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Composites Based on Fly Ash and Clay

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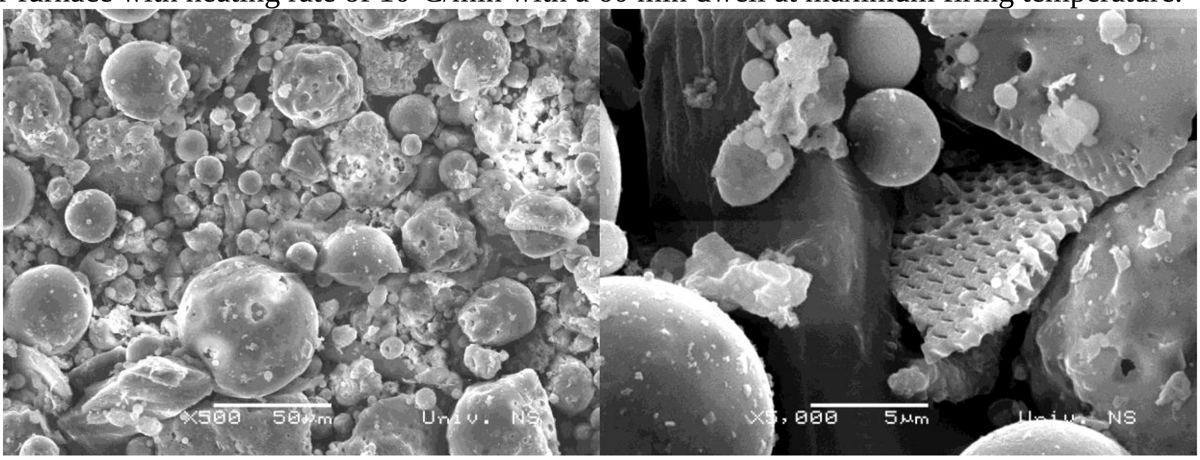
INTRODUCTION

Fly ash is a waste generated from the coal combustion during the production of electricity in the thermal power plants. It presents industrial by-product containing Technologically Enhanced Natural Occurring Radioactive Materials (TENORM) with the great potential for valorisation (1). Fly ash is successfully utilized in cement and concrete industry (2), also in ceramics industry (3) as component for manufacturing bricks and tiles, and recently there are many investigations for production of glass-ceramics (4) from fly ash. Although the utilization of fly ash in construction and civil engineering is dominant, the development of new alternative application for its further exploitation into new products is needed. This work presents the possibility for fly ash utilization for fabricating dense composites based on clay and fly ash with the potential to be used in construction industry.

RESULTS

Fly ash (from the thermal power plant REK Bitola, Republic of Macedonia) with the chemical composition (SiO_2:52.00wt.%, Al_2O_3:23.61wt.%, Fe_2O_3:7.31wt.%, CaO:7.42wt.%, MgO:2.11wt.%, Na_2O:0.90wt.%, K_2O:1.67wt.%, SO_3:1.20wt.%, LOI: 3.12wt.%) was used as raw material for fabricating composites. The particle size distribution of the fly ash showed that the content of the fine fraction (less than 0.063mm) was dominant (47.10wt.%) and it was used in this investigation. The phase compositions of the fly ash consisted of: quarts, albite, hematite, anorthite, anhydrite and an amorphous phase. The concentrations of the natural radionuclides in fly ash as industrial by product were: ^{266}Ra:59±6 Bq/kg; ^{232}Th:76±8 Bq/kg; ^{40}K:376±29Bq/kg and are in accordance with the reported (5). The typical morphology of the fly ash is presented in the figure 1. It is evident the presence of spherical particles and particles with irregular geometry and dimensions. The evident presence of diatomite can be seen from the honey sake morphology (fig. 1 b).

Clay (with granulometry less than 0.063mm) from the same region with the similar chemical composition (SiO_2:58.48wt.%, Al_2O_3:19.18wt.%, Fe_2O_3:7.44wt.%, CaO:6.18wt.%, MgO:1.43wt.%, Na_2O:2.10wt.%, K_2O:2.51wt.%, LOI: 2.05wt.%) was introduced to fly ash varying the quantity from 10 to 90wt.%. Quarts, feldspar, aragonite, illite, chlorite and calcite were the major crystalline phases present in clay. The composites were consolidated by uniaxially pressing at 45 MPa and the green samples were dried (105^{0}C) prior to sintering. Sintered composites were fabricated by firing at temperatures: 900, 1000, 1050, 1100^{0}C in chamber furnace with heating rate of 10^{0}C/min with a 60 min dwell at maximum firing temperature.

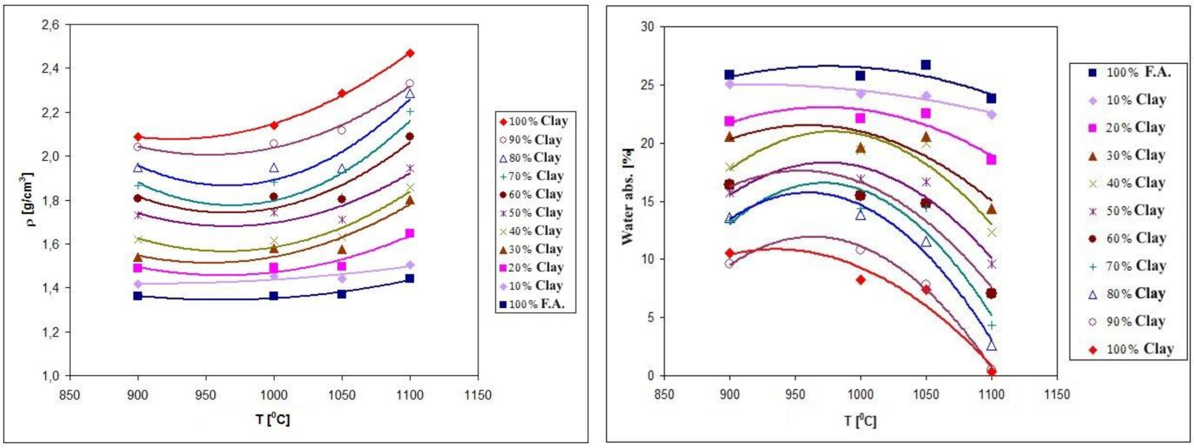


(a) (b)

Figure 1. Morphology of the fly ash (a). bar 50μm, (b). bar 5 μm

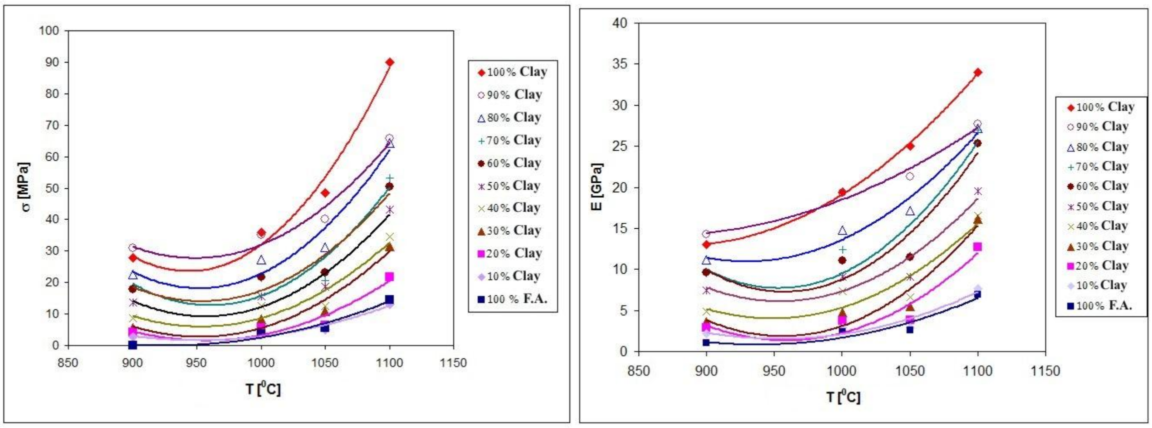
The dependence of density and water absorption from the temperature for different fly ash –clay composites is presented in figure 2 and figure 3 presents the dependence of bending strength and E-modulus from temperature for the same composites.

Chemical durability of composites (sintered at 1050 and 1100^{0}C) was tested using the standard methods for glass and ceramics. It was determined as mass lost after treatment in neutral (H_2O) and aggressive mediums (0.1M HCl and 0.1M Na_2CO_3) during the period of 24, 168 and 720 hours. The results of the leach testing of the composites in acid medium (0.1MHCl) are presented in figure 4.



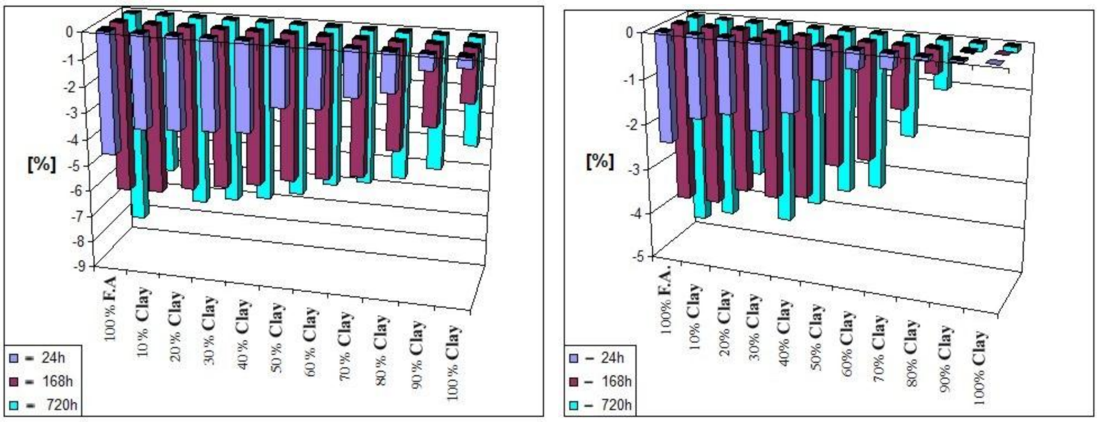
(a) (b)

Figure 2. Dependance of : a. density from sintering temperature;
b. water absorption from temperature



(a) (b)

Figure 3. Dependence of: a. bending strength from temperature; b. E-modulus from temperature



(a) (b)

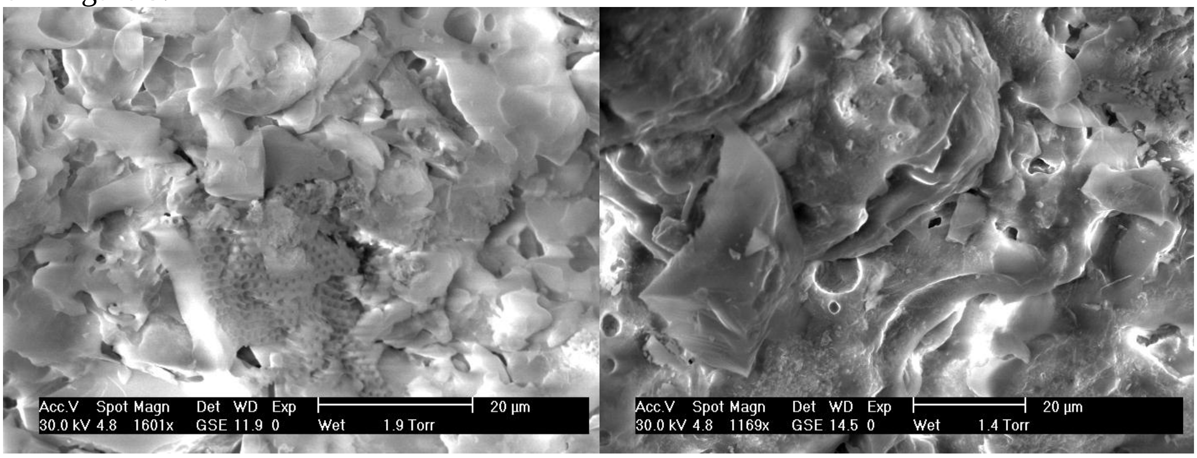
Figure 4. Leaching of the composites in acid medium (0.1MHCl) a. composites sintered at 1050^{0}C,
b. composites sintered at 1100^{0}C

It is evident from the the figure 2 that clay content generally influences on the incensement of density and decreasemant the water absorption. Significant densification of the compacts was achieved by increasing the temperature from 1050^0C to 1100^0C. The mechanical properties (bending strength and E-modulus), figure 3, of the composites also increase with the addition of clay and the rapid densification was at temperature of 1100^0C.

The clay content influenced positively on the durability of the compacts and it is directly connected to the density of the compacts. Namely, the densest composites i.e composites with higher content of clay have lower mass lost i.e. higher durability.

From the above investigation, as an optimal was chosen a composite containing 60wt.% clay and 40wt.% fly ash sintered at 1100^0C. The density and water absorption of the composite were 2.09 g/cm^3 and 7.02%, respectively, and the mechanical properties i.e bending strength and E-modulus were 50.47 MPa and 25.35GPa, respectively.

The microstructures of the composites with fly ash content of 40wt.%, sintered at 1050 and 1100^0C are presented in figure 5.



a. b.

Figure 5. Microstructures of composites with 40wt.% fly ash content (bar 20µm) a. sintered at 1050^0C b. sintered at 1100^0C

The degree of densification is evident, namely at temperature of 1050^0C the morphology of diatomite is still present, but at 1100^0C the composite is extensively sintered (more homogenous and smoother) with the evident appearance of small closed pores.

CONCLUSION

Fly ash as industrial by product can successfully replace certain quantity of clay as naturally occurring raw material to fabricate composites which can be potentially used as dense ceramics in construction industry.

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