OVERVIEW OF THE PREVIOUS STUDIES ABOUT WASTE GLASS UTILIZATION IN CERAMIC BRICKS AND TILES

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Abstract
Paper presents a literature review relating to the potential waste glass collection and processing as glass cullet (crushed waste glass) for its use as raw material in brick and ceramic tile production. The analysis and evaluation of the vast amount of experimental research showed that glass cullet is a potentially valuable resource for the manufacture of ceramic products, such as clay fired bricks and tiles, where it can be used as substitute for expensive natural resources, improving the physical, mechanical and environmental performance of ceramic products.

Introduction

Production of ceramic – clay products, especially brickyard production, is a significant production of basic construction materials required in all spheres of constructional activities. Bricks are bonded together with mortar to yield a composite building component generally a wall. Concrete block and brick are the most common types of brickyards production. These construction materials are extensively employed worldwide both in developed and developing countries.

Construction ceramic – clay materials are very important materials for building and for them the need is constantly growing. In this respect, for the development of ceramic products with waste materials, further research and development is necessary, not only on the technical, economic and environmental features, but also public education related to waste reusing and sustainable development is required for wide production and application of ceramic product with waste materials. Clay materials are mostly used for the manufacture of bricks and ceramic tiles and waste can be added in order to enhance theirs properties [1]. Solid waste is a great concern among governmental agencies, and environmentalist regarding the increasing amount of waste throughout the world [2].
One waste material which has potential as a ceramic product's additive is waste glass [3]. Waste glass is not biodegradable and because of that creates a problem for solid waste disposal [4]. The disposal into landfills, also, does not provide an environment – friendly solution [5]. For example, waste glass in construction materials can be a worthy solution to the environmental problem caused by this solid waste [2]. United Nations estimates that the volume of annually solid waste amount which is disposed of over the world would be 200 million tons, and 7% of that is made up of glass [6].
Ceramic – clay materials, which are manufactured at high temperatures into non-metallic and inorganic solid products, are used in several fields of engineering, due to their specific properties. As a result of the wide range of existing ceramic applications and the manufacturing process involving high temperatures, ceramic products are ideal candidates for the incorporation of waste glass as glass cullet (crushed glass) a substitute of natural resources [1].
The main objective of this paper is to focus on the analysis and on the evaluation of the experimental research which are showed that glass cullet is a potentially valuable resource for

the manufacture of ceramic products, where it can be used as substitute for natural resources, and also improving physical, mechanical and environmental ceramic product performances.

Methodology

In the period since 2002, more recent research has been carried out around the world that have studied and summarized how to use waste glass as a potential resource in the production of ceramic products in order to improve the product's properties. The use of waste glass in various mass percentages in a mixture with clay is shown in order to prepare high quality ceramic products.

The first step in preparing the review of previous studies of using waste glass in ceramic products was collection of an initial list of publications, based on various factors, like: type of waste glass as substitute; particle size of glass cullet; application in which it was used and available data adequate for statistical analysis which are showed on Figure 1.

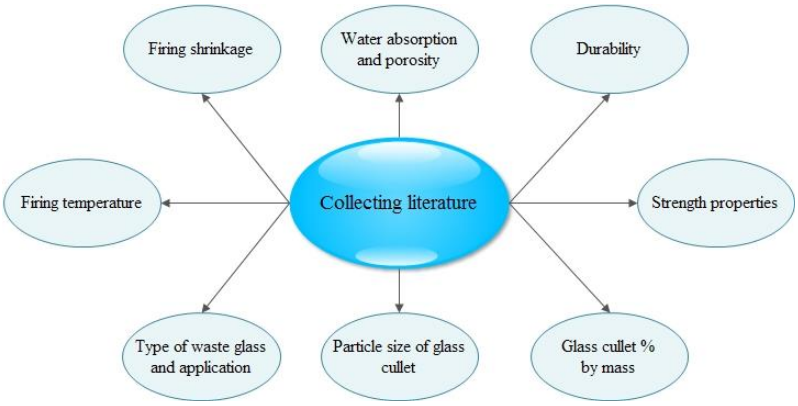

Figure 1. Evaluation of various factors for using waste glass in ceramic – clay products

On the basis of examination and selection of certain literature, the second step in the paper research involved the separation of the basic properties of ceramic products with glass cullet and their analysis, according to the type of waste glass and application, particle size of glass cullet and its mass percentage. It is investigate the effect of the addition of waste glass on the properties of the fired ceramic products. Considered properties of ceramic products with a certain mass percentage of glass cullet are:

1. Firing shrinkage;
2. Firing temperature;
3. Strength properties;
4. Water absorption and porosity;
5. Durability.

Recently, reviewing collected literature, several researches around the world have been carried out summarizing the use of waste glass as additives for ceramic tile and fired clay bricks to enhance its properties. The waste glass can be mixed with clay in different proportions to prepare high quality ceramic product. The addition of waste glass to ceramic product specimen range from 0.5 to 94% by mass, most studied tended to concentrate on range between 5% and 20% of glass by mass, with the glass particle size ranging from 45 to 600 μm.

Results and discussion

During the literature review, it was observed that different types of glass were used as a resource in the production of ceramic – clay products which summarized within Table 1.

Table 1. Different types of waste glass used as a resource in the production of ceramic – clay products (fired clay bricks, tiles and stoneware) by literature review

Type of waste glass	Application	Literature
Ground waste glass	Fired clay bricks	[7]; [3]; [8].
Waste glass from structural glass walls	Fired clay bricks	[9].
Container glass cullet	Fired clay bricks	[10]; [11].
Used waste broken bottles	Ceramic tiles	[12].
Non – recycled waste glass additives	Fired clay bricks	[13].
Funnel and panel glass of TV and PC waste glass	Clay bricks and roof tiles	[14].
Wastes glass from thin film transistor – liquid crystal display (TFT-LCD) optical waste glass (TVs and computers)	Eco – brick	[15].
TV/PC cathodic tube and screen glass	Typical porcelain stoneware body	[16].

Authors of literature number [17] concluded that there was no major difference between window glass and post-consumer glass being utilized in clay products, and other types of glass addition to ceramic products has also contributed to enhance their properties.

Discussion of the results of testing the propreties of ceramic product with a waste glass mass fraction obtained in the considered research framework are presented in Table 2.

Results of the strength properties of specimens containing waste glass in previous studies were determined by both compressive strength and modulus of rupture testing. The range of compressive strength values varied between specimens, which may be attributed to slight variations in particle size, specimen size, and firing temperature for each testing method.

Results reported for examples of rupture demonstrate an increase in modulus of rupture with increased percentage of glass by mass ([11], [12], [14], [15], [16], [18], [19]). In the literature [18] was studied the influence of particle size, plasticity and pressing pressure on the properties of a ceramic products containing 90% by mass of recycled waste glass. The result shown that a progressive increase in the proportion of fines in the sample results in a progressive increase in the degree of sintering, as reflected in increased strength.

Table 2. Propreties of ceramic bricks and tiles through the considered literature

Propreties of ceramic products with waste glass	Description	Literature
Shrinkage	Shrinkage was found to increase as percentage glass by mass increased, as well as with increased firing temperature.	[3]; [9]; [11]; [12]; [13]; [15]; [16]; [17]; [19].
	The finer glass, particle size of 5 µm, exhibited twice the shrinkage of the coarse glass, particle size of 150 µm, in compositions.	[17].
Firing temperature	The use of 10 % by mass of waste glass and firing at 900ºC yielded bricks with similar strength compared to that of normal clay brick fired at 1000°C.	[8].
Strength properties	Results indicates an increase in compressive strength with increased addition of waste glass, especially between 10% and 30% by mass.	[3], [7], [8], [9], [10], [13], [15], [18].
	The amorphous phase of waste glass particles enhances the sintering action, which leads to achieving a better strength in bricks.	[3].
	Rapid increase in compression strength in samples containing glass powder with particle size of 140 – 315 µm.	[10],.
Water absorption and porosity	Decrease as percentage glass by mass increased, as well as with increased firing temperature.	[3], [7], [8], [9], [10], [11], [12], [15], [16], [17], [18], [19].
	Water absorption as low as (2-3) % was achieved for bricks containing (15–30) % by mass of waste glass and fired at 1100°C.	
	When the glass waste content was 45 % by weight, porosity and water absorption was rapidly increased. With smaller particle size of glass, this problem can be avoided.	[9].
Durability	When water infiltrates into the clay brick, it decreases the durability.	[3].
	Results of the absorption coefficient testing, which is often a means of estimating durability, suggested an increase in durability with increasing waste glass addition.	[3], [10], [13].

Conclusion

Analyzed researches within the literature showed that lots of efforts have been done for investigating the effect of using waste glass materials as an additive in the fired clay bricks and ceramic tiles, but all of them are trying to conform to the relevant specifications in their local areas. Also, according to the literature review conclusion is that by using glass cullet, as fluxing agent, it is possible to achieve the desired shrinkage at lower temperatures, which may result in increased production rates and lower production costs. This leads to the need for more extensive research to prove it.

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