Upcycling of waste glasses in novel sustainable construction materials

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ABSTRACT

In the field of sustainability, recycling of glass is complex process. Not all type of glasses are easly recyclable and the exclusion may be due to the strict chemical composition and/or optical quality demands on final products, or to possible noxious emissions during re-melting [1]. COVID-19 emergency has increase the production of boro-alumino-silicate pharmaceutical glass that is not recyclable in a 'closed-loop'. One way could be 'open-loop' recycling, when glass could be reused for a new generation of marketable products, in a different context. The difference between economic value of the new products and manufacturing costs represents an undoubtedly challenging factor: only if high, open-loop recycling can be properly seen as 'upcycling' [2]. This work is focused on alkali activation of glass waste to obtain innovative and sustainable construction materials. The activation process is performed suspending fine milled waste (Ø < 75 μm) in weakly alkaline solution (2.5 – 5 M) of NaOH and/or KOH. The solid loading is 60 wt%. During the mechanical stirring (500 rpm, 3 h) the alkaline solution partially dissolves the waste. The suspension is dried at 40°C for 7-14 days to obtain the final building material: new bonds between particles are created during this last phase of the process.

Pharmaceutical boro-alumino-silicate glass (referred as BASG; chemical composition: SiO_2 = 72 wt %, B_2O_3 = 12 wt %, Al_2O_3 = 7 wt %, Na_2O = 6 wt %, K_2O = 2 wt %, CaO = 1 wt %, BaO < 0.1 wt %) with different grades of impurities has been tested in order to evaluate the efficacy of recycling processes; at the same time sodalime glass (referred as SLG; chemical composition: SiO_2 = 71 wt %, Al_2O_3 = 1.2 wt %, Na_2O - K_2O = 14.5 wt %, CaO = 7.5 wt %, MgO = 4 wt %) has been tested with addition of volcanic ash to improve mechanical properties. Preliminary comparative studies between BASG and SLG matrices allow to say that the first is better in harsh performances. Concerning BASG, best results have been obtained increasing stirring temperature (40°C) or molarity (5 M). Thanks to its properties, BASG has been used also as a matrix to embed other waste materials after mechanical stirring such as Plasmastone, foundry sands and bricks powder. Speaking about sodalime glass, it's possible to observed best results thanks to the addition of volcanic ash. It's possible to notice a significant increase in compressive strength, thanks to the replacement of glass with volcanic ash up to 50 wt%. In addition to compact products, to obtain materials with thermal and acoustic insulation properties, it has been also explored the possibility to foam, at room temperature, the activated mixture using sodium perborate monohydrate as foaming agent and sodium dodecyl sulphate (SDS) as stabilizing agent. First studies show that it's possible to tune pores dimension and mechanical resistance changing stabilizing agent and volcanic ash quantities, respectively. Samples have been characterized from different point of view. Boiling tests have been pursued to evaluate the stability of the gel formed during the drying phase. From the physical and chemical side, it has been used FTIR spectroscopy and XRD. Density and porosity analyses has been performed because of the interest to evaluate close and open porosity. To evaluate the mechanical properties the samples have been subjected to compressive strength. Finally, selected samples have been analysed using SEM-EDX for microstructural characterization.

Thanks to these preliminary studies it is possible to conclude that building materials could be obtained using glasses for which the conventional recycling methos are not allowed, such as the pharmaceutical BASG. The addition of foaming agent and stabilizing agent allows to obtain materials for thermal and acoustic insulation applications. Moreover, inert materials could be added to the glass matrix to obtain products comparable with the ones on the market and eventually that the use of other industrial waste

materials like wastewater or glass allow to obtain building materials, therefore a high degree of purity of the starting materials is not required.

Keywords: Alkali activation, Construction materials, Foam, Pharmaceutical glass, Waste valorizatio

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