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## The manufacturing of sintered bricks from clay and red mud derived from the alumina processing plant

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In this study, the manufacturing of sintered bricks from clay and red mud was presented. The initial materials and obtained bricks were characterized by X-ray diffraction (XRD), scanning electron microscope (SEM), transmission electron microscope (TEM), X-ray fluorescence (XRF), and differential scanning calorimetry-thermal gravimetry (DSC-TG). The compressive strength, water absorption, bulk density and sintering shrinkage of sintered bricks were performed. The effects of components of raw materials, sintering temperature and time on physico-mechanical properties of the products was investigated. The results showed that the bricks prepared at 1000 °C for 1 hr with raw material containing up to 50% of red mud provided excellent physico-mechanical properties. The obtained brick met the Vietnam standard VS1451-1998 and was satisfied the construction material requirements that were safe to human's health and friendly with environment in terms of alkaline leaching and radioactivity indexes.

Key words: Red mud, Clay, Sintered brick.

### Introduction

Red mud (RM) is the major wastes of Bayer process of alumina extraction from bauxite. The worldwide amount of RM is about 50 to 80 million tons per year [1, 2]. In Vietnam, about 5.5 billion tons of bauxite are reserved in Tay nguyen plateau. Many aluminum plants have developed recent years in this plateau. At present, Tanrai (Lamdong) and Nhanco (Daknong) aluminaplants have released approximately 650,000 tons dry RM per year. The main composition of RM consists of iron and aluminum oxide minerals, calcium aluminum silicates, sodium and redundant alkaline amount that is toxic, strongly contaminated soil and groundwater and destroyed ecosystem. Therefore, many researches have been performed to encourage the reuse of RM. The utilization of the RM in different fields such as production of steel [3, 4], Portland cement clinker [5], inorganic pigments [6], ceramics [7-12], unsintered bricks [2, 13], alumina, titan oxide [14], recovery of rare earths [15], and arsenic adsorption from aqueous solution [16, 17] have been reported.

In Vietnam, there is a large amount of bricks used for construction. According to the Vietnam Ministry of Construction data, about 99% of sintered bricks in total of 22 billion of bricks are utilized per year. About 150,000 tons of coal and 1.5 million tons of clay (equivalent to the area of 75 ha of agricultural sand

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with the depth of 2.0 m) are employed as fuel and initial materials to produce 1 billion of sintered bricks with standard size. Consequently, 0.57 million tons of  $CO_2$  and many other toxic gases such as  $SO_2$ ,  $NO_x$  are emitted every year.

From the environmental point of view, the increasing of percent of RM in materials for brick production does not only diminish contamination, but also controls the exploitation of clay resources. However, almost studies of sintered bricks production, the percentage of RM in initial materials was less than 10% [10, 18]. In this study, the manufacturing of sintered bricks containing high percentage of RM was investigated. The influences of RM proportion, sintering temperature, and setting time on physico-mechanical properties were surveyed. The kinetics of the sintering process between RM and clay was addressed.

### **Experimental**

#### **Raw materials**

RM employed in this study was collected from the waste storage of Tanrai alumina plant in Baolam district, Lamdong province, Vietnam. Clay was gathered from initial materials storage of Huongthuy sintered brick Joint Stock Company, Thua thien Hue province, Vietnam. The RM and clay were dried at 105 °C for 24 hrs, grinded using ball mill and sieved through the mesh (the diameter of mesh is 0.154 mm). The chemical component of the RM and clay were determined by the X-ray Fluorescence (XRF, Advan't XAA173, Thermo Scientific). The particle size analysis

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of the RM and clay were carried out using a laser scattering particle size distribution analyzer (LA-950V2, Horiba).

### **Preparation of sintered bricks**

The production process of sintered bricks from clay and RM was shown in Fig. 1.

The mixtures of feedstock of samples were prepared with the increase of amount of RM from 10 to 60% (w/w) which are denoted as M10 to M60, respectively and wetted up to 40% humidity by water. The plastic method was used to shape bricks using wooden molds with dimensions of  $4 \times 4 \times 4$  cm<sup>3</sup> and  $5 \times 10 \times 20$  cm<sup>3</sup>. Green bodies were placed at ambient temperature for 24 hrs before drying at 100 °C for 8 hrs until constant mass. The dried specimens were sintered at temperature from 900 to 1000 °C for 1 hr with the heating rate of 5 °C·min<sup>-1</sup>. The samples sintered at 900 to 1000 °C were denoted as GN900 to GN1000, respectively. The brick prepared from clay (M0) without RM was used as a reference sample.

Some physico-mechanical properties of sintered bricks were performed according to the Vietnam standards VS6355:1998. The compressive strength R (MPa) was calculated form Eq. (1).

$$R = \frac{F}{S} \tag{1}$$

where, F (N) is for the force of breaking specimens, S  $(mm^2)$ - the average value of force area of specimens

The water absorption H (%) was calculated from Eq. (2).  

$$H = \frac{m_1 - m_0}{m_0} \times 100$$
(2)



Fig. 1. Schematic diagram of the production of sintered bricks.

**Table 1.** The chemical components of clay and RM.

where,  $m_1$  (g) is the weight of specimens after submerging in water for 24 hrs and reweighed every 24 hrs until the values of two consecutive weightings differed by less than 1%, yielding;  $m_o$  (g) is the weight of specimens after drying at 110°C for 24 hrs.

The bulk density D (g.cm<sup>-3</sup>) was calculated form Eq. (3).

$$D = \frac{m}{V_1} \tag{3}$$

where, m (g) is the mass of specimen;  $V_1$  (cm<sup>3</sup>) - the volume of specimen after sintering.

The sintering shrinkage T (%) was calculated from Eq. (4).

$$T = \frac{V_0 - V_1}{V_0} \times 100$$
 (4)

where,  $V_0$  (cm<sup>3</sup>) is the volume of specimen before sintering.

The radioactivity of specimens was assessed by the method of usual technical of health and environment using RIKEN KEIKE RD-2E. The raw materials were characterized by TG-DSC ( Labsys TG/DSC Setaram, France) in ambient atmosphere with the maximum temperature of 1200 °C, heating rate of 10 °C.min<sup>-1</sup>. Crystal phase of samples were determined by X-ray diffraction (XRD, Brucker D8 Advance, Germany) with  $\lambda_{CuK\alpha} = 1,5406$  Å. The morphology of sintered bricks was observed by scanning electron microscope (Hitachi S4800). Atomic composition of sintered bricks was indicated in Energy-dispersive X-ray spectrum (EDX, Hitachi S4800) instruments.

### **Results and Discussion**

### Raw materials characterization

The chemical components of clay and RM which was analyzed by XRF are showed in Table 1. The RM consisted of high content of Fe<sub>2</sub>O<sub>3</sub> (up to 49.66%) which was similar to the RM for production of steel [1, 3]. The higher amount of  $Al_2O_3$  (18.28%) than that of SiO<sub>2</sub> (4.39%) was favorable for forming mullite phase (3Al<sub>2</sub>O<sub>3</sub>.2SiO<sub>2</sub>) in sintered brick. In addition, the Na<sub>2</sub>O (4.28%) in the RM as a melting additive also promoted minerization process.

Table 2 presents pH of RM in water ( $_{PH_{H,O}}$ ) and in KCl solution ( $_{PH_{KCl}}$ ). The results showed that RM exhibited high alkalinity (pH > 11) that exceeded limitation of Vietnamese standard (VS 7377-2004) for

Raw materials	Percentage composition (w/w)									
	Fe <sub>2</sub> O <sub>3</sub>	$Al_2O_3$	TiO <sub>2</sub>	Na <sub>2</sub> O	SiO <sub>2</sub>	CaO	F	$P_2O_5$	$SO_3$	LOI (1000 °C)
RM	49.66	18.28	6.17	4.28	4.39	2.19	0.55	0.27	0.35	15.73
Clay	6.25	17.2	_	0.55	65.05	2.65	_	_	_	7.45

(LOI: loss on ignition).

VS 7377-2004 RM No. Parameter Unit (for cultivated land) 1 11.35 4.4-6.87  $pH_{H,O}$ 2 11.18 3.73-5.82 pH<sub>H,O</sub> 60 size. 40 tive Particle size

Table 2. The pH value of RM.

Fig. 2. Particle size distribution patterns of RM (A) and clay (B).



Fig. 3. XRD diagram of (A) RM and (B) clay samples



Fig. 4. TG-DSC diagram of (A) RM and (B) clay sample

cultivated land. This could damage to ecosystem and cause environment pollution. This result was similar to previous report [19].

The particle size distributions of the RM and clay are given in Fig. 2. Mean particle sizes (diameters on cumulative 50%) of the RM and clay were 0.78  $\mu$ m and 3.75  $\mu$ m, respectively. Moreover, the particle size distribution of clay exhibited narrower than the RM in which RM and clay vary from 0.33  $\mu$ m (diameter on cumulative 10%) to 1.33  $\mu$ m (mean diameter on cumulative 90%) and 3.22  $\mu$ m to 4.32  $\mu$ m, respectively.

XRD patterns of RM and clay are shown in Fig. 3. The large background of XRD diffraction suggested the amorphous phase existing in RM. The characteristic diffraction peaks of gibbsite (Al(OH)<sub>3</sub>), hematite (Fe<sub>2</sub>O<sub>3</sub>) and goethite (FeO(OH)) were obtained indicating that these were main crystal phase of RM (Fig. 3(A)). This result had agreed with the chemical components (see Table 1). The clay used exhibited the major phase of cristobalite (SiO<sub>2</sub>). This result was an advantage because SiO<sub>2</sub> contributes almost 65% in the components of the sample showed in the XRF analysis. It was also

found that the sample contained a great variety of clayey minerals (Fig. 3(B)), as well as the kaolinite  $(Al_2Si_2O_5 (OH)_4)$ , haloysite  $(Al_2Si_2O_5 (OH)_4.2H_2O)$  with rather high intensity of peaks. These compositions are responsible for the plasticity when mixing of clay with the right proportion of water, as well as the subsequent hardening in the drying stages.

TG-DSC diagrams of RM and clay are presented in Fig. 4. For RM (Fig. 4(A)), endothermic peak observed at 92 °C on DSC line of RM with weight loss of 3.3% was assigned to the adsorption water. Low intensity peak at 246 °C corresponded with the decomposition of gibbsite into boehmite ( $\gamma$ -AlO(OH)) based on the reaction (5) [20, 21]:

$$Al(OH)_3 \rightarrow \gamma - AlO(OH) + H_2O$$
 (5)

Continuously, strong intensity peak at 327 °C was observed with the change of goethite into hematite ( $\alpha$ -FeO(OH)) based on the reaction (6) [20]:

$$2\alpha$$
-FeO(OH)  $\rightarrow$  Fe<sub>2</sub>O<sub>3</sub> + H<sub>2</sub>O (6)

The total loss of weight of two above endothermic processes was about 13.9% indicating that the main compositions of RM were goethite and gibbsite minerals.

Finally, there was a small endothermic peak at 529 °C with weight loss of 2.8% that proved the decomposition of boehmite [22] as follows,

$$2\gamma$$
-AlO(OH)  $\rightarrow$  Al<sub>2</sub>O<sub>3</sub> + H<sub>2</sub>O (7)

For clay (Fig. 4(B)), two endothermic peaks were observed in DSC curve at 78 and 545 °C. The first peak with weight loss of 1.68% could be contributed to the evaporation of physical water adsorbed between clay layers. The second peak at 545 °C corresponding with the decomposition of kaolinite (Al<sub>2</sub>O<sub>3</sub>.2SiO<sub>2</sub>. 2H<sub>2</sub>O), haloysite (Al<sub>2</sub>O<sub>3</sub>.2SiO<sub>2</sub>.4H<sub>2</sub>O) into metakaolin (Al<sub>2</sub>O<sub>3</sub>.2SiO<sub>2</sub>) and water [9].

The morphology of RM consisted of spherical particles with size of 20-30 nm in diameters as shown in Fig. 5. The RM particles were agglomerated into patches with size of  $1.0-5.0 \,\mu$ m. Due to small size, RM particles hardly deposited and easily desiccated. Hence, there were many difficulties in removing abundant alkaline.



Fig. 5. (A) SEM and (B) TEM images of RM

# The effect of sintering temperature and RM content on the physical mechanical properties of bricks

Physico-mechanical properties of brick samples containing different contents of RM and sintered at different temperatures from 900 to 1000 °C for 1 hr are presented in Fig. 6. The compressive strength increased quickly through increasing the amount of RM (20% (w/w)) (Fig. 6(A)). A further increase in the RM amount caused a reduction in the compressive strength. The RM enhanced the efficiency of the solid phase reactions. The access amount of RM caused the insufficient amount of silica and alumina which are considered to be the main components for forming strength frameworks of bricks. The same behaviors were observed for the temperatures of 900, 950 and 1000 °C. However, the temperature is favorable for enhancing compressive strength. It is worth noting that the bricks sintered at 1000 °C exhibited the higher compressive strength than 20 MPa that is required by Vietnam standard for sintered brick (VS1451-1998) even the replacement of RM amount up to 60%. The brick sintered at 950°C possessed higher 20 MPa as RM amount replaced from 10-20%. Therefore, the employment of RM for sintered brick production does not only decrease the environmental effect of RM, but also reduces sintering temperature and saves energy [9].

The water adsorption values of brick were presented



**Fig. 6.** Effect of sintering temperature and RM content on (A) compressive strength; (B) water absorption; (C) bulk density and (D) sintering shrinkage of bricks.

in Fig. 6(B). The results indicated that samples sintered at 900 °C exhibited high values of water adsorption from 18.4 to 25.9% that were higher than acceptable limit of VS1451-1998 (lower than 18%). This implied that these samples were low-level sintered brick. Conversely, the water adsorption decreased significantly as sintering temperature increased from 950 to 1000 °C because high sinterability was enhanced. The water adsorption of samples sintered at 1000 °C was lower than 18% that met the requirement of VS 1451-1998. Otherwise, the higher content of RM was, the higher value of water adsorption was. This result was similar to compressive strength investigation.

Fig. 6C represented bulk density values of brick samples. It was found that all the samples exhibited values of bulk density much higher than acceptable limit of VS 1451-1998. With each sample, the higher sintering temperature was, the higher value of bulk density was. In detail, bulk density values increased from about 1.8-1.9 g.cm<sup>-3</sup> to 1.9-2.05 g.cm<sup>-3</sup> and 2.0 to 2.2 g.cm<sup>-3</sup> at temperatures of 900; 950 and 1000 °C, respectively. These results agreed rather well with compressive strength survey.

Finally, the effect of RM content on sintering shrinkage values is shown in Fig. 6(D). The higher sintering temperature was, the higher sintering shrinkage value was. Especially, at 1000 °C, sintering shrinkage value of brick was about 15-25% being much higher than that at 900 and 950 °C (5-10%).

The above mentioned results suggested that the



Fig. 8. XRD diagram of bricks sintered at 900°C, 950 °C and 1000 °C for 1 hr.



Fig. 7. SEM images of bricks sintered at (A) 900 °C, (B) 950 °C, (C) 1000 °C for 1 hr.

adding an appropriate amount of RM into initial clay for production of sintered brick was feasible. Not only was the environment pollution causing by RM diminished, but also clay resource was economized remarkably. Although the maximum amount of added RM could be up to 50%, sintering temperature of 1000 °C and sintering time of 1.0 hour, physicomechanical properties of obtained brick met the requirement of building purpose according to VS1451-1998.

SEM images of fraction of brick sample M50 sintered at different temperatures are presented in Fig. 7. The sintering level of brick samples increased when temperature increased. In detail, unconnected particles of brick sample sintered at 900 °C was bound at sintering temperature of 950 °C and decreased holes between particles. At sintering temperature of 1000 °C, the obtained brick sample exhibited high packing; large size and abnormal holes were not observed inside the material.

Crystal phase composition of M50 sample sintered at different temperatures from 900 to 1000 °C for 1 hr is shown in Fig. 8. As can be seen, hematite (Fe<sub>2</sub>O<sub>3</sub>) was the main crystal phase of sintered brick. Besides, characteristic peaks of quartz (a mineral existed in initial material) were also observed. The higher sintering temperature was, the sharper peaks of hematite and quartz were. There were no peaks of goethite and gibbsite in XRD diagram of brick because they might be decomposed or dissolved at high temperature and existed in the form of amorphous state. The characteristic diffraction of mullite ( $3A12O_3 \cdot 2SiO2$ ) could be observed in GN1000 sample.

### The effect of sintering time on the properties of bricks

Fig. 9 presents the compressive strength of M50 sample sintered at 1000 °C for different time from 0.5 to 7 hrs. As can see from Fig. 9 that the values of compressive strength and water adsorption of product



Fig. 9. Compressive strength and water absorption of bricks sintered at 1000 °C from 0.5 to 7 hrs.

varied in opposite directions when sintering time was enhanced from 0.5 to 4 hrs. Due to the appearance of liquid phase, gas bubbles was released and holes inside the material disappeared resulting the uptrend of the value of compressive strength from 22.4 to 26.6 MPa and the downtrend of the value of water adsorption from 19.2 to 16.8%. This proved that the sintering of brick have not completed in this range of sintering time.

In this study, compressive strength kinetic was studied by the *pseudo*-first order and pseudo-second order models.

For *pseudo*-first order model:

$$\frac{dF}{dt} = k_1(F_f - F) \longrightarrow \frac{dF}{(F_f - F)} = k_1 dt$$
$$\longrightarrow \ln(F_f - F) = -k_1 t + I_0$$

It is assumed that  $I_0 = F_0$  at t = 0, Then ln

$$\frac{(F_f - F)}{(F_f - F_0)} = -k_i t$$

By rearranging,  $F = F_f - (F_f - F_0)e^{-x_1 t}$  (8) For pseudo second order model:

$$\frac{dF}{dt} = k_2 (F_f - F)^2 \rightarrow \int \frac{df}{(F_f - F)^2} = \int k_2 dt \rightarrow \frac{1}{(F_f - F)} = k_2 t + I_0$$

With boundary condition, 
$$t = 0 \rightarrow \frac{1}{(F_f - F)}$$
.  
In rearranging,  $F = \frac{k_2 t (F_f^2 - F_0 F_f) + F_0}{1 + k_2 t (F_f - F_0)}$  (9)

Where  $k_1$  and  $k_2$  are the rate constants of *pseudo*-first order kinetic equation (h<sup>-1</sup>) and *pseudo*-second order kinetic equation (MPa. h<sup>-1</sup>), respectively.  $F_f$  and  $F_o$  are compressive strength (MPa) at *t* (*h*) and full compressive value at time in which the sintrability is complete.

The parameters of models (as expressed by Eqs. 8 and 9) were estimated by non-linear regression method using Solver function in Microsoft Excel. The parameters  $k_1$  and  $F_f$  are 26.12 MPa and 3.2 h<sup>-1</sup> respectively. Fig. 10 illustrates the experimental points and regression line for two models. The experimental points were distributed



**Fig. 10.** Compressive strength kinetic follows (A) the pseudo-first order and (B) the pseudo-second order models.



**Fig. 11.** Bulk density and sintering shrinkage of bricks sintered at 1000 °C from 0.5 h to 7 hrs.

very close to regression line of *pseudo*-first order kinetic model. The high determination coefficient of  $R^2 = 0.981$  in comparison with that of  $R^2 = 0.539$  for *pseudo*-second order kinetic model suggested that experimental data of compressive strength had good fitness with *pseudo*-first order model.

Another suitable information inferred from Fig. 11 was the raise of the value of bulk density from 1.92 to 2.22 g.cm<sup>-3</sup>. With the value of sintering shrinkage, it strongly increased in the range time from half an hour to 1 hr and then varied unremarkably. The compressive strength, bulk density and sintering shrinkage increases and water adsorption decreases with an increase in the sintering time. It can be concluded that the higher efficiency of sintering process was obtained as the sintering time was prolonged.

SEM images of M50 sample sintered at 1000 °C for different times from 2 to 7 hrs as shown in Fig. 12 indicated that the longer sintering time was, the higher packing of product was. This demonstrated that the sintering of product took place strongly in this time.



Fig. 14. Images (A) and EDX diagram (B) of bricks sintered at 1000 °C for 1 hr.

Table 3. Alkaline release and radiation of bricks sintered at 1000 °C for 1 hr.

	pН	Radiation (µSv/h)			
Socking time (days)	M50	M0	M50	RM	
1	7.5	6.9			
3	7.4	7.2	$0.28\pm0.02$	$0.50\pm0.05$	
6	7.7	7.1			

With the aim of clear observation of the grain boundary of particles of material, M50 sample sintered at 1000 °C for 2 hrs was under etching treatment in mixture of HCl 5% and HF 5% for 10 seconds. Its morphology is shown in Fig. 13. The boundary grain was appeared and exhibited uniform size in the range of 100-150 nm.

### Characterization of sintered brick

Fig. 14A presents the photographs of M50 sample sintered at 1000 °C for 1 hr. Almost of sintered brick specimens with dimensions of  $4 \times 4 \times 4$  cm<sup>3</sup> and  $5 \times 10 \times 20$  cm<sup>3</sup> of standard Vietnamese brick were not split, distorted and well-sintered.

EDX study on M50 sample was shown in Fig. 14(b). The main composition of sintered brick included  $SiO_2$ ,  $Fe_2O_3$ ,  $Al_2O_3$  with content of 31.24, 27.16, 17.3%, respectively. In addition, there was a small amount of



Fig. 12. SEM images of bricks sintered at 1000 °C for 2 hrs (A), 4 hrs (B) and 7 hrs (C).



Fig. 13. SEM images of sintered bricks (etching condition: 5% HF + 5% HCl solution).

Na<sub>2</sub>O, TiO<sub>2</sub>, CaO, K<sub>2</sub>O. This agreed well with chemical component of initial material presented in Table 1.

Alkaline release and radiation of sintered brick for samples soaking in water for 1 to 6 days are presented in Table 3. It was found that pH of solutions after soaking brick varied from 7.4 to 7.7 that were similar to those of conventional bricks prepared for clay. Therefore, alkaline contents released from brick was too small to be harmful to human being. The alkaline forms may react with SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub> to form the stable compounds such as Na<sub>2</sub>O.SiO<sub>2</sub>, Na<sub>2</sub>O.Al<sub>2</sub>O<sub>3</sub>.SiO<sub>2</sub> [23]. The reaction could describe as following

$$2NaOH + SiO_2 = Na_2O.SiO_2 + H_2O$$
(10)

$$Na_2CO_3 + SiO_2 = Na_2O.SiO_2 + CO_2$$
(11)

$$Na_2O.SiO_2 + Al_2O_3 = Na_2O.Al_2O_3.SiO_2$$
(12)

Radioactive level of obtained brick was assessed due to the existence of radioactive elements in Tanrai RM [19]. The low radioactive level of 0.28  $\mu$ Sv/h suggesting the obtained bricks are safe for consumers.

### Conclusions

In the present work, suitable conditions of preparation of sintered brick from clay and RM were determined. The obtained brick containing 50% (w/w) of RM and sintered at 1000 °C for 1 hr exhibited excellent physico-mechanical properties that met requirement of the Vietnam standard (VS1451-1998) for building brick such as compressive strength, water adsorption, bulk density and sintering shrinkage of 23.3 MPa; 18.3%, 2.22 g.cm<sup>-3</sup>, 19.8%, respectively. Alkaline release of brick was trivial and pH of solution after soaking brick for 6 days was approximate neutral (7.8). Its radioactive level was small (0.28  $\mu$ Sv/h) and safe for human health and environment.

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### References

- X. Li, W. Xiao, W. Liu, G. Liu, Z. Peng, Q. Zhou, T. Qi, Trans. Nonferrous Met. Soc. China, 19 (2009) 13421347.
- 2. J. Yang, B. Xiao, Constr. Build. Mater. 22 (2008) 2299-2307.
- K. Jayasankar, P.K. Ray, A.K. Chaubey, A. Padhi, B.K. Satapathy, P.S. Mukherjee, Int. J. Min. Met. Mater. 19[8] (2012) 679-684.
- 4. W. Liu, J. Yang, B. Xiao, J. Hazard. Mater. 161 (2009) 474-478.
- P.E. Tsakiridis, S.A. Leonardou, P. Oustadakis, J. Hazard. Mater. B116 (2004) 103-110.
- J. Pera, R. Boumaza, J. Ambroise, Cem. Concr. Res. 27 (1997) 1513-1522.
- E. Annan, B. Agyei-Tuffour, L.N.W. Damoah, D.S. Konadu, B. Mensah, J. Eng. Appl. Sci. 7 [12] (2012) 1587-1594.
- 8. H. He, Q. Yue, Y. Qi, B. Gao, App. Clay Sci. 70 (2012) 67-71.
- 9. H. He, Q. Yue, J. Hazard. Mater. 203-204 (2013) 53-61.
- S. Piskin, A.K. Figen, E. Özkan, U. Özçay, Int. J. Chem. Environ. Biol. Sci. 1 (2013) 732-736.
- L.P. Villarejo, F.A.C. Iglesias, S.M. Martinez, R. Artiaga, J.P. Cosp, Constr. Build. Mater. 35 (2012) 656-665.
- 12. J. Yang1, D. Zhang, J. Hou, B. He, B. Xiao, Ceram. Int. 34 (2008) 125-130.
- 13. A. Kumar, S. Kumar, Constr. Build. Mater. 38 (2013) 865-871.
- S.A. Leonardou, P. Oustadakis, P.E. Tsakiridis, C. Markopoulos, J. Hazard. Mater., 157 (2008) 579-586.
- 15. M.O. Petropulu, T. Lyberopulu, K.M. Ochsenkiihn, G. Parissakis, Anal. Chim. Acta, 319 (1996) 249-254.
- H.S. Altundogan, S. Altundogan, F. Tumen, M. Bildik, Waste Manage, 20 (2000) 761-767.
- 17. R.C. Sahu, R. Patel, B.C. Ray, J. Hazard. Mater. 179 (2010) 1007-1013.
- V.M. Sglavo, S. Maurina, A. Conci, A. Salviati, G Carturan, G Cocco, J. Eur. Ceram. Soc. 20 (2000) 145-252.
- 19. L.D. Hai, N.X. Khai, T.V. Quy, N.X. Huan, Int. J. Res. Earth. Environ. Sci. 1 [6] (2014) 1-7.
- 20. A. Atasoy, J. Therm. Anal. Calorim. 81 (2005) 357-361.
- V. Balek, J. Subrt, J. Rouquerol, P. Llewellyn, V. Zeleoak, I.M. Bountsewa, I.N. Beckman, K. Gyoryova, J. Therm. Anal. Calorim. 71 (2003) 773-782.
- 22. S.N. Meher, Int. J. Chem. Stud., 1 [5] (2014) 1-9.
- 23. S. Rai, D.H. Lataye, M.J. Chaddha, R.S. Mishra, P. Mahendiran, J. Mukhopadhyay, C. Yoo, K.L. Wasewar, Adv. Mater. Sci. Eng. 2013 (2013) 1-7.