Phyllite clays from southeast Spain: an overview on the improvement of their engineering properties by chemical stabilization and biocementation

Eduardo Garzón (1), Vanesa García-Garzón (1), Luis Pérez-Villarejo (2), Pedro José Sánchez-Soto (3*)

(1) Departamento de Ingeniería, Universidad de Almería, La Cañada de San Urbano s/n, 04120-Almería (España)
(2) Departamento de Ingeniería Química, Ambiental y de los Materiales, Escuela Politécnica Superior de Linares, Universidad de Jaén, Campus Científico-Tecnológico, Cinturón Sur s/n, 23700-Linares, Jaén (España)
(3) Instituto de Ciencia de Materiales de Sevilla (ICMS), Centro Mixto Consejo Superior de Investigaciones Científicas (CSIC)-Universidad de Sevilla, c/Américo Vespucio 49, 41092-Sevilla (España) *corresponding author: pedroji@icmse.csic.es

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INTRODUCTION

Phyllite clays or phyllites are rocks of slate clay materials having an abundance of fine-grained phyllosilicates, which gives them and unctuous feel and the existence of preferential cleavage makes them easily breakable into thin sheets (Adom-Asamoah & Owusu-Afrifa, 2010; Oliveira et al., 2015; Ramamurthy et al., 1993). Phyllites are found in several parts of the world, for instance, in Brazil, China, Greece, Portugal (Adom-Asamoah & Owusu-Afrifa, 2010; Karakitsios & Rigakis, 2007; Oliveira et al., 2015). They are abundant in the Betic Cordilleras (Andalusia, South Spain), e.g., in the provinces of Almería and Granada, mainly in the Alpujárride and Maláguide Complexes (Lonergan & Platt, 1995; Ruiz-Cruz et al., 2006). These phyllite clays have traditionally been used in southeast Spain as sealing material to impermeabilize roofs, construction, embankments, ponds, as core material in zoned dam/reservoir construction and waste landfill. However, a systematic program of investigations at the University of Almería in collaboration with the ICMS was conducted to study and characterize these phyllites in deep concerning their engineering and thermal properties, chemical stabilization and biocementation. In this communication, an overview of the main results obtained is presented.

MATERIALS, PREPARATION AND METHODS

Representative samples of 53 Spanish phyllite clays were gathered from several quarries located in the Alpujárride Complex (Almería and Granada, Andalusia Region, southeast Spain), as described by Garzón et al. (2009, 2012). The thickness of these phyllite clay deposits was variable, but after removing the first surface layer (1-30 cm), the thicknesses were 1-2 m. The raw materials were crushed and passed through a 200 ASTM sieve. Chemical, mineralogical and thermal analyses were performed using conventional Techniques (XRF, XRD and DTA-TGA); microstructural and textural studies by SEM-EDX and Fisisorption, respectively. Multivariate statistical analysis was applied concerning the chemical and phase composition of these phyllite clays. Physical, geotechnical and hydro-mechanical characterization was performed using ASTM standards and equipments, as described previously (Arce et al. 2019; Garzón et al, 2010, 2015, 2016; Morales et al., 2019).

SUMMARY OF MAIN RESULTS AND FINDINGS

The samples of phyllite clays contain clay minerals (chlorite, illite and mixed-layer illite smectite), quartz, feldspars, iron oxide and dolomite, as revealed by XRD (Garzón et al., 2009, 2012). Multivariate statistical analysis (MVSA) of their chemical and mineralogical characteristics was performed and correlations were found (Garzón et al., 2012). In a next investigation (Garzón et al., 2016), a correlation between chemical and mineralogical characteristics and a relevant property (permeability) was obtained analyzing the nitrogen adsorption-permeability dependence. According to the characterization by thermal methods (Garzón et al., 2020), these phyllite clays were classified: (I) Micaceous, characterized by predominant layer silicates, mainly muscovite or illite, alkaline elements (K_2O higher than 3.5 wt.%); (II) Quartzitic, with predominant quartz and SiO_2 and (III) Carbonaceous, characterized by predominant dolomite, with medium contents of CaO and MgO.

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A study on the physical and geotechnical properties of phyllite clays was performed (Garzón et al., 2010). With these results, the stabilization and improvement of engineering properties of phyllite clays was achieved by the addition of lime (3, 5 and 7 wt.%) and cement (5, 7 and 9 wt.%) (Garzón et al., 2015, 2016). Phyllite clay–lime mixtures had good compaction properties and very to extremely low permeability-coefficient values, with a semi-logarithmic correlation between increasing permeability and increasing proportion of lime additive. The addition of 3 wt.% lime was sufficient to reach the index of capacity amble specified in the Technical General Prescriptions for Works of Roads and Bridges (Spanish Highways Agency, 2008), significantly reducing the plasticity index, with the compacted mixture undergoing no swelling under soakage. However, with the addition 5 wt.% cement was deemed most suitable for certain construction material applications, having a plasticity index of 10.5 %, maximum dry density of 2.17 Mg/m^3 and optimum water content of 8% and very low permeability coefficient (7.4 x 10^{-11}m/s). Potential material applications for these composites include roofs, flexible pavements and building construction. In a next step it was investigated if phyllite clays could be raw materials replacing cement in mortars. The finding of this investigation were new impermeabilizing mortars with interesting applications in building construction. First of all, the results were patented (P201530329 ES) and published after evaluation of pozzolanicity (Arce et al., 2019).
On the other hand, calcium carbonate generated by a microorganism of the *Bacillaceae* family was also studied (Morales et al., 2019). It was investigated the geotechnical properties of the phyllites evolved. The objective was to develop a biotechnological tool for new applications of phyllite clays in linear works. The microbiological treatment of phyllite clays tends to aggregate the original particles, being in part these aggregates associated to the formation of calcium carbonate. A reduction of the specific surface area and plasticity values is consequence of an addition of a non-plastic component to the sample, producing a more aggregated structure by precipitation of $CaCO_3$ from the bacteria, which is filling the pores. All these results were promising enough to perform new studies on phyllite clays.

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