ARCHITECTURE

PROSPECTS FOR USING WASTE GLASS IN CONCRETE

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Abstract

The construction of residential buildings, as well as major or ongoing repairs, restorations or reconstructions are a key factor in the construction process. At the same time, construction waste is increasing, as well as the problems of its disposal. The most common way to dispose of any material is through burial. It examines the process of recycling cullet to create new concrete. Crushed glass reacts with the cement paste, as a result of which the chemical composition improves the properties of Portland cement: increases strength, durability; does not retain (absorb) water like conventional cement. Due to the flowing chemical reaction of the broken glass with the astringent material inside the concrete, a stream of strengthening glue is formed, thanks to which, at the age of 28 days, concrete samples are strengthened, acquiring normal strength. By mixing finely ground, finely dispersed powdered glass into a concrete mixture of up to 20%, partially replacing the binder, new concrete is obtained, which has stable strength properties. Crushing of broken glass makes it possible to discard autoclave hardening in the production of glass concrete, since autoclave polymerization significantly increases cost and energy consumption. Due to the simplicity of the technology for obtaining concrete from cullet, its introduction into the construction industry is possible.

Keywords: cullet, concrete, recycling, chemical composition, binder, pozzolann properties, structurally amorphous, isotropic, crystallization, suspension, silicates, strength.

Introduction

People needed housing back in the period of the primitive communal system, where people lived in various caves, huts, dugouts, etc., were unfamiliar with building materials. With changing weather conditions, especially during the Ice Age, people created their homes in the form of round or square rooms, where they placed places for a fireplace in the middle and a hole for smoke to escape from above, and they almost always spent the night there with their pets.

With the evolution of society, construction activities have also developed. The construction of residential buildings, major or ongoing repairs, restorations or reconstructions have become the backbone of construction progress. The material used to design more and more new buildings and structures of the new generation in In Yerevan and throughout Armenia (such a material is used in different operating conditions, emphasizes a high architectural and construction style using local raw materials, and also has environmental safety and operational reliability, which differs from other building materials in its affordable technology) is the oldest building complex composite material – concrete [3]. It is known that concrete is a hard artificial building stone obtained as a result of solidification of a rationally selected mixture of binder, water and aggregates (sand, crushed stone or gravel), and, if necessary, special additives. Aggregates (inert materials) play an important role in the formation of the physical and mechanical properties of concrete. Grains of sand and crushed stone make up the stone skeleton in concrete.[5].

Millions of tons of glass are produced in every country these days. However, after its intended use, only a quarter of the glass is recyclable, the other part is disposed of as garbage (transparent dishes, containers, namely: glass glasses and glasses; laboratory and chemical dishes; construction plate glass, bottles, cans, etc.) at landfills, or are disposed of because This is a common way of disposing of glass waste.

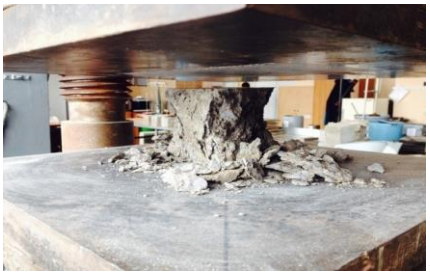
In the construction industry, glass chipping (Fig.1) cannot become garbage, on the contrary, it is possible to recycle it for reuse.

Urban waste is cullet:

a) waste from glass products and flat glass;

b) crushed household waste containing inorganic refractory impurities are corundum, mullite, quartz, porcelain, etc.;

c) impurities of magnetic and non-magnetic metals are cans, metal stoppers, rings, etc.; organic impurities are paper, cardboard, plastic.



Picture 1. The culvert. Picture 2. Sample testing.

Of the listed municipal waste, a culvert is allocated, which is intended for secondary use in concrete, which is treated in such a way that the physico-mechanical properties of glass do not change during its application. Undoubtedly, glass waste is the most difficult to dispose of, but it does not decompose under the influence of alkalis, acids, salts and climatic conditions. It is a well-known fact that glass is an inorganic durable, structurally amorphous, isotropic, brittle, transparent material that transitions from an aggregate state (viscous, liquid) to a glassy solid amorphous metastable state. The glass melt cooling process proceeds at a speed that prevents the crystallization of the melt, which is obtained by melting the raw materials (charge) [10]. Studies show that quartz sand (74%) is contained in excess in glass, hence the name transparent window silicate glass (Table 1). Consequently, glass has pozzolan properties. [9, 11].

Table 1

The chemical composition of glass.

Names of the material	Chemical formula	Content, %
Quartz sand (strap dioxide)	SiO_2	69-74 %
Quicklime (calcium oxide)	CaO	5-14%
Alumina (alumina oxide)	Al_2O_3	0-3%
Soda ash (sodium carbonate)	Na_2CO_3	0-16%
Periclase (burnt magnesia – magnesium oxide)	MgO	0-6%
Other elements	others	0-6%

Pozzolan is translated from Italian as Pozzolana (the name of the city of Pozzuoli), it is a flour, a pulverized product, in other words, a suspension of volcanic ash, pumice, tuff. Pozzolans are used as hydraulic additives to air lime and to binders that harden in a humid environment.

At t = 3000C, with the addition of soda to quartz sand, a more fluid glass melt is obtained, where bubbles are more easily removed during the melting process, and products made from it are easily formed.

$$\mathbf{6SiO_2 + Na_2O + CaO = Na_2O \cdot CaO \cdot 6SiO_2} \quad (1)$$

In order for glass products from such a melt not to break under the influence of climatic conditions, lime (chalk - CaCO3) is introduced into the glass.

When heated, soda and chalk decompose to release carbon dioxide (2):

$$\mathbf{Na_2CO_3 => Na_2O + CO_2 \text{ и } CaCO_3 => CaO + CO_2} \quad (2)$$

Acidic silicon oxide reacts chemically with sodium and calcium oxides, developing an amorphous polymer structure, where a brittle, chemically inert material is formed during crystallization (1). During smelting, sodium carbonate and calcium carbonate decompose as follows (3) [13]. As a result, complex glass compounds (silicates) are formed (3).

$$\mathbf{Na_2CO_3 = Na_2O + CO_3;\ CaCO_3 = CaO + CO_2} \quad (3)$$

Of course, there is an option to alternate the oxides, for example, apply K2O instead of Na2O, and CaO instead of MgO, PbO, ZnO, BaO. Each of the oxides provides glass with uniqueness, for example, boric acid oxide reduces the coefficient of thermal expansion of glass, therefore, glass increases its resistance to weather changes, lead increases the refractive index of glass, alkali metal oxides contribute to the solubility of glass in water.

ASTM C618 (American Society for Testing of Materials) suggested that glass waste has the ability to replace cement. This means that when using cullet, it is necessary to grind it almost to the fineness of grinding cement. The crushed glass reacts with the cement dough, as a result of which the chemical composition improves the properties of cement: increases strength, durability; does not retain (absorb) water like ordinary cement.

The activity of the cullet binder is influenced by: chemical composition; fineness of grinding; water-cement (W/C) ratio. As the fineness of the cement grinding increases, the density increases, the porosity decreases, resulting in an increased contact area between the components of the cullet and the fillers. This is due to the increased strength of glass concrete.

Table 2

The chemical composition of Portland cement

Names of the material	Chemical formula	Content, %
calcium oxide	CaO	67%
silicon dioxide	SiO_2	22%
aluminum	Al_2O_3	5%
oxides, iron	Fe_2O_3	3%
oxide, and other elements	Others	3%
for ground cement: baked clay, fuel ash.		25-40%

Pozzollan cement is made from clinker, gypsum and additives with pozzolanic properties, i.e. reacting with lime. The additives reveal hydraulic properties and develop slightly alkaline calcium hydrosilicates. As a result (from the table. 2), the composition of the hardened material is very different from the composition on ordinary Portland cement, namely:

a) the high density (high density) of the cement solution;

b) strengthening the water resistance of concrete;

c) increased water resistance;

d) sensitivity to temperature when setting the solution;

e) mandatory setting in conditions of high humidity, as crystallization decreases in a dry environment.

The hardened solution shrinks in volume, i.e. shrinkage deformations occur.

In 2022, in the Stepanakert (present-day Khankendi) construction laboratory of the seismic department, 10 concrete samples were tested on a hydraulic press P50 (Fig. 2) according to GOST-u (5-control concrete samples - cubes and 5-glass concrete samples (with 20% binder replaced) with dimensions 10x10x10cm, (Fig.1)). The following materials were used to mix the concrete mixture: M400 portland cement, coarse aggregate - crushed stone with a diameter of up to 20 mm, sand-gravel mixture with a fraction of up to 20 mm and broken (almost like ground) glass (Table 3).

Table 3

Composition of samples

Materials used	Control concrete samples, g	Glass concrete samples up to 20%, g
Portlandcemnt	1155	985
Sand	2100	2100
Crushed stone	4445	4445
Water	695	695
broken glass	-	170

Using the crushing load R on P50, the strength of the samples was determined according to formula (1).

$$\mathbf{R = P/S} \quad (4)$$

Where P is the crushing load, N;

S = 100 cm2 is the working cross-sectional area of the sample.

When tested for compression at the age of 28 days, the strength of the glass concrete samples (average strength -177.6 kg/cm2) was more stable (increased by 10%) than that of the control concrete samples. When comparing the results of the vitreous concrete experiment with the results of the scientific works of a number of scientists, the following conclusions were drawn:

- with shelving in concrete as a partial replacement for the binder, there is an increase in durability and a decrease in the permeability of concrete [1], this results from an increase in pozzolan activity, which causes microcracks in the cement matrix to become clogged.;

- broken glass particles were used up to 60 micrometers in size (in a ball mill);

- the mechanical properties of concrete, however, deteriorate when using cullet as a filler [4], however, scientific papers have confirmed that cullet is able to optimize the mechanical properties of concrete [2].

- an important component in the composition of Portland cement is undoubtedly silica

(SiO2-22% from Table.2.), which gives strength to cement due to the formation of dicalcium and tricalcium silicates, and the abundance of silica in Portland cement slows down setting.

- in finely ground glass, according to a number of scientists (Table.4), amorphous silica (SiO2 > 70%,) is almost 3.5 times more than in the composition of Portland cement, which means that glass has the following properties: a) high chemical resistance; b) electrical non-conductivity; c) thermal stability; d) hardness and scratch resistance; e) thermal insulation qualities; f) resistance to moisture; g) aesthetics; h) recyclability.

Table 4

Chemical composition of broken glass

Scientific works	SiO_2	Al_2O_3	Na_2O	SaO	MgO	Fe_2O_3	K_2O	TiO_2
7	72.76	1.67	12.56	9.74	2.09	0.79	0.76	0.04
12	73.30	1.80	10.80	10.70	1.90	0.30	0.60	-
13	71.40	1.01	11.80	8.74	3.55	0.67	0.40	0.05
6	72.00	0.50	10.20	10.00	2.50	3.50	-	-
8	1.24	1.24	11.19	9.28	-	0.73	-	-

Glass crushing technology fundamentally determines the properties of concrete when used as a partial substitute for cement in concrete. The hydration of cement with modified glass is carried out gradually (slowly) compared to portland cement. The results indicate that the physical properties of glass grinding are as follows:

1. the density of crushed glass is 2528 kg/m3;

2. The average surface area is 3350 g/cm2;

3. The average particle size is reached up to 25.80 microns [7].

The compressive strength of concrete with partial binder replacement on fine-grained glass (20%) was weakened (reduced) at an early age (7 days) due to the slow reaction rate of the glass-crushed mass, but already at 28 days of age, the compressive strength of concrete increased compared to the control sample [13]. Such transformations occurred due to the reaction (Pozzollan reaction) between the broken glass and the binder.

Due to the reaction, a stream of reinforcing glue appeared in the concrete, which strengthened the concrete at the age of 28 days, gaining strength up to B22.5 (M300).

Conclusion

The amorphous silica (SiO_2>70%) in the glass is almost 3.5 times more than in the composition of Portland cement, therefore, broken glass has the following properties: high chemical resistance; electrical nonconductivity; thermal stability; hardness and scratch resistance; thermal insulation qualities; resistance to moisture; aesthetics; probability of recycling.

Due to the ongoing chemical reaction of broken glass with a binder, a stream of reinforcing glue forms inside the concrete, thanks to which, at the age of 28 days, the concrete sample strengthens, acquiring normal strength.

Crushing of broken glass makes it possible to discard autoclave hardening in the production of glass concrete (autoclave polymerization significantly increases cost and energy consumption).

At the stage of creating environmentally friendly, cost-effective autoclave-free technologies for the production of new building materials based on broken glass, the prospect of providing a wide range of materials for comprehensive use (concretes, mortars, fine-grained concretes, porous thermal insulation materials) is emerging.

Glass concrete is suitable for use in road cons.truction, in the installation of sewers, in the construction of runways and airfields, in thermal insulation, as well as in the decoration of fences (protecting from radiation), where they have improved protective, strength, and anti-corrosion properties.

Obtaining a new secondary material consists in partially replacing the binder with finely dispersed powdered glass to increase the strength properties of the concrete matrix with lower costs.

Due to the simplicity and convenience of the technology for producing glass concrete, its introduction into the construction industry is possible and necessary.

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