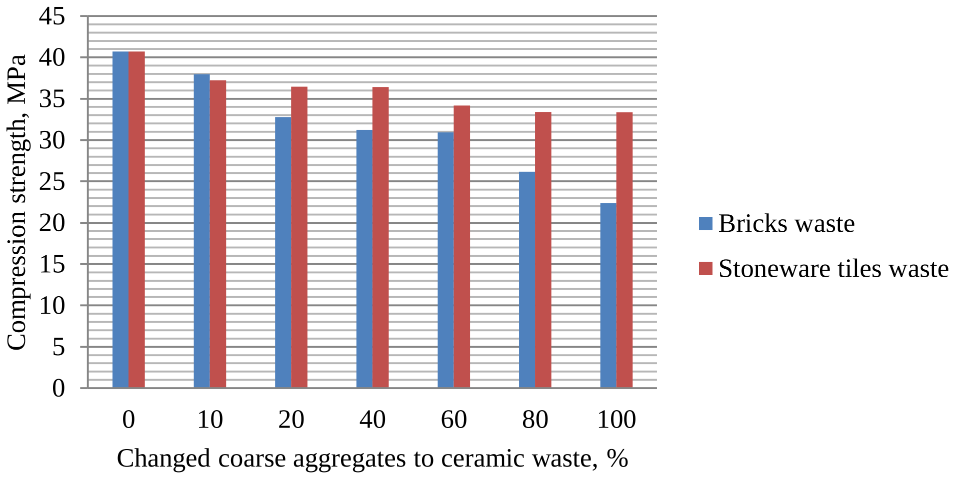
According to compression strength test results (Table 2, Fig. 1) can be stated that increasing ceramic bricks waste amount in concrete have a negative effect. For example, changing 100 % of coarse aggregates to bricks waste the strength loss will be about 45 %. In this case, the concrete strength class will go from C30/37 to C12/15. Strength loss can be explained that ceramic strength is lower than granite and density loss of concrete. However, small amount of ceramic bricks waste is not so dangerous – the strength loss of concrete with 20 % bricks waste will be up to 20 %. Comparing the influence of different ceramic waste on concrete strength it was estimated that cut stoneware tiles waste show better results (Skominas eta al., 2020). In almost all cases, the concrete class was reduced to C25/30, and when the coarse aggregates in the mix were changed by 80 and 100 % with stoneware tiles waste, the concrete class was reduced to C20/25. Here the strength loss can be explained by several aspects: the density of concrete with a higher amount of stoneware tiles waste is lower and more porous; tile waste particle does not adhere so well to cement paste due to its shape (two planes have smooth surfaces).

The increasing amount of bricks waste in concrete had a negative effect on water absorption (Fig. 2). The increasing amount of waste in concrete increases the water absorption from 5.6 to 9 %. The higher water absorption than 7 % is dangerous for outside structures which have a contact with water during the winter time. Therefore, the concrete with 40 % and higher amount of bricks waste is not suitable for these types of structures. Comparing results with the results (Skominas eta al., 2020) of concrete with other ceramic waste (stoneware tiles) it is possible to conclude that stoneware tiles waste are more suitable for concrete production. The concrete with this type of waste not reached 7 %

limit. The difference of water absorption can be explained by the higher water absorption of ceramic bricks waste (7.1 %) compared to stoneware tiles waste (0.41 %).

Table 2. Compression strength test results (Results of concrete with stoneware tiles waste taken from article (Skominas et al., 2020)

Amount of coarse aggregates changed to ceramic waste, %	**Ceramic type**	**Compression strength, MPa**	**Class**	**Strength loss, %**
0	none	40.72	C30/37	-
10	Bricks	37.97	C25/30	6,75
	Stoneware tiles	37.24	C25/30	8,55
20	Bricks	32.78	C20/25	19,50
	Stoneware tiles	36.46	C25/30	10,46
40	Bricks	31.25	C20/25	23,26
	Stoneware tiles	36.41	C25/30	10,58
60	Bricks	30.94	C20/25	24,02
	Stoneware tiles	34.17	C25/30	16,09
80	Bricks	26.18	C16/20	35,71
	Stoneware tiles	33.41	C20/25	17,95
100	Bricks	22.38	C12/15	45,04
	Stoneware tiles	33.36	C20/25	18,07



Figute 1. Ceramic waste impact on concrete strength

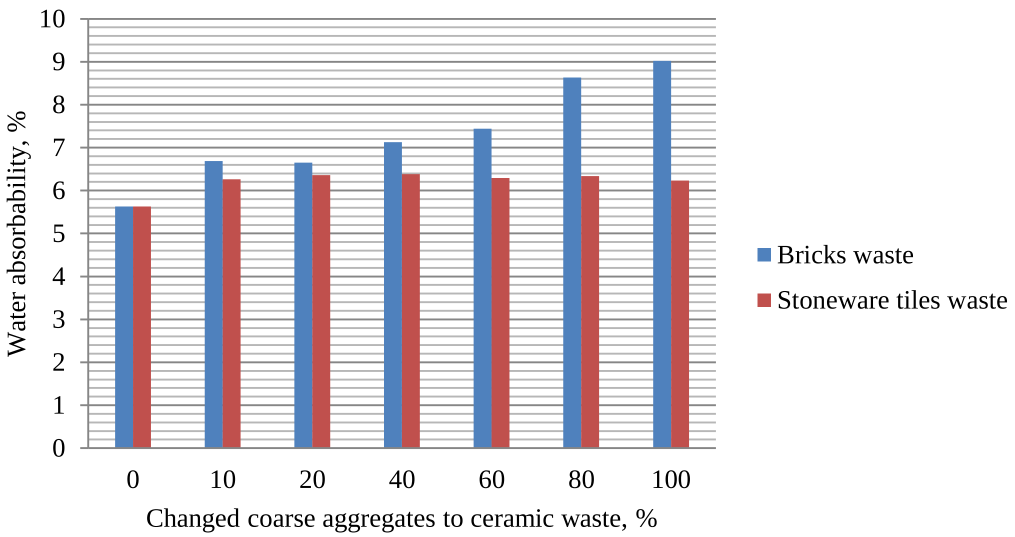


Figure 2. Ceramic waste impact on water absorption

According to frost resistance calculation results (Fig. 3) the ceramic bricks waste decrease the longevity of concrete. The frost resistance mark decreased from F150 to F100 changing up to 60 % of coarse aggregates to bricks waste. When 80 and 100 % of coarse aggregates were changed to ceramic bricks waste, the frost resistance decreased dramatically and passes only F50 mark. Meanwhile the stoneware tiles waste show better results (Skominas et al., 2020), here in all cases frost resistance decreased to F100. The frost resistance relates with compression strength and water absorption. Therefore, decreasing compression strength and increasing water absorption impacted changes on frost resistance.

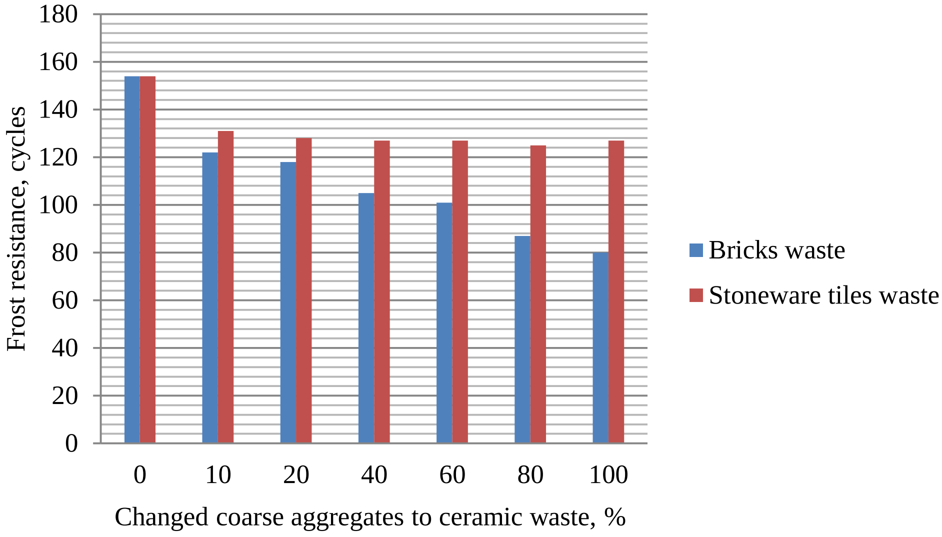


Figure 3. Ceramic waste impact on frost resistance

Generalizing all results can be stated that ceramic waste has a negative effect to all concrete properties. Ceramic bricks waste should be used to replace coarse aggregate in a lower ratio, such as the possible option of replacing 10 % of coarse aggregates, as the concrete class decreased in only one position. The stoneware tiles waste can be used replacing up to 60 % concrete coarse aggregates. In this case, concrete class decreases by one position. According to all results can be concluded that stoneware tiles waste is better choice for coarse aggregates production.

CONCLUSIONS

Ceramic bricks waste had a negative effect on all concrete properties. At the maximum bricks waste amount (replacing 100% of the coarse aggregates), the compressive strength decreased by 45 %, frost resistance by 48 % and water absorption increased by 60 %. Taking into account all the obtained results, it is recommended to change up to 10 % of coarse aggregates into bricks waste, as the concrete compressive strength class was reduced only by one position.

Comparing ceramic bricks waste with stoneware tiles waste the concrete with stoneware tiles waste show better results and it is recommended to change up to 60 % of coarse aggregates into stoneware tiles waste. Till this amount concrete compressive strength class was reduced by one position (from C30/37 to C25/30).

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