Clay Mixtures and the Mechanical Properties of Microporous and Nanoporous Ceramic Water Filters

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Abstract: This paper presents the results of an experimental study of the effects of clay mixtures on the mechanical properties of mixed clays with controlled levels of plasticity, prior to the firing of porous ceramic water filters for water filtration. Two clays with well-characterized initial compositions (Iro and Ewuya clays) are mixed with varying proportions to control their plasticity. The mechanical properties of the mixed and fired clays are then studied using a combination of experiments and theoretical models. These include the flexural strength, fracture toughness, Young's modulus, and thermal shock resistance of fired clay mixtures. The results show that clay mixtures with 45–60 vol.% of Iro clay and 40–55 vol.% Ewuya clay can be used to produce clay composite filters with robust mechanical properties. The thermal shock resistance of a mixed clay filter (containing 50% Iro clay and 50% Ewuya clay) is also explained using a combination of elastic and viscoelastic crack-bridging models. The regimes for effective viscoelastic crack bridging are identified by comparing the relaxation times to the thermal shock durations. The implications of the results are then discussed for the mixing of locally available clays into robust micro- and nanoporous materials for applications in clay ceramic water filters. **DOI: 10.1061/(ASCE)MT.1943-5533.0001596.** © *2016 American Society of Civil Engineers.*

Author keywords: Clay mixtures; Microporous/nanoporous filters; Mechanical properties; Theoretical models; Viscoelastic crack bridging.

Introduction

Clays are ubiquitous materials and that are accepted as building materials in most cultures (James 2009; Liu et al. 2010). In most cases, these include applications of porous clay ceramics as building blocks that also provide thermal comfort, as a result of their low thermal diffusivities (Sultan et al. 2002; Robinet et al. 1996; Soboyejo et al. 2001).

More recently, micro- and nanoporous clay ceramics have been developed for applications in water filtration, termed ceramic water filters (Yakub 2012; van Halem 2006; Lantagne 2001). They have also been shown to remove bacteria (Yakub et al. 2013; van Halem 2006) and chemical contaminants (Yakub and Soboyejo 2013) from contaminated water. There is, therefore, the potential to integrate giant porous ceramic water filters in the form of buildings in urban/rural communities (Annan et al. 2014). Porous aluminasilicates also exhibit high melting points and can therefore be applied as refractory ceramics in the metal-melting industry (Bodsworth 1994).

Most of the early buildings in Africa were constructed from clay and silt (James 2009). The clay structural products, classified as traditional ceramics structures, were generally produced by forming/molding, drying, and burning/firing (James 2009). These processes were facilitated by the control of clay mixtures with appropriate proportions of plastic and less plastic clays, water, and binder materials.

Furthermore, after drying, the heating of the fine particles of the clay causes the particles to agglomerate into cohesive, much stronger, finished/sintered product. However, the shrinkage of clays and the effects of mechanical loads can induce cracking in such structures (Liu et al. 2010). Cracking can also be exacerbated by the effects of thermal cycling and the environment (Sultan et al. 2002; Robinet et al. 1996). These setbacks are often mitigated or solved by the addition of other materials such cement, laterite, fibers, and also heating rate/regime.

Generally, in an effort to improve strength and fracture toughness of traditional ceramics, materials such as industrial waste materials (blast furnace slag for example) (Savastano et al. 2001), agricultural waste materials (including natural fibers from sisal) (Yan et al. 2000; Joseph et al. 1999; Zhong et al. 2007; Tan et al. 2012), banana trunk (Sapuan et al. 2007), eucalyptus trees (Tonoli et al. 2010), sugar cane bagasse (Ghazali et al. 2008; Monteiro et al. 1998; Teixeira et al. 2012), and millet (Adegunwa et al. 2014) are

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