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Attack of discarded soda-lime glass with sodium aluminate for the manufacturing of sustainable geopolymer components

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ABSTRACT

Discarded soda-lime glass (SLG) may contain small amounts of ceramic, metallic, and polymeric contaminants, therefore recycling of this material is far from ideal. The quality of newly made glass products made by remelting of cullet, as a result, declines. Consolidation at low temperatures to form materials similar to geopolymers could enable the complete re-use of contaminated cullet. SLG powders, either as received or after pre-washing in an acid solution, were added to a sodium aluminate solution and mechanically stirred at a low speed for three hours at room temperature. The formation of microporous semi-crystalline monoliths involved suspensions casting into plastic molds, followed by an overnight cure at 75 °C. The monoliths prepared from both untreated SLG particles and pre-washed SLG particles contained crystalline phases of zeolite LTA and hydrosodalite. The mechanical characteristics showed good agreement with the properties of cementitious materials, with compressive strength ranging from 22 to 29 MPa and flexural strength ranging from 13.2 to 19.9 MPa. Furthermore, the technique effectively produced Venetian terrazzo-like samples by adding coarse glass particles as fillers with particle sizes of up to 3 mm, which could lead to significant material and energy savings in their fabrication. The suggested method could be expanded to include other challenging-to-reuse glass formulations, providing attractive and versatile recycled materials.

1. Introduction

Processing of glass waste in the 21st century is one of the better-mastered parts of waste management, yet far away from being perfected. Only within the European Union, on average, more than 18.5 mil tons of glass waste are produced, and more than a quarter of this amount remains unaddressed [1], mostly because of specific compositions [2,3,4,5,6] and difficulties emerging during the processing of fine fractions of cullet, in which heterogeneous impurities are typically concentrated [7,8]. These problems are causing serious discrepancies in theoretical energy savings calculated for glass recycling and their comparison to other materials. The energy expense, or embodied energy, per 1 kg of glass is only 10 MJ, which is favorably low compared to 30 MJ per kg of steel or 80 MJ per kg of PET. However, when compared to the material production from virgin resources, using recycled glass is beneficial only for a 25% (e.g., in case of aluminum, the saving in embodied energy approaches 90%) [9]. Most of the energy is consumed during the complicated cullet-sorting step [4], which is demotivating for manufacturers.

Easy, cheap and energetically beneficial way of cullet processing could boost the interest of manufacturers in glass recycling and reduce the amount of glass waste. Besides the requirement for an amorphous structure, a promising method for processing inorganic wastes with a suitable Si/Al ratio involves their partial dissolution in an alkaline solution. This process enables the formation of geopolymers through subsequent condensation reactions at ambient temperature, leading to the formation of stable three-dimensional alumino-silicate networks with varying degrees of connectivity [10]. Geopolymers are attractive products for the construction industry, and other high-value applications beyond construction [6,11,12,13,14,15], and even though these studies yielded chemically safe products with excellent mechanical properties, the actual implementation on a large scale is oftentimes limited due to the need for economically and ecologically expensive additives, such as alkali silicates [16]. These additives create a basic

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environment, essential for the partial dissolution of material and, at the same time, adjust the final composition supplying part of the missing so-called "active silica", necessary for the formation of stable geopolymers, together with alkali ions that enable the switch to 4-fold coordination of the Al ions [13]. However, alkali silicates can be replaced through activation in NaOH solutions of different molarities, as shown by Toniolo et al. [17] who successfully prepared geopolymers from soda-lime glass (SLG) and fly ash (FA).

As NaOH is relatively inexpensive and yields promising results, it was also added to glass to produce sodium silicate solutions [5,11,14,18,19,20,21]. It could be beneficial to pay attention to other cheap chemicals as well. At the same time, it could also be beneficial to explore products based on a single waste stream, due to the generally unpredictable waste production volume, which is one of the most criticized factors in waste-based geopolymers production [13]. Since most glasses feature a high SiO_2/Al_2O_3 ratio, an alumina supply would be needed such as the one provided when using $NaAlO_2$ as an activator [22,23,24].

Sodium aluminate ($NaAlO_2$) is cheaper by nearly two-thirds compared to sodium metasilicate (data obtained through a market survey). This is supported by the crystallization of a solution formed by direct dissolution of $Al(OH)_3$ (the basic component in Al-yielding ores), into NaOH [25]. $NaAlO_2$ can be used for the production of geopolymers from silica waste, as shown in the work of Brew and MacKenzie [26]. The combination of silica fume and $NaAlO_2$ solution yields well-defined, thoroughly polycondensed geopolymers. This study, alongside with that of Greiser et al. [27], confirmed the formation of geopolymers, by means of NMR analysis, observing the simultaneous presence of tetrahedral ^{27}Al and ^{29}Si Q4 units, forming a three-dimensional network alumino-silicate network, as generally observed for more conventional geopolymers [28,29,30]. Different by-products beside sodium aluminosilicate gel might be formed, with possible effects on the particular application of the resulting geopolymers [31,32]. Moreover, since the geopolymer formation depends on the kinetics of the dissolution reaction, the presence of readily available silica and its combination to achieve an ideal Si/Al ratio might promote a full conversion of the material into sodium alumino-silicate, which could lead to a final material with improved engineering properties [27].

In the hypothesis of reaction between $NaAlO_2$ and glass cullet, it must be noted that commercial glasses contain, besides glass network forming oxides, also glass network modifiers, particularly sodium oxide in the case of SLG. It can therefore be expected that, during alkali-activation, Na^+ ions are released into solution, and their excess could cause insufficient polymerization of the gels [23]. However, if Na^+ ions were extracted prior to geopolymerization (i.e., by acid extraction), in the sites of excess charge a hydrated silica phase (reactive silica) would be formed [22] and this could enhance the connectivity of the alumino-silicate network.

In our research, we compared geopolymers prepared from SLG waste, in the form of fine powders, activated by $NaAlO_2$, which were used either as received or pre-washed in acid solution. Microstructural observation, demonstrate the sustainability of the proposed approach.

2. Materials and methods

Discarded soda-lime glass fine powders (SLG, mean particle size 30 μm, courtesy SASIL Srl, Biella, Italy; 71.6 SiO_2–1.0 Al_2O_3–13.5 Na_2O-0.4 K_2O-3.9 MgO-9.0 CaO-0.1 FeO in wt.%) and sodium aluminate aqueous solution (45 wt.%, $NaAlO_2$ reagent grade, Sigma Aldrich, Gillingham, UK) were the only constituents used in this study.

Two different approaches were tested. In the first approach, SLG powder was cast into a $NaAlO_2$ solution in 50/50 solid/liquid ratio, the suspension was mechanically mixed at 300 rpm for 3 h, and then poured in closed polystyrene molds and left at 75 °C overnight. In the second approach, SLG powders were subjected to a preliminary washing ('pre-washing') step, consisting of the immersion of the same powders, for 3 h, in an aqueous solution at pH=5, obtained by HCl addition. The pH of the solution was continuously monitored (by means of a pH probe) and kept constant by the dropwise addition of HCl. The glass acid suspensions were centrifuged, washed 6-times in demineralized water (DIW) and finally filtered and dried at 40 °C overnight. Afterwards, the pre-washed SLG powders were cast into the $NaAlO_2$ solution in 50/50 solid/liquid ratio, and samples were prepared as described above. The suspensions underwent mechanical mixing at 300 rpm for 3 h before being poured into closed polystyrene molds and left at 75 °C overnight

The achievement of stable geopolymer materials was preliminarily assessed by a boiling test, in which the monolithic pieces (4 g each) were boiled in 500 ml of DIW for 30 min.

The mineralogical analysis on all samples, including the as-received and pre-washed SLG, as well as the geopolymer samples prepared from these materials, was performed by X-ray diffraction (XRD; Bruker D8 Advance, Karlsruhe, Germany - CuKα radiation, 0.15418 nm, 40 kV-40 mA, 2θ =10–70°, step size 0.05°, 2 s counting time). The phase identification was performed using the semi-automatic Match!® program package (Crystal Impact GbR, Bonn, Germany), supported by data from the PDF-2 database (ICDD-International Centre for Diffraction Data, Newtown Square, PA, USA). Scanning electron microscopy (SEM, FEI Quanta 200 ESEM, Eindhoven, The Netherlands) was employed for the morphological and microstructural characterizations of selected hardened samples, which were prepared by creating fresh fractures to avoid alterations that could result from polishing.

Solid state NMR spectra acquired on finely powdered samples were collected on a Varian 400 spectrometer equipped with a narrow bore, triple resonance T3 Magic Angle Spin (MAS) probe spinning 4 mm rotors and operating at ^{27}Al and ^{29}Si frequencies of 104.32 and 79.53 MHz, respectively. The nominal temperature of the probe was always set to 298 K. Single pulse spectra were acquired at 10 kHz MAS with 800 scans for ^{27}Al and 12 kHz MAS with 1248 scans for ^{27}Al. The repetition delay was set to 2 and the chemical shifts were referenced against aluminium nitrate (^{27}Al) and Q8M8 (^{29}Si).

The geometric density was evaluated by considering the mass-to-volume ratio of cubic samples (5 mm × 5 mm × 5 mm) and bars (approximately 2 mm × 2 mm × 25 mm) cut from larger specimens. The same samples were used for the determination of elastic modulus, by means non-destructive dynamic resonance testing (GrindoSonic Mk5, Leuven, Belgium), and bending strength (Instron 1121 UTS, Instron, Danvers, MA, operating in a three-point configuration - 16 mm span - with a crosshead speed of 0.5 mm/min). Each data point represents an average value obtained by testing ten specimens.

3. Results and discussion

The consolidation of glass suspension yielded samples in the form of thick discs, as shown in Fig. 1a, which were easily extracted from the polystyrene containers. For both types of samples, whether prepared from as-received or pre-washed SLG, no disintegration or dissolution was observed during the 30-minute boiling test in DIW, confirming that the geopolymerization reaction proceeded to a sufficient extent to generate a continuous three-dimensional network.

The microstructural details of the fracture surfaces of geopolymer samples are shown in Fig. 2. The microstructure is homogeneous, consisting of a micro-porous gel (binder) connecting unreacted glass particles, irregularly shaped owing to the original crushing of glass cullet. Samples from as received SLG, shown in Fig. 2a, still contain recognizable starting cullet particles. We could assume that a fracture propagating across the gel and glass particles might preferentially expose glass surfaces uncovered by the binder. However, at the higher magnifications (see Fig. 2b), no interfacial crack was observed, proving that a strong bond between the binder and particles existed. The many pores shown by Fig.2a,b resulted in a total porosity of about 36%, mostly open, as reported in Table 1.

Geopolymer material from pre-washed SLG, shown in Fig. 2c, shows less visible cullet particles; the glass fragments exhibited a substantial

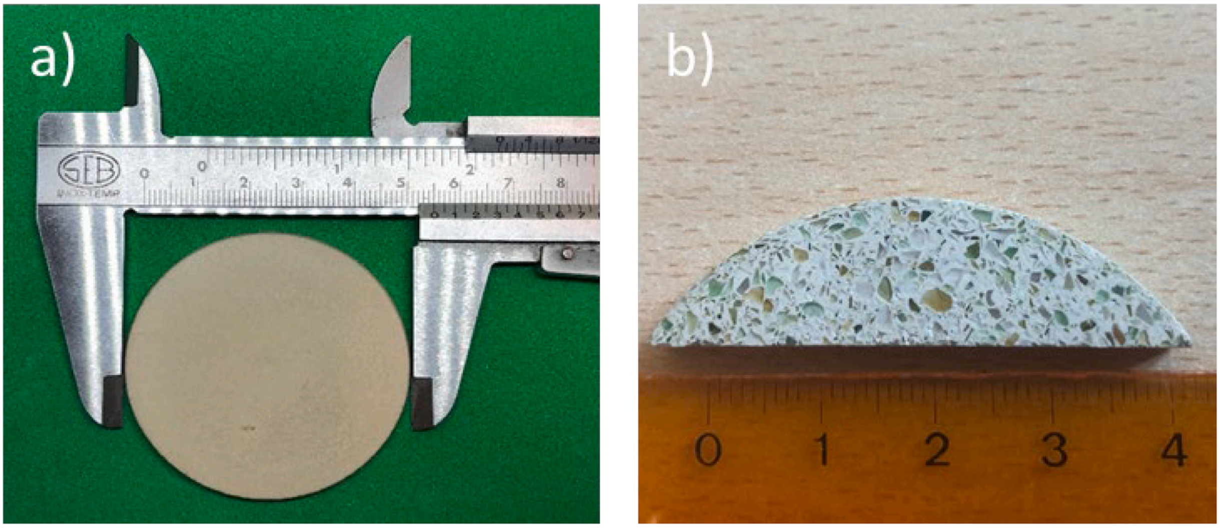

Fig. 1. a) Sample prepared via low-temperature consolidation of fine SLG powders activated in $NaAlO_2$ solution and; b) example of composite comprising coarse glass fragments.

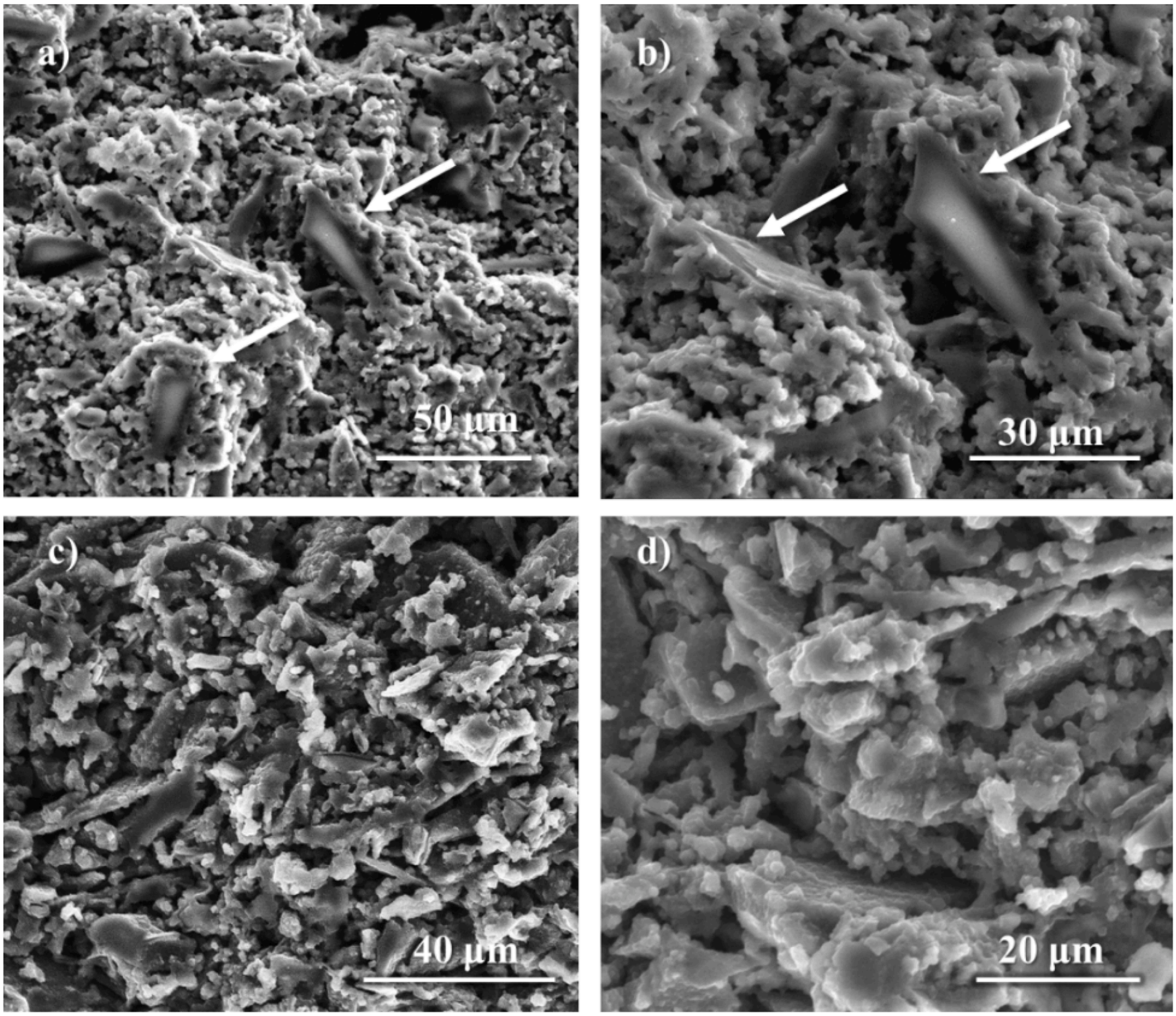

Fig. 2. a,b) sample prepared from as received SLG, arrows highlighting the SLG cullet particles embedded in the binder phase; c,d) sample prepared from pre-washed SLG, where the lack of arrows indicates a better reaction of the SLG cullets with the binder phase.

Table 1
Density and mechanical properties of geopolymers prepared from as received SLG and acid washed SLG.

	Glass-based geopolymer		Normal concrete	Lightweight concrete	Marble	Granite
	SLS as rec.	washed SLG				
Density, ρ (g/cm^3)	1.61 ± 0.03	1.58 ± 0.03	2.2 - 2.6	1.4 - 2	2.7 - 2.9	2.6 - 3.2
Total porosity (vol%)	36.4	43.0	–	–	–	–
Closed porosity (vol%)	15	16.8	–	–	–	–
Open porosity (vol%)	21.4	26.2	–	–	–	–
Elastic modulus, E (GPa)	11.1 ± 0.6	7.6 ± 0.4	15 - 25	11 - 21	50 - 70	50 - 70
$I = E^{1/3}/\rho$ (GPa$^{1/3}$·cm^3/g)	1.4	1.5	1.1	1.5	1.4	1.3
Bending strength, σ_b (MPa)	19.9 ± 0.6	13.2 ± 1.8	1.7 – 2.4	3 - 17	6 - 10	8 - 23
$I'=\sigma_b^{1/2}/\rho$ (MPa$^{1/2}$·cm^3/g)	2.8	2.3	0.6	1.6	1	1.3
Crushing strength, σ_c (MPa)	29.4 ± 6.6	22.0 ± 6.9	13 - 30	11 - 28	55 - 105	110 - 255
$I''=\sigma_c/\rho$ (MPa /g)	18.2	13.9	8.4	10.6	27.3	57.7

surface texturing, as shown in the magnified image in Fig. 2d. In this case also, the crack propagated mostly in the binder phase. Also in this case the porosity was quite abundant; as reported in Table 1, the porosity even increased (44% total porosity, still mostly open).

According to the mineralogical analysis, the differences in the starting glass powders affected the phase evolution. The XRD patterns in Fig. 3a show that the starting SLG contained some quartz traces (PDF #46–1045), consistent with the above-mentioned contaminations of discarded cullet fractions. The reaction of SLG with $NaAlO_2$ is testified by the shifting of the amorphous halo to higher 2θ angles, characteristic of silica-based glasses, which is known to be correlated with the incorporation of network modifiers [33,34]. Indeed, it can be noted that before the activation the halo was centered at a 2θ value ~25°, while it shifted to ~30° after activation). In addition, the reaction led to the precipitation of both hydrosodalite ($(Na_8Si_6Al_6O_{24}(OH)_2]\cdot 2\ H_2O$, PDF #72–2329) and zeolite LTA ($Na_{12}[(SiO_2)_{12}(AlO_2)_{12}]\cdot 27\ H_2O$, PDF #73–2340) crystals.

The formation of zeolite LTA was enhanced by the use of pre-washed glass. This was expected, since acid attack is known to determine the removal of alkali ions from the glass surface, transforming it into a hydrated silica layer [35]. The Na/Al/Si atomic balance in zeolite LTA (Na/Al/Si=1/1/1) effectively matches the hypothesis of an equimolar reaction between $NaAlO_2$ and (hydrated) silica (1 $NaAlO_2$ + 1 SiO_2). This is in a good agreement with what was observed in geopolymer composites obtained from the reaction between $NaAlO_2$ and silica fume [27,36]. On the contrary, hydrosodalite features an alkali excess (Na/Al/Si=4/3/3) that could be explained as the effect of Na^+ inclusions in the binder, originating from $NaAlO_2$ and dissolved glass.

The more significant evidence of the formation of a (semi-crystalline) geopolymer alumino-silicate gel, binding unreacted SLG particles, came from the NMR spectroscopy. The ^{27}Al NMR spectra, shown in Fig. 4,

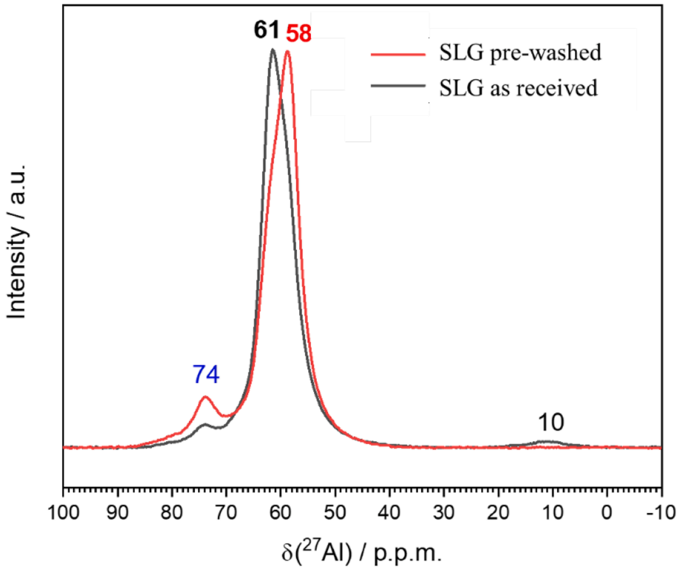

Fig. 4. ^{27}Al NMR spectra of geopolymers prepared from as received SLG and pre-washed SLG.

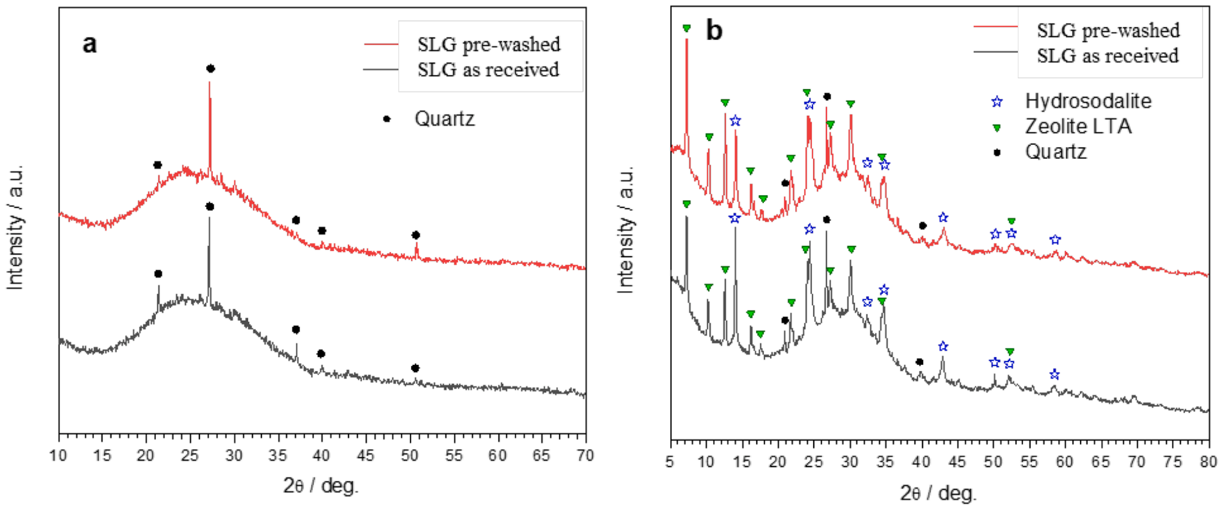

Fig. 3. X-ray diffraction patterns of a) SLG as received and pre-washed; b) geopolymer samples prepared from respective material.

featured strong peaks centered around 60 ppm, consistent with the presence of Al ions in tetrahedral coordination (Al^{IV}), forming a Si^{IV}-O-Al^{IV} network (with Na^+ fundamental for the stabilization of AlO_4 units, by charge compensation), as in conventional geopolymers [37]. The tetrahedral coordination and a strong ^{27}Al NMR peak centered around 60 ppm coordination are also typical of the crystal phases [38,39]. A full reaction of $NaAlO_2$ can be assumed from the absence of the characteristic peak at $\delta \sim 80$ ppm [27]. Both samples also contained some Al in five-fold coordination ($\delta \sim 74$ ppm), as found in other alumino-silicate gels [30]. The signal was weaker for the sample from pre-washed SLG, compared to that from as received glass, which conversely exhibited as small peak at $\delta \sim 10$ ppm, consistent with six-fold coordinated Al ions, attributable to $Al(OH)_3$. The latter side-product had been previously noted in gels obtained from silica/$NaAlO_2$ interaction [26].

The strong peak at $\delta \sim 60$ ppm had itself some differences passing from samples deriving from as received SLG to the ones prepared from pre-washed SLG. In fact, the peak can be attributed to the overlapping of two signals, a main peak and a shoulder positioned at $\delta \sim 58$ ppm and $\delta \sim 61$ ppm, respectively. The sample from pre-washed SLG contained an enhanced ordering of AlO_4 units, considering the dominating contribution $\delta \sim 58$ ppm [27], while the peak at $\delta \sim 61$ ppm is typical of less ordered units [30].

Additional information was given by the ^{29}Si spectra, shown in Fig. 5. The broad peak was affected by zeolite signals, as previously found in the literature [27–30,37,40]. The signal at $\delta \sim -86$ ppm (marked by a green arrow) is consistent the presence of hydrosodalite, which is dominant in the sample prepared from as received SLG. Similarly, the presence of zeolite LTA is confirmed by the signal at $\delta \sim -89$ ppm (marked by a red arrow), prevalent in the sample prepared from pre-washed SLG.

Fig. 5a suggests possible contributions to the broad peak from Q_4 species derived from different Si-O-Al structures, in the alumino-silicate gel (the binder). Signals at $\delta \sim -84$ ppm, $\delta \sim -91$ ppm, $\delta \sim -96$ and $\delta \sim -102$ ppm are assigned to Si-based Q_4 units surrounded by 4 Al ions (Q_4 4Al), 3 Al ions (Q^4 3Al), 2 Al ions (Q^4 2Al) and a single Al ion, respectively [27]. Q_4 4Al structures appear dominant in the sample from pre-washed SLG, whereas samples from as received SLG contained more of Q_4 3Al and Q_4 2Al.

As shown in Fig. 5b, signals at $\delta \sim -84$ ppm and $\delta \sim -93$ ppm could be assigned to both Q_2 and Q_3 units [35]. Interestingly, the geopolymers from pre-washed SLG did not present the shoulder attributable to Q_2 and exhibited a weak shoulder at $\delta \sim -107$ ppm, consistent with Q_4 units. In our opinion, the difference is due to the previously mentioned alkali excess in the gel, for the as received SLG. The excess of Na^+ compared to Al and Si ions reasonably led to the formation of a less polymerized gel.

The polymerization degree of the alumino-silicate network, in alumino-silicate glasses as well as in geopolymers, affects the mobility of alkali ions. Fig. 6 shows the evolution of the pH value of distilled water, initially at pH=7, after the immersion of crushed (<2 mm) geopolymers. The samples from as received SLG immediately reached pH=10, then the pH later increased to a plateau at 12.5. The samples prepared from the pre-washed SLG recorded a progressive increase of pH, from 7 to 12.5, within 10 min from the beginning of the experiment. This is reasonable, since the alkali release is typical of geopolymers [41]; anyway, the delay observed at the early stage of the immersion experiment can be motivated by the reduced overall sodium content and by a more polymerized gel, using acid-treated glass particles. The delay could be easily verified even by simple hand contact of bulk pieces: samples from pre-washed SLG were not as slippery as those from as-received SLG (in the latter samples, the sudden release of alkali likely induced saponification of epidermal fats).

Table 1 reports data from the preliminary mechanical tests on the obtained 'glass-based' geopolymers. The samples from acid treated SLG featured a lower modulus and a lower bending strength, compared to those from as received SLG. However, they were also significantly more porous. Anyway, both materials compared well with recognized construction materials, such as lightweight concrete, and natural stones, such as marble and granite (data extracted from the Cambridge Engineering Selector database [42]), in terms of I and I' material indices. These indices ($I = E^{1/3}/\rho$, or $I' = \sigma_b^{1/2}/\rho$) are expected to be maximized for the construction of light and stiff, or light and strong, panels [43]. The newly formed materials exhibited also a good crushing strength (σ_c), comparable to that of normal and lightweight concrete (the strength-to-density ratio was even higher).

The above-documented cold consolidation of fine glass powder could be exploited beyond the manufacturing of monolithic (or foamed) pieces. For the sake of sustainability, we tested the method also for binding larger SLG granules (300–1400 μm). Diluting the mixture based on SLG fine powders by 50 wt%, with coarse granules, implied definite savings in the activating solution (the overall $NaAlO_2$/SLG ratio passed from 0.31 to 0.14, with 1 g fine SLG corresponding to 0.31 g $NaAlO_2$ and 1.31 g coarse SLG). Extra energy expenses were limited (fine SLG, as written above, came as a waste by-product of the refining of glass cullet; coarse SLG came from crushing of large fragments of container glass, followed by sieving).

The casting of coarse granules in $NaAlO_2$-activated suspensions of fine powders was followed by sonication (5 min). Such treatment led to a homogenous packing of the filler particles, as shown by Fig. 1b; it can be

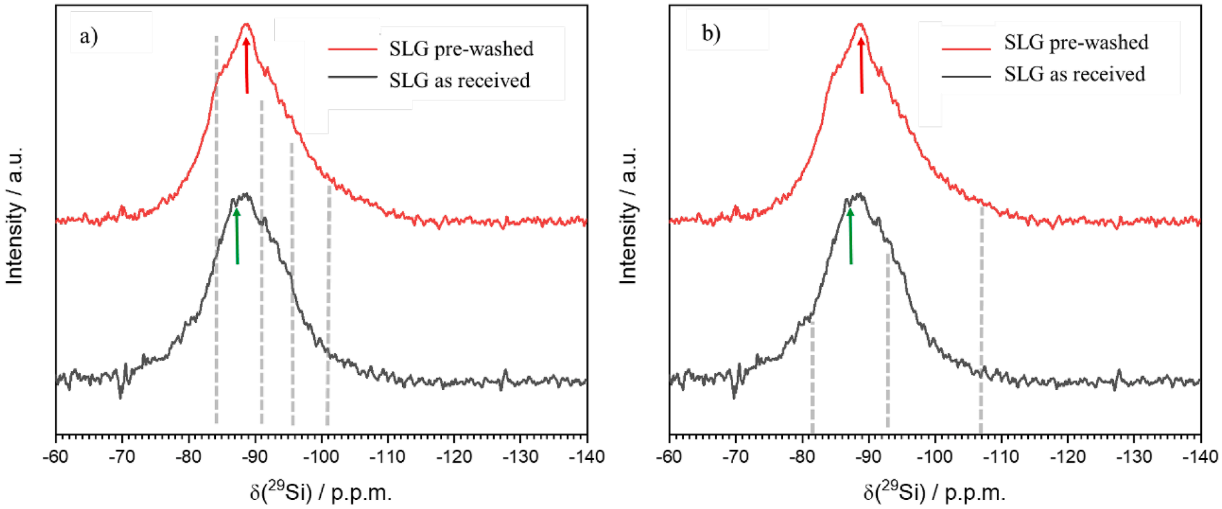

Fig. 5. ^{29}Si NMR spectra with studies on a) the coordination of Al-O-Si structures, and b) SiO_2 with modifiers.

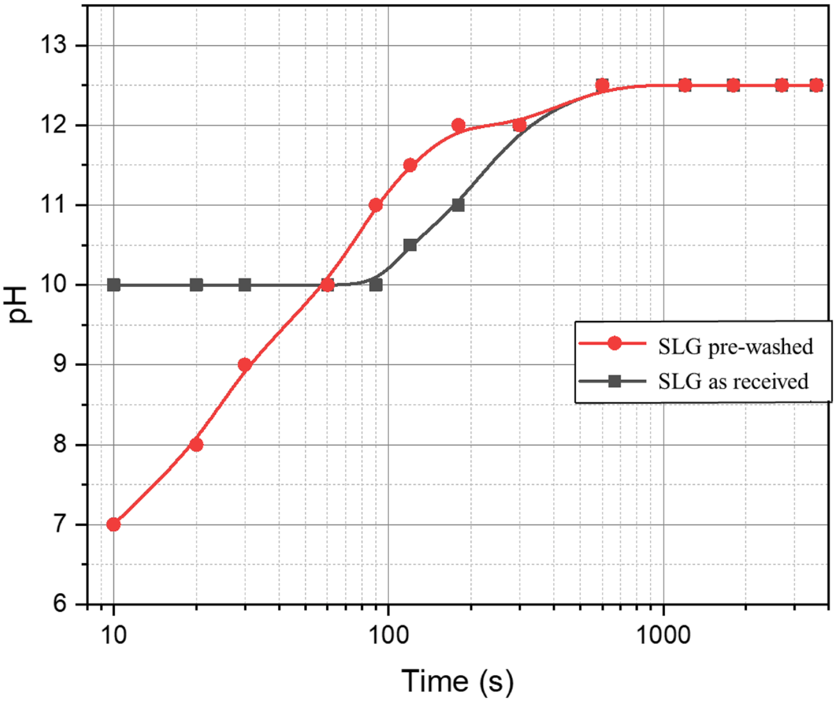

Fig. 6. Evolution of pH in geopolymer leachates prepared from as received SLG and pre-washed SLG.

noted that the obtained composites had a pleasant aesthetic appearance, resembling that of ‘terrazzo’ tiles [44], with different colors of the large glass fragments resulting from avoiding any expensive sorting step for the glass cullet.

The filler particles had a homogenous packing in all dimensions, as demonstrated by the polished cross-sections shown in Fig. 7a. The good bonding of filler particles in the matrix from as-received fine glass powders is confirmed by Fig. 7b, showing a crushed piece: it is evident that the fracture propagated mostly in the gel, but it could even go across coarse particles, without pull-out. Using as-received fine SLG powders resulted in efflorescence at the polished surface, shown in Fig. 7c: according to energy dispersive X-ray spectroscopy (not shown), the efflorescence corresponded to the formation of hydrated sodium carbonate, in turn consistent with the lower stabilization of alkali in the gel formed with not acid-treated glass.

Efflorescence is quite typical in geopolymers, and it may be reduced or prevented by the introduction of additives (as an example, Provis and co-workers discussed the increase of alumina content in the gel by the addition of Ca aluminate [45] or slag [46] or selecting potassium as the alkali ion. Interestingly, samples from coarse particles immersed in a gel

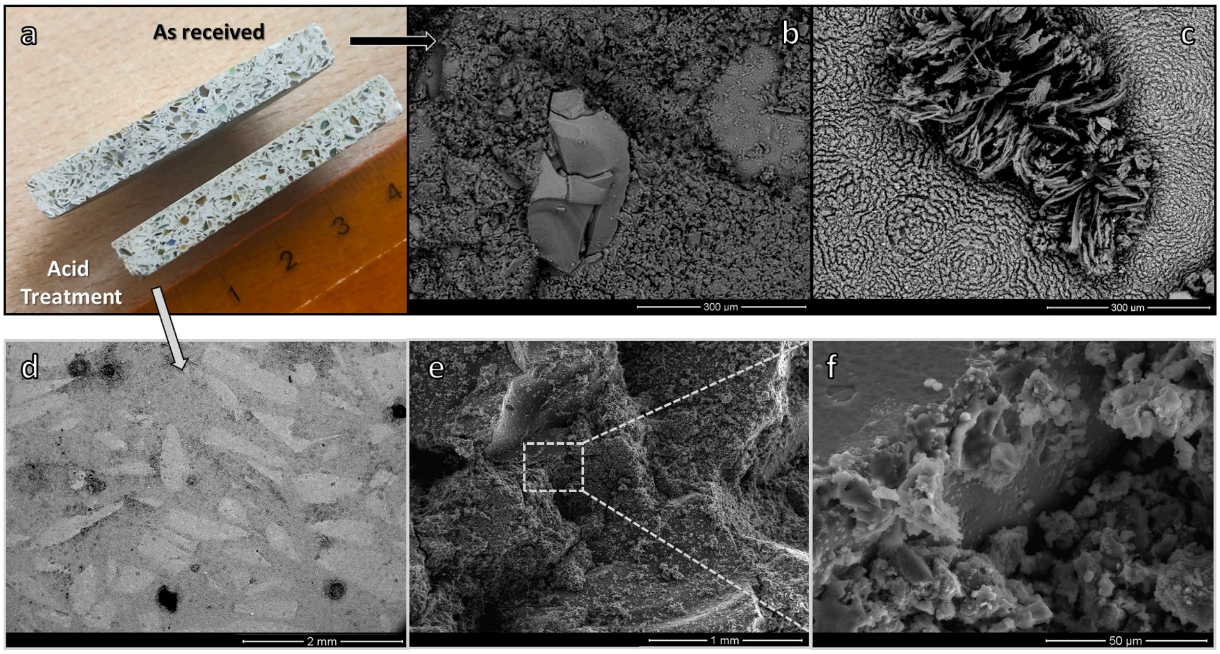

Fig. 7. a) Cross-section of composites prepared from the mixture of coarse glass cullet and binder from as-received or acid washed fine SLG powders; b-c) details of composite from as-received SLG; D-f) details of composite from acid washed SLG.

from acid-treated SLG did not present any efflorescence (Fig. 7d). The fracture was confirmed to pass mostly through the gel (Fig. 7e), with no pull-out; in addition, the surface of coarse particles presented some texturing (Fig. 7f), which could be interpreted as evidence of reaction with the surrounding gel.

The present investigation is undoubtedly preliminary and further studies will be performed in the future to assess the evolution of strength with time and to study the impact of coarse particles (we did not apply any mechanical test on 'terrazzo-like' samples considering their limited dimensions: for the sake of data reliability, the thickness should far exceed the size of the fillers). Anyway, we think that the use of a SLG-based binder is promising also for the incorporation of fragments from other types of glass that are currently landfilled (e.g., glasses from dismantled cathode ray tubes, artistic - even Pb-based - glasses, opal glasses, slag-derived glasses). Finally, the activation with $NaAlO_2$ solutions could be also applied to glasses containing Al_2O_3 and B_2O_3 (e.g., fiber glass, pharmaceutical glasses); in this case, the stabilization of alkali ions in the gel could be enhanced by the formation of $[AlO_4]$ and $[BO_4]$ tetrahedral units [6].

4. Conclusions

We may conclude that:

- The combination of fine soda-lime glass powders with $NaAlO_2$ aqueous solutions has a great potential for the production of components based on stable Na-alumino-silicate gels;
- The glass-solution interaction led to semi-crystalline gels, comprising hydrosodalite and LTA zeolite; the formation of AlO_4 units (stabilized by alkali ions) was confirmed by means of NMR analysis;
- The process can be tuned by subjecting the SLG glass powders to an acid washing pre-treatment; (surface) de-alkalinized powders led to gels with enhanced content of LTA zeolite, less prone to alkali release;
- The sustainability of the process may be significantly enhanced by using fine soda-lime glass powders and $NaAlO_2$ aqueous solutions for the development of a binder phase connecting coarse glass granules, leading to components with a pleasant aesthetic appearance. Furthermore, Na-carbonate efflorescence was not present when using a binder containing acid-washed soda-lime glass powders.

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Data availability

Data will be made available on request.

CRediT authorship contribution statement

Durgaprasad D. Ramteke: Investigation, Formal analysis. **Miroslava Hujova:** Writing – review & editing, Writing – original draft, Data curation. **Jozef Kraxner:** Writing – review & editing, Data curation. **Dusan Galusek:** Project administration, Funding acquisition. **Hamada Elsayed:** Writing – review & editing, Writing – original draft, Data curation. **Paolo Colombo:** Writing – review & editing, Supervision. **Enrico Bernardo:** Writing – review & editing, Writing – original draft, Supervision, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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