



Research paper

Application of differently treated illite and illite clay samples for the development of ceramics

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ABSTRACT

This study represents the results of investigations on the possible geopolymer formation of an alkali, mechanically and thermally (including hydrothermally) activated 2:1 layer silicate, namely, illite and illite clay, for low-temperature ceramic products. The main starting materials were Quaternary illite clay samples taken from the Apriki–Laza pit in Latvia. For the investigations, an intermediate composition of illite clay and separated illite were used. The following research methods for the treated illite and illite clay were used: the phase transition was analysed by differential thermal analysis, while the phase compositions, microstructures and structures were analysed by X-ray diffraction. Structures were also investigated using scanning electron microscopy and Fourier transform infrared spectroscopy. It is shown that the destruction of the clay mineral illite structure during the different treatments is partly achieved. A noticeable treatment effect was observed when using thermal processing at temperatures of 550–580 °C and by chemical treatment with a 8 M NaOH solution, which led to the formation of the zeolite group mineral, sodium aluminium silicate hydrate $\text{Na}_6(\text{AlSiO}_4)_6 \cdot 4\text{H}_2\text{O}$. It is shown that the treatment effect in both illite and illite clay is connected with the lowering of the sintering temperature for the respective ceramic samples by granting them high compressive strength and acceptable ceramic properties. As an example this is true in the case of sintering at 600–700 °C traditional building bricks.

1. Introduction

Clay minerals are essentially hydrous aluminous sheet silicates with variable compositions and water contents. They are an important component of mudstones and clay stones, which are sedimentary rocks that may also contain other minerals, such as quartz and calcite. Both, mudstones and clay stones, are widely distributed in the surface of the Earth and significantly affect the physical, chemical and biological processes of soils. Clay minerals are generally extremely fine grained and rarely exist as macroscopic crystals (Wenk et al., 2004; Velde and Meunier, 2008). In recent years, studies of clay have focused on clay minerals, such as natural soil nanoparticles (Wilson, 1999; Ismadji et al., 2015; Zhang et al., 2016), as well as soil colloids (< 2000 nm) (Egli et al., 2008; Deepthy and Balakrishnan, 2005). In this regard, previous studies have had different practical directions, for example, the development of high-end technologies and high-performance products, including cellulose modification and the combination with organic/inorganic materials. For instance, it is known that clay particles alter the thermal properties of cellulose fibres (Lin et al., 2008), titanium oxide particles enhance photocatalytic activity (Uddin et al.,

2007) and silica improves durability (Nypeloe and Rojas, 2012). It is also known that illite nanoparticles promote the sintering and densification process of high-temperature ceramics (Sedmale et al., 2011).

Simultaneously, there are relatively broad studies related to the change in structure of the clay minerals (clays) in order to obtain ceramic products at lower temperatures. The ability to achieve an increased compressive strength of aluminosilicate materials by mixing with an activating alkali solution is well documented (Palomo et al., 1999; Duxson et al., 2007; MacKenzie et al., 2007; MacKenzie et al., 1985). One of the more investigated solid aluminosilicates under highly alkaline conditions is the 1:1 layer lattice aluminosilicate mineral kaolinite (Duxson et al., 2007; MacKenzie et al., 2007). It has been determined that to attain the final strength of an aluminosilicate inorganic polymer at ambient temperatures, the presence of an X-ray amorphous network of aluminium and silicon atoms solely in tetrahedral coordination with oxygen is required. The correlation between increases in silicon concentration in the activating solution of geopolymers and increases in the compressive strength is related to an increase in the densification of the material at temperatures ranging from 600 to 900 °C. It is also observed that alkali cations have no significant

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Table 1
Chemical composition and granulometric data of the Apriki-Laza illite clay (wt%).

	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	TiO ₂	CaO	MgO	K ₂ O	Na ₂ O	Ignition loss (at 1000 °C)
Illite clay	46.87	18.74	7.06	0.59	6.62	3.25	3.62	0.41	12.84
Chemically separated illite	44.0	19.7	10.3	0.8	0.6	2.3	5.3	0.0	-
Illite clay	Sand fraction > 50 μm 1.33			Aleirite (dust) fraction 50–5 μm 8.67			Clay mineral fraction < 5 μm int. al. < 2 μm 90.00 60.60		

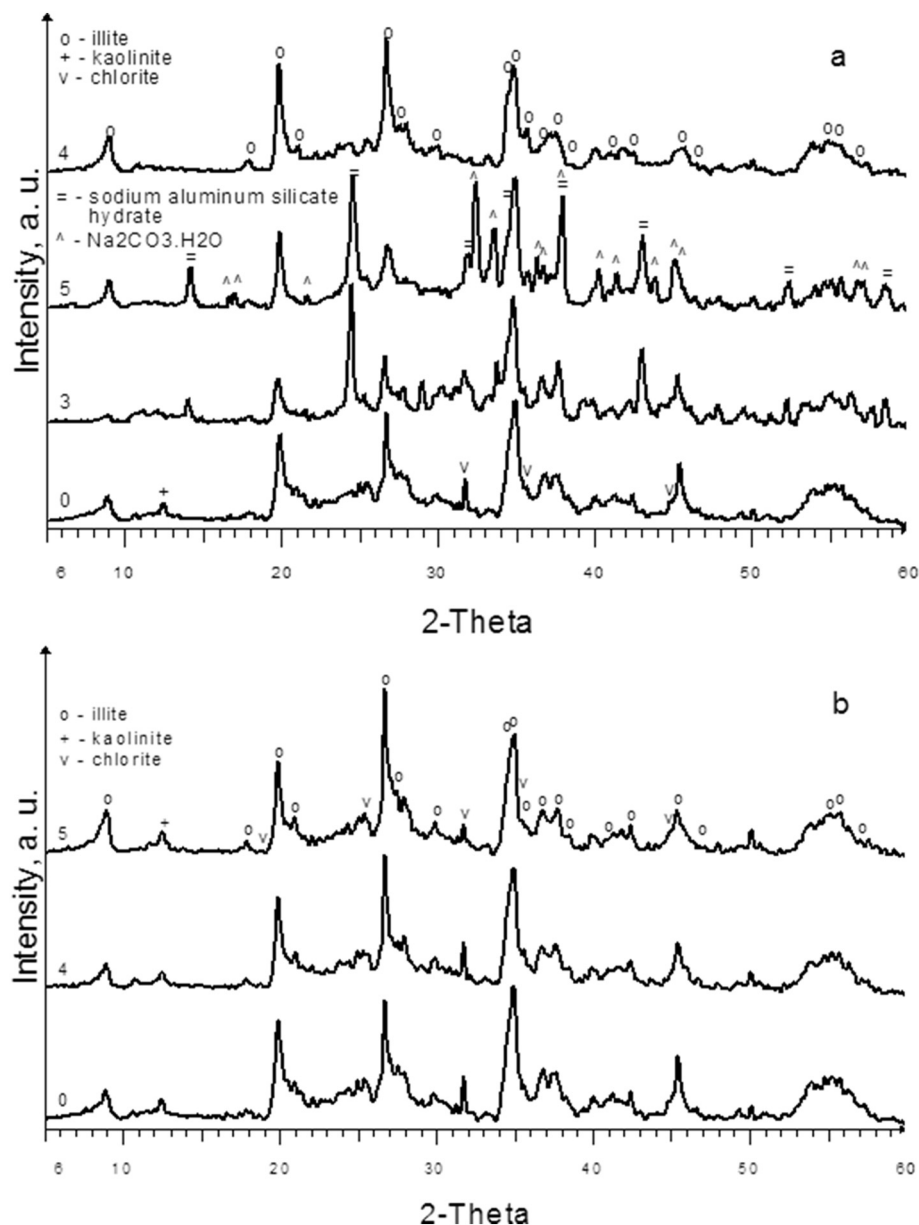


Fig. 1. XRD patterns for differently treated illite: (a) 0 – untreated, 3 – treated with 6 M NaOH solution, 5 – treated with 8 M NaOH solution, 4 – treated thermally at 580 °C; (b) 0 – untreated, 4 – treated hydrothermally at ~1 MPa and ~170 °C for 72 h, and 5 – treated hydrothermally at ~1 MPa and ~170 °C for 96 h.

effect on the onset temperature of crystallisation and the quantity of crystalline phase developed in geopolymers. The amount of crystalline phase decreases in aluminosilicate systems with increases in the Si/Al ratio. Despite the similar composition of all geopolymers, the onset temperature of densification is observed to be higher in all K-geopolymers compared to NaK- and Na-specimens with analogous Si/Al ratios.

Although 1:1 layer lattice aluminosilicates are mainly used in the preparation of geopolymers, 2:1 minerals are also of interest, for example, the 2:1 analogue of illite–pyrophyllite with the unit structure $\text{Al}_2\text{AlSi}_3\text{O}_{10}(\text{OH})_2$, in which the octahedral Al–O sheet is enclosed

above and below by two tetrahedral Si–O sheets to form a repeating unit (MacKenzie et al., 1985). Attempts to produce fully reacted aluminosilicate geopolymers from the crystalline 2:1 lattice mineral pyrophyllite were unsuccessful. Dehydroxylation of pyrophyllite at 800 °C produces significant changes in the Al coordination, but does not form a viable geopolymer. It was suggested that the inability to form viable geopolymers may be due to the retention of the crystalline 2:1 layer structure in pyrophyllite and its dehydroxylated phase. According to the authors (MacKenzie et al., 1985), the Al–O sheet enclosed by the upper and lower Si–O sheets is protected from alkaline attack in

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