# Title: Treatment with alkaline-activated binders of waste soil for their reuse in the construction of large infrastructures.

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# Proposal

Soil improvement techniques with traditional binders (lime, cement) are used in a variety of geotechnical engineering applications, with the aim of modifying the physical and mechanical characteristics of waste soils. The growing need, on the one hand, to identify methodologies for the integral reuse of waste materials, and on the other hand, to use materials with a low impact on the environment, are directing scientific research towards improvement techniques based on the use of innovative binders, for greater sustainability of the construction process.

Alkaline-activated inorganic binders are synthesised from amorphous alumina-silicate powders (precursors) that are cold-activated through an alkaline solution, mainly sodium hydroxide and/or sodium silicate. During alkaline activation, the dissolution of silicon and aluminium promotes the formation of polymer chains, the result of polycondensation of silicate and aluminate ions that give rise to an amorphous or semi-crystalline three-dimensional structure (gel) of hydrated aluminosilicates with cement-like properties (Provis and Bernal, 2014). Various industrial by-products have been used as precursors for the synthesis of alkali-activated binders (fly ash, blast furnace slag, rice husk ash, crushed glass, etc.), some of which have also been successfully used in the treatment of waste soils in geotechnical applications (Vitale et al. 2017, Coudert et al. 2019, 2020, 2022, Turan et al. 2022). Recently, the focus is also on natural precursors such as volcanic ash and pyroclastic soils (Costa et al. 2023).

The research project aims to define a methodology for the integral reuse of waste soils by means of improvement techniques based on the use of innovative binders. The project intends to demonstrate how the use of innovative binders with a low impact in terms of atmospheric emissions is immediately transferable to construction practice, while respecting already established operating methodologies.

# Research Program

# Studying the treatment of waste soils using alkaline-activated binders requires an experimental analysis methodology based on a multi-scale approach (Russo 2019).

# The first phase of the research is dedicated to the selection and mineralogical and physical characterisation of the precursors underlying the alkaline-activated binders, with reference to an artificial precursor (blast furnace slag, fly ash) and a natural one (volcanic ash). Activating solutions are designed and manufactured according to the specific mineralogical composition of the precursors. The chemical-physical evolution and mechanical properties of the binder are determined experimentally depending on the curing time and formulation of the activating solution.

# The second phase of the research consists of the treatment of waste soils with the alkaline-activated binder. This part of the study is aimed at verifying the efficiency of the treatment in terms of the physical and mechanical characteristics of the treated soil, with reference to the treatment parameters (binder percentage, initial density, water content) and the curing time. The experimental study of this research phase is divided into three levels of analysis:

# (a) chemo-physical evolution of the soil+binder+water system, by identification of mineralogical phases and their evolution over time based on X-ray diffractometry, differential thermal analysis, infrared spectroscopies.

# b) analysis of the microstructural reorganisation of solid particles, using mercury intrusion porosimetry, scanning electron microscopy, X-ray microtomography

# c) Analysis of the hydro-mechanical behaviour of the treated soil by means of geotechnical laboratory testing.

# The third phase of the research is aimed at implementing the improvement technique. This phase will be developed at a fully operational site, with the aim of verifying the efficiency of the treatment techniques developed during the laboratory study, and to validate the construction procedures. To this end, an experimental embankment will be constructed using soils treated with alkaline-activated binders, according to the solutions developed during the laboratory study. The control of the construction process of the experimental embankment will be carried out with reference to the relevant treatment parameters (density, water content, amount of binder), as function of curing time. A geotechnical monitoring of relevant quantities will be implemented during and after the construction phase, with particular reference to the physical state parameters of the treated soil (density, suction, volumetric water content) and the mechanical behaviour of the embankment (deformability, strength).

# The experimental research will be developed in collaboration with the Université Gustave Eiffel, Nantes, France, for the part concerning the analysis of the chemical-physical evolution of the binder, and with the Université de Lorraine, Nancy, Grance for the part concerning the hydromechanical behaviour of soils treated with innovative binders.

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