Durability of alkaline activated materials from two industrial by-products: diatomites and sewage sludge

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The main objective of this work is to study the durability, in different media, of a set of alkaline-activated materials in which, for their manufacture, two industrial by-products have been used as precursors: diatomites (Diat) and sewage sludge (SS).

These industrial by-products, taken separately, do not provide good mechanical properties. Studying the fluorescence of x-rays (FXR) in Table 1, it can be observed that they have a suitable chemical composition to act as precursors in the manufacture of alkaline-activated materials, since diatoms have 89.09% SiO_2, 3.22% Al_2O and 1.21% CaO, while the sewage sludge has 26.95% SiO_2, 8.13% Al_2O and 21.80% CaO. Therefore, in a previous study, alkaline activated materials were made with mixtures of both residues. Five different blends were made, from 30% diatoms with 70% sewage sludge to 70% diatoms with 30% sewage sludge. All the mixtures were made using the same procedure and the same conditions, in which a mixture of 8M NaOH (98% purity) with 50% Na_2SiO_3 (29.2% SiO_2, 8.9% Na2O and 61.9% H_2O),) was used as the alkaline activator, the solid liquid ratio 1.0 and the particle size of 100 μm. Finally, curing was carried out at room temperature. In this way, the effect produced by the addition or decrease of these industrial by-products can be studied and both the mechanical and physical properties can be evaluated.

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	LOI
Diatomites (Diat)	89.09	3.22	2.72	1.21	0.42	1.35	0.21	0.41
Sewage Sludge (SS)	26.95	8.13	8.21	21.80	4.64	1.93	1.31	3.79

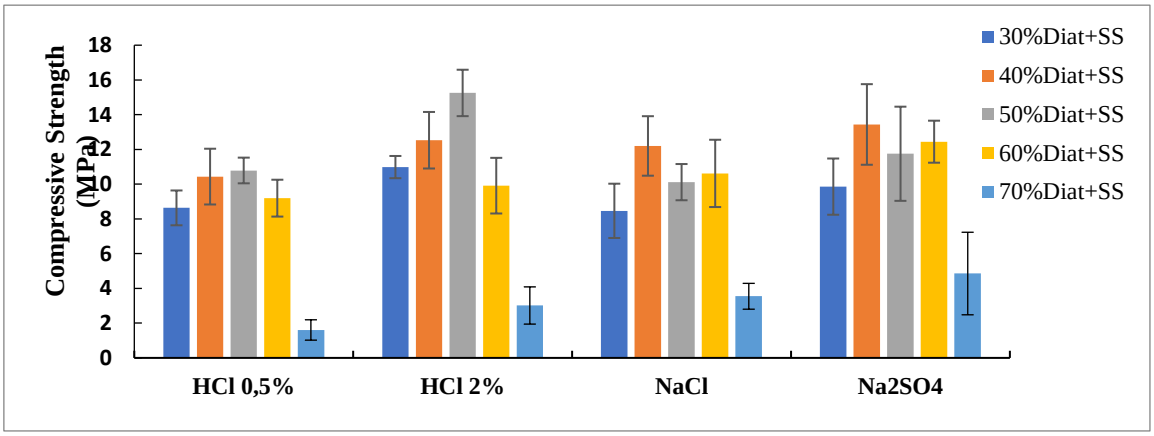
Table 1. Chemical composition of raw materials

Since the results obtained from this study were quite optimal, reaching compressive strengths of 14.9 MPa with 30% Diat up to a maximum of 32.8 MPa with 60% Diat at 28 days of curing, we proceeded to study the durability of these alkali-activated materials in three different media: HCl 2%, NaCl 3,5% y Na_2SO_4 4.4%.

For this study, the procedure followed was the same for all five mixtures, testing 4 specimens of each mixture in each of the different media. First, the dry specimens were weighed, after being in an oven at 40°C for 24h, and then immersed in the corresponding solutions. The saturated specimens are weighed 24 hours after the inversion and, subsequently, every 7 days up to 28 days, making a total of 5 weighing. After each weighing, except for the first one (24h), the solution is replaced by a new one where they will be immersed again until the next control. On day 28, after weighing the specimens, the specimens are dried in ambient conditions and, subsequently, the mechanical tests, such as compressive strength, are carried out.

As can be seen in Graph 1, the compressive strengths obtained after the durability test follow two trends. On the one hand, there are the acid media (0.5% HCl and 2% HCl), where the mixture that provides the greatest resistance is 50% Diat+SS, reaching 15.3 MPa with the 2% HCl medium and 10.8 MPa with the 0.5% HCl medium, followed by the 40% Diat+SS mixture, achieving 12.5 MPa with the 2% HCl medium and 10.4 MPa with the 0.5% HCl medium, followed by the 60% Diat+SS mixture, achieving 9.9 MPa with the 2% HCl medium and 9.2 MPa with the 0.5% HCl medium and finally, the 70% Diat+SS mixture, with values of only 3.0 MPa and 1.6. MPa in respective media. On the other hand, in the basic media (3.5% NaCl and 4.4% Na2SO4) the mixture that provides the greatest resistance is 40% Diat+SS, reaching 13.4 MPa with the 4.4% Na2SO4 medium and 12.2 MPa with the 3.5% NaCl, followed by the 60% Diat+SS mixture, achieving 12.4 MPa with the 4.4% Na2SO4 medium and 10.6 MPa with the 3.5% NaCl medium, followed by the 50% Diat+SS mixture, achieving 11.8 MPa with the 4.4% Na2SO4 medium and 10.1 MPa

with the 3.5% NaCl medium, and finally, as occurs in acidic media, the 70% Diat+SS mixture, with very low values of 4.9 MPa and 3.5 MPa in respective media.



Graph 1. Compressive strength (MPa)

In general, it can be concluded that the acid medium that provides the best results is 2% HCl, where the mixtures that offer the highest compressive strength results are those of 50% Diat+SS and 40% Diat+SS. While the basic medium with which the best results are obtained is Na_2SO_4 4.4%, in this case the mixtures that work best are those of 40% Diat+SS followed by 60% Diat+SS. Also, it should be noted that the 70% Diat+SS mixture is the one that suffers the most from the effects of the durability test, since with no medium it exceeds 5 MPa. However, despite the general decrease in compressive strength compared to the results obtained after 28 days of curing, optimum and sufficient strength is obtained depending on the purpose for which the construction materials are intended. Thus, it can be affirmed that the manufacture of activated alkaline materials using industrial by-products of diatoms (Diat) and sewage sludge (SS) as raw material is a good alternative to the use of traditional Portland cement (PC) since, in addition to offering good physical and mechanical properties, most of these mixtures have optimal resistance to contact with different aggressive media. In this way, the sector is offered a new type of material that is less aggressive with the environment since it requires less energy consumption than PC, reducing greenhouse gas emissions into the atmosphere and avoiding the extraction of new natural raw materials. In the same way, a new use is found for the use of waste, entering a circular economy.

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