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# CHEMICAL ACTIVATION OF INERT SILICATE WASTE INTO POZZOLANIC GLASS AS A REPLACER OF ORDINARY PORTLAND CEMENT IN MAKING CONCRETE

BY

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**Abstract.** The current paper concerns the possibility of partial replacing Portland cement, the production of which creates ecological difficulties, with the widely available waste glass in manufacturing process of construction concrete. Converting the glass from an inert waste into one with pozzolanic properties similar to those of cement through fine grinding the glass represents an adequate method to achieve this objective. The experiment described in this paper allowed replacing cement with pozzolanic glass in proportions under 36%. Using for the first time recycled amber-glass from post-consumer drinking bottles together with cement as binders, fine and coarse aggregates, sodium lignosulfonate as a water-reducing superplasticizer, and working-water, four concrete versions were made, where compressive strength was increased up to 49.8 MPa corresponding to the use of 36 % cement replacement and at the end of the 56-day curing process. Also, flexural strength reached a maximum value of 11.4 MPa.

**Keywords:** cement, residual amber-glass, pozzolanic, superplasticizer, strength.

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## 1. Introduction

The global cement industry is facing special challenges at the beginning of the 3rd millennium. The excessive $CO_2$ emissions of the cement industry until the last decade of the last century blocked cement production by international decisions, which generally stagnates despite the very high demand for this material from the construction sector. In particular, the European Union and China have recorded significant decreases, but some areas of the world (sub-Saharan Africa, South America, India, and others) still record increases in cement production. The general trend at a global level is the search for and adoption of environmentally friendly alternative materials whose characteristics are relatively similar to those of cement (Adiguzel, 2024).

One of the recent fundamental discoveries with implications for the choice of suitable alternative materials is the activation of the pozzolanic properties of available inert wastes, which will be further developed in this work.

Pozzolanic peculiarities refer to the properties of certain materials, which, although not themselves cementitious, have the ability to react with lime (calcium hydroxide) in water presence to form cementitious compounds. These compounds, called pozzolans, have the ability to develop the strength and durability of construction concrete or other cement-based products. Since they do not have their own cementitious features, pozzolans cannot harden themselves by combining with water. However, it has been found a self-activate by fine grinding before being brought into direct contact with $Ca(OH)_2$ in wet environment (Yao *et al.*, 2020a).

Within the research on the use of mine tailings as additional cementitious materials in cement, the pozzolanic activation and hydration of quartz as a typical mineral phase of mine tailings after mechanical processing by grinding were investigated. It was found that prolonged grinding led to a gradual increase in pozzolanic activation and the percentage of the material dissolution in alkaline solution as well as decrease of the relative crystallinity. In this work, the optimal particle size below 15 μm was achieved after 40 min of grinding. However, the specific surface area reached the required value after more than 100 min of grinding. The activated cementitious product after hydration of the ground quartz was C-S-H gel as a result of the reaction with calcium hydroxide (Yao *et al.*, 2020a, b).

Inorganic mineral wastes represent potential precursors for the manufacture of geopolymers and geopolymeric concretes. It has been observed that the pozzolanic activation of these wastes is extremely low, being practically inert materials. Therefore, pozzolanic activation is necessary, grinding to micron grain size being the indicated operation. Quartz being one of the main mineral phases of this waste type, has a major influence on properties of mineral wastes (Kohobhange *et al.*, 2018). C-S-H gel was the main hydration product of the ground mineral waste in the mine tailings-calcium oxide (CaO)-anhydrite ($CaSO_4$) system. By increasing the curing time, the composition of C-S-H gel changed towards a lower Ca/Si ratio (up to 0.84) after 28 curing days. Cements made by mixing with mine waste between 10-30% obtained adequate physical-mechanical properties almost similar to composite Portland cement.

After early research, it was found that pozzolans significantly contribute to the increase of the concrete strength following the reaction with $Ca(OH)_2$. On the other hand, the strength may decrease if the concrete remains unreacted. Also, the mentioned reaction facilitates the reduction of the concrete permeability and the increase of the resistance to aggressive effect of chemical substances (sulphates, alkali-silica reaction, etc.).

Materials that exhibit pozzolanic abilities may be natural (e.g. volcanic ash, siliceous sedimentary rock, and others), or artificial (such as: fly ash, silica fume, rice husk ash, etc.).

As mentioned above, ordinary Portland cement is the main component and binder of construction concrete. It is used in usual dosages between 300-500 $kg \cdot m^{-3}$. According to the literature (Bye, 2024), by additional use of other alumina-silicate precursors were also developed other cement types such as: rapid hardening Portland cement, high alumina cement, and cements that have ability of setting time reduction and improving early strength (calcium sulpho-aluminate cements).

Along with the main residual materials resulting in the form of industrial by-products (coal fly ash, silica fume, and granulated blast furnace slag), waste glass constitutes an inexhaustible source of residues that can be easily transformed into pozzolanic materials suitable for the manufacture of concrete as a substitute for Portland cement (Okeke and Adejedi, 2015). Optimal proportion of waste glass was experimentally determined at under 30% for satisfactory strength-concretes.

Until the last decades, due to lack of economic motivation, post-consumer drinking bottles were thrown into landfills without being recycled. Being a non-biodegradable material, storing the glass in landfills cannot be a sustainable operation in terms of environmental protection. The recent discovery that finely ground glass (recommended under 150 μm) acquires pozzolanic features, making it viable as a cement substitute (between 15-30% of the cement mass). Compressive strength and durability can be significantly improved by a degree of cement replacement with glass powder of 30% (Kalakada *et al.*, 2020).

It was experimentally found that commercial glass (soda-lime glass type) ground below 100 μm exhibits higher pozzolanic activity than coal fly ash after 90 days of concrete curing process, under conditions of a low cement replacement (Nodehi *et al.*, 2021).

According to the literature (Mc Carthy and Dyer, 1998), the main composition of a pozzolan includes silica, or silica and alumina, which have the ability to react with $Ca(OH)_2$ at ambient temperature, under the conditions of their fine granulation and the existence of a wet environment. The result of the mentioned reaction is the formation of C-S-H gel with cementitious features similar to those of ordinary cement. Additional materials with cementitious properties are frequently used in the mixture for preparing concrete as partial replacers for cement. The usual cement compounds symbolically noted $C_3S$ representing $3CaO \cdot SiO_2$ and $C_2S$ representing $2CaO \cdot SiO_2$ react with water (through the hydration process) forming the C-S-H gel ($3CaO \cdot 2SiO_2 \cdot 3H_2O$) that gives the concrete strength and $Ca(OH)_2$ as a by-product of the reaction. The water-soluble by-product is removed from the concrete, leading to growing the concrete porosity and simultaneously to strength decrease.

Within the pozzolanic reaction, supplementary cementitious materials react with $Ca(OH)_2$ to form an additional C-S-H gel. Consequently, the total amount of required cement is reduced. Thus, $CO_2$ emissions during the making process are reduced, durability is increased due to lowed permeability and higher resistance to chemics attack.

The primary hydration reaction (of cement) and the secondary hydration reaction (of pozzolanic material) are different through the nature of reactants and the reaction rate. Primary hydration is initiated immediately after the addition of water to the cement, favouring the early increase of concrete strength. Secondary (pozzolanic) hydration is felt after generating the cement hydration by-product [$Ca(OH)_2$], that becomes the main reactant of the secondary hydration. The pozzolanic reaction is characterized by a slower rate and it continues to proceed depending on the amount of $Ca(OH)_2$ provided by primary hydration (Poudel *et al.*, 2025).

Very high level of pozzolanic reactivity is reached by silica fume, which on the one hand has very high $SiO_2$ content and on the other hand is characterized by the existence of extremely fine particles facilitating the rapid reaction with $Ca(OH)_2$ and thus generating large amounts of C-S-H gel. In this way, the strength and durability performances of concrete with silica fume added are significantly improved (Hamada *et al.*, 2023).

Results of the experimental use of recycled waste glass in the composition of construction concrete are promising, especially since the concrete requirement in civil construction is increasing. However, until now, the effect of waste glass added in concrete manufacturing techniques has not been fully elucidated. The work (Guo *et al.*, 2020) took into account the influence of several types of waste glass (soda-lime glass, cathode ray tube glass, lead glass, and borosilicate glass) on the properties of concrete specimens both in the fresh state and in the final hardened state. The analysis carried out by the authors highlighted that the adequate use of pozzolanic glass certainly improves the fluidity, permeability, mechanical strength, and resistance to freeze-thaw cycles of concrete.

Experiments conducted by (Berdnyk and Vuhovskyi, 2023) have shown that waste glass can be introduced into concrete by partially replacing any component of the mixture (cement, or aggregate) in various forms (powder, or crushed) with/without additives, or plasticizers. By using glass as a partial replacement (up to 25%) for cement, increases of compressive, flexural, and tensile strengths as well as workability can be obtained. Partial replacement (up to 20%) of fine aggregate with glass powder allows reaching maximum values of compressive strength. On the other hand, producing concrete containing glass powder has become more cost-effective and environmentally friendly compared to traditional concrete.

Research conducted in recent years has shown that finely ground glass waste can constitute an adequate pozzolanic material in concrete or mortar, partially substituting cement, but improving the strength and durability of concrete or mortar (Li *et al.*, 2022). The formation of additional cementitious compounds similar to fly ash or silica fume as pozzolans already known in the literature, following the reaction of pozzolanic glass with $Ca(OH)_2$, has thus contributed to reducing the cement requirement and implicitly, to reducing $CO_2$ emissions. Results exposed in this paper showed that about 20% recycled glass with grain size between 20-44 μm allows to obtain higher fluidity of the fresh material compared to reference sample. Using the glass ground within the limits of 44-150 μm, compression strength of mortar decreased under the reference sample level corresponding to any curing duration. By using optimal sizes of glass (20-44 μm), the strength after early hardening (7 days) decreased, but further (at 28 and 90 curing days), the strength registered increases of 3.5 and 9%, respectively.

Despite their wide availability, especially in the form of drinking bottles and window glass, glass products have a relatively short lifespan, followed by their transformation into waste. Being non-biodegradable, glass waste is difficult to store in landfills. Thus, waste recycling needs to be expedited after their lifespan is consumed and then reused in the form of other products with newly created value. One of the easiest applications of waste glass is based on creating its pozzolanic properties by finely grinding the waste and then reacting it with $Ca(OH)_2$ in wet environment, mentioned above. The paper (Mahajan and Bhagat, 2022) investigated the behaviour of recycled pozzolanic glass applied as a partial cement replacement for the manufacture of construction concrete. The proportion of cement substitution with pozzolanic glass was experimentally varied between 15-30% and the glass particle size was chosen in the range of 100-150 μm. The glass powder reacts with the lime in the early hydration phase to form additional C-S-H gel, contributing to increasing the cement density and thus improving durability of the hardened concrete. Compared to the fly ash-based concrete, the strength of concrete made with the glass addition was slightly higher.

The main field of application of glass waste was that of construction, the pozzolanic glass being used as a component of construction materials. The experiment presented in (Rani *et al.*, 2021) aimed at the use of glass powder as a replacer of concrete aggregates. According to the results, the use of pozzolanic glass through partial reduction of aggregate amounts under 10% favours obtaining the desired concrete strength after 28 curing days. Also, the replacement of aggregates with waste glass between 15-20% leads to lower strength values.

Other attempts to use glass powder for partial replacement of Portland cement, but also for replacement of up to 20% of coarse aggregate in the starting mixture were reported in the work (Manzoor *et al*., 2022). The effect of applying the mentioned compositional changes was the improvement of compressive, flexural, and tensile strengths. In the case of glass addition above 20%, the strength and durability of the new concrete type decreased.

Numerous other works referring to the partial replacement of Portland cement with different types of recycled glass powder and evaluation of applying effects of this cheap and ecological method on properties of construction materials, especially concrete, should be mentioned in this study (Omran *et al*., 2017; Shayan and Xu, 2006; Du and Tan, 2017; Islam *et al*., 2017). Although results reported in the literature are quite different and sometimes even slightly contradictory, in principle, research in this field has proven the possibility of obtaining at least satisfactory performances, especially regarding the strength and durability of these new versions of construction materials.

A research team containing authors of the actual paper has carried out own investigations on using recycled post-consumer green drinking bottles as a partial replacer for fly ash in a geopolymer concrete (Paunescu *et al*., 2024). Results confirmed that the optimal solution for increasing compressive and flexural strength of geopolymer concrete at early curing time (7 days) and after 28 curing days at ambient temperature is to replace 18% of the initial fly ash content of the concrete mix with recycled pozzolanic glass. Compressive strength reached values of 34.8 MPa (at early time) and 46.0 MPa (after 28 days) and flexural strength registered 5.9 and 8.9 MPa respectively, after the same times of the concrete curing.

The current paper presented further had as its objective preparing a fly ash-based geopolymer concrete using the partial replacement procedure of ordinary Portland cement choosing recycled post-consumer amber drinking bottle finely ground through an advanced mechanical processing.

## 2. Methods and Materials

The methodology of hydration reactions that occur in the manufacturing process of cement-based concrete with the addition of pozzolanic material is interpreted by specialists as follows. The primary hydration reaction is that of cement with lime in a wet environment and contributes in the early development of concrete strength, while the secondary hydration reaction (with the addition of pozzolanic material) becomes felt after the formation of the secondary product of cement hydration i.e. $Ca(OH)_2$, which becomes the basic reactant of secondary hydration. The pozzolanic reaction has a much slower rate and takes longer depending on the amount of calcium hydroxide supplied during the primary hydration. In the case of the current experiment, the chosen pozzolanic material was amber glass powder obtained by fine grinding.

Considering that the common compounds of cement are $C_3S$ ($3CaO\cdot SiO_2$) and $C_2S$ ($2CaO\cdot SiO_2$), which react with water to form C-S-H gel ($3CaO\cdot 2SiO_2\cdot 3H_2O$) according to (Poudel *et al.*, 2025), the stages (in symbolic form) that are included in the gel formation mechanism are:

$$2C_3S + 6H \rightarrow C_3S_2H_3 + 3Ca(OH)_2 \quad (1)$$

$$2C_2S + 4H \rightarrow C_3S_2H_3 + Ca(OH)_2 \quad (2)$$

$$(Pozzolanic\ glass) + Ca(OH)_2 + H_2O \rightarrow C-S-H\ (gel) \quad (3)$$

In order to recycle waste glass, the influence of waste on the rheological properties of the cement paste of concrete was investigated. The results showed that in the case of cement production as a slurry, by growing the amount of glass powder as a cement substitute up to 20%, the slurry viscosity gradually increases, while the yield stress decreases. A small addition of superplasticizer as a water-reduction agent favours the reduction of viscosity and yield stress of the cement slurry. It was found that by adding glass powder, the rheological features of fresh concrete underwent changes by growing the viscosity and decreasing the yield stress after approximately 60 min (Li *et al.*, 2021).

The concrete workability, was tested by a slump. Thus, the fluidity and consistency of the mix were determined by measuring the vertical settlement of the concrete specimens after removing the conical mould (Poudel *et al.*, 2025). Flow slump under conditions of modifying the glass waste ratio as a cement substitute between 0-30 wt. % has led to important differences between results of several authors in the world. Thus, some researchers have reported growing between 36-83% of the slump value for 20 wt. % substituting the cement with waste glass. According to other authors, decreases between 19-30% of slump value were found. In the paper (Li *et al.*, 2021), it was found that the slump value could gradually increase to 18% in the case of 20 wt. % cement substitute, followed by a gradual decrease up to the level of cement replacement with glass powder of 40 wt. %.

A cement-based concrete manufacturing method was adopted, in which Portland cement was partially replaced by pozzolanic glass prepared by finely grinding glass waste recovered from post-consumer amber drinking bottles. The type of residual glass was commercial soda-lime glass, which has the ability to be converted from an inert glassy material into an active one with pozzolanic properties almost similar to those of ordinary Portland cement by the method of finely grinding this waste before the contact with lime - $Ca(OH)_2$ in a wet environment. Only the energy consumption of the mentioned mechanical processing is taken into account, considering that the conversion process into pozzolanic material does not require additional energy consumption.

The first technological stage in producing the new concrete type included grinding and mixing granite gravel as the coarse aggregate with river sand as the fine aggregate. The chosen size range of the gravel was between 4-17 mm, while the size of the sand grains was below 3 mm. The recycled glass was ground to a particle size of under 100 µm. The glass powder was mixed together the cement (CEM I type) in a separate canister from the one containing the aggregate. The fine cement-glass mix was added over of the aggregate mixture. The required water quantity was calculated considering the adopted water/binder ratio value of 0.47 recommended in the literature. Water was added and the mix was blended for 6-7 min. After completion of mixing, the concrete workability was highlighted by the slump test. In all experimental variants including glass powder addition, the slump values of the fresh concrete fell within the recognized optimal limits of 100-125 (Poudel *et al.*, 2025). The fresh material was poured into metal moulds and kept for 24 hours in a special enclosure with controlled humidity at 75-80%. The hardened specimens were removed from moulds and free stored for 7-56 days before determining the strength features.

Materials chosen to be used in this experiment included the following: ordinary Portland cement (CEM I type), amber glass powder recovered from commercial post-consumer drinking bottle, river sand as fine aggregate, granite gravel as coarse aggregate, sodium lignosulfonate as the adopted superplasticizer, and working-water.

CEM I cement type, known also as ordinary Portland cement consists in at least 95% clinker. The clinker is composed of several major phases such as $C_3S$ ($3CaO·SiO_2$), $C_2S$ ($2CaO·SiO_2$), $C_3A$ ($3CaO·Al_2O_3$) and $C_4AF$ ($4CaO·Al_2O_3·Fe_2O_3$) as well as minor compounds (MgO, $SO_3$, and free CaO). Typical chemical constituents of Portland cement are: 61-67% CaO, 19-23% $SiO_2$, 2.5-6% $Al_2O_3$, 0-6% $Fe_2O_3$, 1.5-4.5% $SO_3$ (ASTM C150 standard).

Amber glass powder was procured through post-consumer drinking bottle recycling. Among the coloured commercial glass, amber glass has the highest $Al_2O_3$ content (6.35%) and also a sufficiently high $SiO_2$ content (70.66%) (Poudel *et al.*, 2025), emphasizing the alumina-silicate peculiarity of waste. Also, fine grinding of this glass waste (under 100 µm) contributed to creating pozzolanic properties of the powder, necessary to be adequate for partial substitution of Portland cement in the concrete making process.

River sand is a commonly used and readily available natural source of fine aggregate, characterized through its spheric particles, good workability, and uniform gradation. Bulk density of river sand is within the limits of 1.64-1.78 $g·cm^{-3}$ (Abdias *et al.*, 2023). The chosen size of the sand grains after grinding was under 3 mm.

Granite-gravel has represented the coarse aggregate type chosen in the current experiment. Gravel, a naturally available aggregate composed of regular oval-shaped stones, is a common and effective choice for coarse aggregate in concrete making. It provides volume and stability to the concrete mix, growing its load-bearing capacity and reducing shrinkage. Usually, gravel is combined with the cement paste to create a strong and durable composite (Patel, 2024). In the current experiment, the gravel dimension range was selected between 4-17 mm. Granite gravel chemical composition contains 70-77% $SiO_2$, 11-13% $Al_2O_3$, 3-5% $K_2O$, 3-5% $Na_2O$, 1% CaO, 2-3% total Fe, and less than 1% MgO and $TiO_2$. These oxides provide from minerals that compose granite, quartz, feldspar, and mica (Baker, 2017).

Sodium lignosulfonate ($C_{20}H_{24}Na_2O_{10}S_2$), also known as a superplasticizer, is a water-reducing agent utilized in concrete making to improve its strength and workability. These agent types operate through dispersing cement grains in a concrete mix, facilitating the decrease of required water quantity, keeping or even growing the required strength (by 20-26%) and consistency. Lignosulfonates are chemicals derived from lignin, that is found in plants. Industrially, they are extracted during the pulping process in the paper manufacturing (Sodium lignosulfonate, 2020). Sodium lignosulfonate applied in the current experiment originated in China is utilized in average proportion of 0.25% reported to the binder quantity.

Several experimental concrete versions made by partial substituting the cement with amber glass powder recycled from post-consumer drinking bottle and utilizing other materials and additives mentioned above were produced and tested. The adopted dosages of the mix components are exhibited in Table 1 corresponding to each version.

**Table 1**

*Composition of experimental concrete versions*

| Composition | Variant 1 ($kg\cdot m^{-3}$) | Variant 2 ($kg\cdot m^{-3}$) | Variant 3 ($kg\cdot m^{-3}$) | Variant 4 ($kg\cdot m^{-3}$) |
|---|---|---|---|---|
| CEM I cement type | 450 | 396 | 342 | 288 |
| Amber glass powder (under 100 μm) | - (0%) | 54 (12%) | 108 (24%) | 162 (36%) |
| Sand (under 3 mm) | 630 | 630 | 630 | 630 |
| Gravel (between 4-17 mm) | 1014 | 1014 | 1014 | 1014 |
| Sodium lignosulfonate | 1.2 | 1.2 | 1.2 | 1.2 |
| Working-water | 216 | 216 | 216 | 216 |

According to the data in Table 1, the total amount of binder including cement and glass powder was kept constant in all variants (450 $kg\cdot m^{-3}$). In contrast, the glass/cement ratio was varied from zero to 0.56 (162/288 $kg\cdot m^{-3}$) in variant 4, in which the maximum level of cement replacement with pozzolanic glass represented 36%.

The methods for investigating features of the new concrete type targeted: workability, density, porosity, compressive and flexural strength, modulus of elasticity, water uptake, and microstructural peculiarities. Workability was measured using Abram's cone (SR EN 12350-2:2009). The density was determined based on ASTM C138/C138M-17a, while ASTM C642:2022 was the standard used to measure the hardened concrete porosity. The compression strength was investigated through the method provided by BS EN 12390-3:2009 on the cubic sample, while the flexural strength was measured on the rectangular specimen by applying the third-point loading test (ASTM C78/C78M;2022). Modulus of elasticity was measured according to ASTM C469-02e1. The water uptake of cement-based concrete was determined using the standard method ASTM C1585:2020 and the microstructural peculiarities of concrete samples were identified with Biological Microscope model MT5000.

## 3. Results and Discussion

Applying the Abram's cone test for slump flow has revealed the satisfactory level of the fresh concrete workability, under the conditions that the slump flow values fell within the range of 112-119 mm, according to Table 2.

**Table 2**

*Results of Abram's cone test for slump flow*

| Variant | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Slump flow (mm) | 115 | 119 | 112 | 116 |

Main features of concrete specimens achieved in the current experiment are exhibited in Table 3.

**Table 3**

*Main features of concrete specimens*

| Feature | Variant 1 | Variant 2 | Variant 3 | Variant 4 |
|---|---|---|---|---|
| Density ($kg \cdot m^{-3}$) | 2250 | 2239 | 2222 | 2216 |
| Porosity (%) | 15.5 | 16.5 | 17.8 | 18.9 |
| Compressive strength | | | | |
| - after 7 days | 27.9 | 32.0 | 38.5 | 42.9 |
| - after 28 days | 35.7 | 38.0 | 42.9 | 47.3 |
| - after 56 days | 38.5 | 40.1 | 45.6 | 49.8 |
| Flexural strength | | | | |
| - after 7 days | 4.7 | 6.1 | 6.9 | 7.7 |
| - after 28 days | 7.3 | 7.9 | 8.6 | 9.7 |
| - after 56 days | 9.1 | 9.7 | 10.8 | 11.4 |
| Modulus of elasticity (GPa) | 31.8 | 28.3 | 26.5 | 25.0 |
| Water uptake (vol. %) | 3.6 | 3.5 | 3.3 | 3.5 |

Because the density of CEM I cement is slightly higher than that of commercial glass (soda-lime glass type), the density of the new concrete type has lower values as long as the weight proportion of the cement is still priority. On the contrary, porosity has a tendency to increase in the range of 15.5-18.9%. Compressive and flexural strengths were measured both for early curing time (only 7 days) and after 28 and 56 curing days and a consistent growing could be noted. The highest values of compressive strength were achieved in the case of replacing cement with 36% pozzolanic glass (variant 4), even at an early hardening time of 7 days and especially after 56 days. The same trend of strength growing was also observed in the case of determining flexural strength, but at a much lower level, within normal limits for concretes.

Modulus of elasticity had lower values compared to the reference concrete, while water uptake values had a relatively constant level (3.3-3.6 vol. %).

The microstructural appearance of the concrete specimens is presented in Fig. 1.

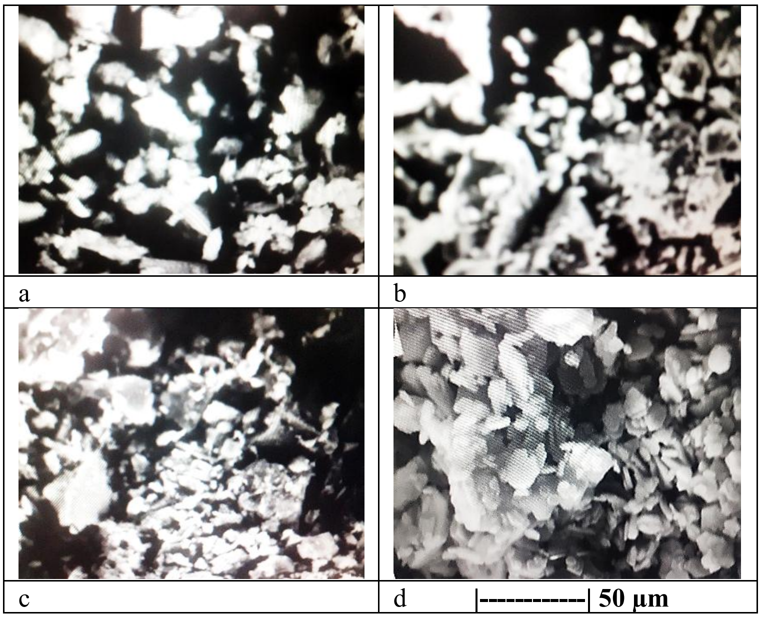


Fig. 1 – Microstructural appearance of concrete specimens
a – variant 1; b – variant 2; c – variant 3; d – variant 4.

Growing the spaces occupied by the glass powder in the microstructural images in Fig. 1 is noticeable in b-d images characterized by additions of 12-36% pozzolanic glass by replacing cement.

Having into account that the industrial making Portland cement, which for almost 200 years has constituted the main binder in the manufacturing process of construction concrete, became a major problem for our planet due to its contribution to $CO_2$ emissions into the atmosphere with negative consequence in the future. Thus, removing the cement, or only partial application of it, by finding other material options represents one of the main actual concerns of researchers. Important steps are already known in testing several procedures of cement replacing by adopting waste or natural alumina-silicate products activated in highly alkaline aqueous solutions (Davidovits, 1991; Davidovits *et al*., 1992).

The current paper refers to recently found ability of recycled commercial glass (soda-lime glass type) to be convert by fine grinding from an inert glassy material into a pozzolanic glass with very similar properties to those of Portland cement. The work originality was the choice of amber residual glass, under the conditions that the different coloured glasses have quite varied chemical compositions from each other. The results confirmed the viability of using amber glass as a pozzolanic material replacing 36% of cement in the concrete manufacture, contributing to obtain high compressive and flexural strengths.

## 4. Conclusions

Obtaining a high-performance concrete through significant reduction of cement consumption, replacing it up to 36% with pozzolanic glass was aimed in the current paper. The pozzolanic glass was made from commercial amber post-consumer glass by finely grinding it. Main results were obtained in terms of compressive and flexural strength, being reached high values (49.8 MPa and 11.4 MPa, respectively after 56 curing days). Chemical activation refers only to the alkaline grinding medium without the use of a chemical additive for activation.

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# ACTIVAREA CHIMICĂ A DEȘEULUI DE SILICAT INERT ÎNTR-O STICLĂ PUZZOLANICĂ CA ÎNLOCUITOR AL CIMENTULUI PORTLAND OBIŞNUT LA FABRICAREA BETONULUI

(Rezumat)

Prezenta lucrare se referă la posibilitatea înlocuirii parțiale a cimentului Portland, a cărui fabricare creează dificultăți ecologice, cu sticlă reziduală disponibilă pe scară largă în procesul de producere a betonului de construcții. Conversia sticlei dintr-un deșeu inert într-una cu proprietăți puzzolanice similare cu cele ale cimentului, prin măcinarea fină a sticlei, reprezintă o metodă adecvată pentru atingerea acestui obiectiv. Experimentul descris în acest studiu a permis înlocuirea cimentului cu sticlă puzzolanică în proporții sub 36%. Folosind pentru prima dată sticlă chihlimbar reciclată din sticle de băut după consum, împreună cu ciment ca lianți, agregate fine și grosiere, lignosulfonat de sodiu ca superplastifiant reducător de apă și apă de lucru, au fost realizate patru variante de beton, la care rezistența la compresiune a fost crescută până la 49,8 MPa, corespunzătoare utilizării a 36% înlocuitor de ciment, la sfârșitul procesului de întărire de 56 de zile. De asemenea, rezistența la încovoiere a atins o valoare maximă de 11,4 MPa.